Chapter 3

Conservation Strategy (Sections 3.4, 3.5, and 3.6)

Tables

Figures

Figures appear at the end of each section.

Acronyms and Abbreviations

Aeration Facility	Stockton DWSC DWR Aeration Facility
AMM	avoidance and minimization measure
BACI	before-after/control-impact
BMP	best management practice
BiOp	biological opinion
BOD	biological oxygen demand
Cal Fire	California Department of Forestry and Fire Protection
CDFA	California Department of Food and Agriculture
CDFW	California Department of Fish and Wildlife
Central Valley Water Board	Central Valley Regional Water Quality Control Board
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
CM	conservation measure
CVP	Central Valley Project
DBEEP	Delta-Bay Enhanced Enforcement Program
DBW	California Department of Boating and Waterways
DO	dissolved oxygen
Draft Tidal Marsh Recovery Plan	*Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWR	California Department of Water Resources
DWSC	Deep Water Ship Channel
EDCP	Egeria Densa Control Program
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FAV	floating aquatic vegetation
FCCL	Fish Conservation and Culture Laboratory
Final Tidal Marsh Recovery Plan	*Final Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*
FR	Federal Register
HCP	habitat conservation plan
HGMP	hatchery and genetic management plan
IAV	invasive aquatic vegetation
IEP	Interagency Ecological Program
LICD	low-intensity chemical dosing
Mercury Basin Plan Amendments	*Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control*

	of Methylmercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary
mgd	million gallons per day
MS4	Municipal Separate Storm and Sewer System
NCCP	natural community conservation plan
NOD	Notice of Decision
NMFS	National Marine Fisheries Service
NPDES	National Pollution Discharge Elimination System
Reclamation	Bureau of Reclamation
ROA	restoration opportunity area
ROD	Record of Decision
RTO	real-time operations
San Joaquin County MSHCP	*San Joaquin County Multi-Species Habitat Conservation and Open Space Plan*
SAV	submerged aquatic vegetation
SWP	State Water Project
TMDL	Total Maximum Daily Load
UC	University of California
USDA-ARS	U.S. Department of Agriculture–Agriculture Research Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
Vernal Pool Recovery Plan	*Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon*
WHCP	Water Hyacinth Control Program
WHIPPET	Weed Heuristics: Invasive Population Prioritization for Eradication Tool
YBFEP	Yolo Bypass Fisheries Enhancement Plan
YOY	young-of-the-year
WWTP	wastewater treatment plant
mgd	million gallons per day
HGMP	hatchery and genetic management plans

Chapter 3
Conservation Strategy (Section 3.4, 3.5, and 3.6)

3.4 Conservation Measures

This section describes in detail all of the 22 conservation measures proposed for the BDCP. Collectively, these conservation measures, plus the adaptive management and monitoring program described in Section 3.6, compose the conservation strategy. Important context for all of the conservation measures, including how the conservation measures were developed over the course of several years of planning, is found in Section 3.2, *Methods and Approaches Used to Develop the Conservation Strategy*, and Appendix 3.A, *Background on the Process of Developing the BDCP Conservation Measures*. See Chapter 6, *Plan Implementation*, for the implementation schedule for each conservation measure.

Conservation measures are given numeric codes for easy reference throughout the Plan. The conservation measures are organized hierarchically in the same fashion as the biological goals and objectives. CM1 and CM2 are at the landscape scale, because they apply to numerous natural communities and covered species. CM3 through CM11 each apply to one natural community. CM12 through CM21 address other stressors for one or more covered species, so these measures apply at the species-specific level. CM22 addresses avoidance and minimization measures and applies to all previous conservation measures.

3.4.1 Conservation Measure 1 Water Facilities and Operation

3.4.1.1 Introduction and Summary

The primary purpose of *Conservation Measure (CM) 1 Water Facilities and Operation* is to construct and operate a facility that improves conditions for covered species and natural communities in the Delta while improving water supply. Specifically, CM1 is intended to meet or contribute to the biological goals and objectives in the manner specified in Section 3.4.1.6, *Consistency with the Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Implementation of CM1 will also produce a variety of other important benefits that are not closely tied to the protection and recovery of covered species and natural communities, and thus are not detailed in this Plan. These include restoring and protecting ecosystem health, water supply, and water quality; reducing SWP/CVP vulnerability to earthquake and flood hazards; and improving the flexibility of the SWP/CVP in the face of climate change.

CM1 will implement flow management changes to address the following flow-related issues for fish.

- Reverse flows in Old River and Middle River.
- Entrainment, salvage, and predation effects on native fish species due to south Delta intakes.
- Delta Cross Channel effects on fish migration.
- Salinity, flow, and habitat in Suisun Marsh.

- Flow modification effects in the Sacramento River.
- Effects on Delta outflows.
- Effects of climate change.

CM1 will be used to manage water facilities operations when and after the north Delta intakes become operational, approximately year 10. Many of the operational constraints under CM1 incorporate constraints placed by biological opinions (BiOps) issued after planning for the BDCP was underway (Chapter 1, Section 1.3.2.2*, Relationship of BDCP to Existing Biological Opinions*); however, CM1 proposes a different approach to management of those constraints. This change in management approach is logical, because the new north Delta intakes will allow an array of beneficial flow modifications that are not possible using the existing water management infrastructure in the Delta. These flow modifications and the management approach to achieving them are described below under Section 3.4.1.4, *Implementation*. Apart from modifying water operations as constrained by the BiOps, CM1 has little effect on operations under State Water Board Water Right Decision 1641 (D-1641)[1] (December 1999, revised March 2002), and would not alter D-1641 operational requirements.

CM1 will make substantial changes to water operations in the Delta through two major components: construction of new water facilities and operations of both new and existing water conveyance facilities once the new facilities become operational. CM1 does not include operations of the existing water conveyance facilities until the new north Delta facilities are completed and operational. Existing operations are subject to the current BiOps.

New facilities construction is summarized in Chapter 4, Section 4.2.1, *CM1 Water Facilities and Operation*. Construction of the north Delta facilities is part of this conservation measure, because it is a necessary precursor to the operational changes. In addition to the basic operating criteria, important aspects of operations include fall outflow and spring outflow decision trees, and real-time operations.

- The fall outflow and spring outflow decision trees identify a structured scientific approach for reducing uncertainty about the effects of initial operations when the north Delta intakes become operational, and conditioning those operations accordingly.
- The use of real-time operations protocols serves to minimize potentially harmful effects on covered species associated with day-to-day or instantaneous system operations.

This conservation measure is described in the following sections.

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[1] The State Water Board's 1995 Water Quality Control Plan (WQCP) for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary (Bay-Delta Plan [1995]) and the State Water Board's Final EIR for the Implementation of the 1995 Bay/Delta Water Quality Control Plan (November 1999) incorporated several elements of the EPA, NMFS, and USFWS regulatory objectives for salinity and endangered species protection. The plan provided various objectives relating to the operation of the Delta Cross Channel gates, outflow, exports, dissolved oxygen, and salinity. It also stated varying flow objectives for rivers, including the San Joaquin River at Vernalis. Pulse flows were to be provided to facilitate migration of salmon in the San Joaquin system. The 1995 WQCP has since been updated, but does not include any substantive changes to water quality standards from the 1995 WQCP. The State Water Board fully implemented the 1995 WQCP with Water Right Decision 1641 (D-1641) in March 2000. D-1641 implements certain water quality objectives for the Bay-Delta estuary on a long-term basis. In order to achieve these objectives, D-1641 ultimately amended certain water rights of the SWP and CVP.

Section 3.4.1.2, *Existing Conditions*, briefly summarizes flow regimes and flow management in the Plan Area (a topic extensively detailed in Appendix 5.C, *Flow, Passage, Salinity, and Turbidity,* particularly Attachment 5C.A, *CALSIM and DSM2 Modeling Results for Evaluated Starting Operations Scenarios*). It refers to descriptions of the primary existing water facilities and also describes current water operations, including a summary of the administrative structure and the real-time operations procedures.

Section 3.4.1.3, *Problem Statement*, describes the seven principal issues associated with flow management in the Delta, and how existing and proposed facilities are used to manage flows.

Section 3.4.1.4, *Implementation*, begins by describing the fundamental approach used in CM1, which is to control a group of important flow parameters within limits that are partly prescribed (Section 3.4.1.4.3, *Flow Criteria*) and partly adjustable through the following processes.

- Decision trees to set fall and spring outflow parameters at the initiation of north Delta diversion operations (Section 3.4.1.4.4, *Decision Trees*).
- Adaptive management to modify operations after that time (Section 3.4.1.5, *Adaptive Management*).
- Real-time operations to optimize operations on a day-to-day basis (Section 3.4.1.4.5, *Real-Time Operational Decision-Making Process*).

Thus, to achieve desired conservation benefits, CM1 will ensure that instream flow criteria are met by limiting the volumes of diverted water in a manner that allows variation within a specified range, adjusted daily via real-time operations and adjusted periodically through the adaptive management process; or by supplementing instream flows entering the Plan Area using water provided through an approved water transfer as described in Chapter 4, Section 4.2.7, *Transfers and Other Voluntary Water Market Transactions*.

The implementation section then details the major elements of CM1 implementation.

- Descriptions of the primary proposed water facilities: north Delta intakes, the alternative North Bay Aqueduct intake, and a Head of Old River operable gate.
- Description of CM1 governance, particularly the monitoring, research, and adaptive management program and the interactions with related entities, especially those involved in real-time operations.
- Description of the proposed flow constraints.
- Description of operating criteria, including the spring and fall outflow decision trees and how they will be implemented, as well as presentation and explanation of each tree.
- Description of proposed real-time operations under CM1.
- Description of facility maintenance.

Section 3.4.1.5, *Adaptive Management and Monitoring*, states the key uncertainties relevant to CM1 and identifies potential monitoring and research actions to resolve those key uncertainties. This resolution will occur in an adaptive management framework, as described below, in Section 3.4.1.4, *Implementation*, and in Section 3.6, *Adaptive Management and Monitoring Program*.

Section 3.4.1.6, *Consistency with the Biological Goals and Objectives*, lists the biological goals and objectives that will be supported by CM1 and describes how CM1 is expected to support each of those goals and objectives.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM1. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM1 on covered species will be avoided or minimized. Refer to Chapter 5, *Effects Analysis*, for detailed information on how CM1 is expected to affect covered species and natural communities.

3.4.1.2 Existing Conditions

3.4.1.2.1 Flow Variability

Flow variability in the Bay-Delta region is complex, perhaps exceeded in complexity only by the problem of understanding the biological consequences of this variability. Historical hydrologic conditions and flow in the Plan Area, including reclamation and water control actions contributing to current conditions, are described in Chapter 2, Section 2.2.1, *Hydrologic and Geomorphic Conditions*, and in Section 2.3.3.3, *Hydrologic Conditions,* which addresses both streamflow and tidal circulation. For detail on current water operations, see Section 2.3.3.3.3, *Water Supply Facilities and Facility Operations*.

3.4.1.2.2 Flow Control Facilities

Current flow control facilities in the Plan Area are described in Chapter 2, Section 2.3.3.3.3, *Water Supply Facilities and Facility Operations*; their locations are shown on Figure 1-1, *Plan Area Location* (Chapter 1). Further detail on these facilities is available in the following sections of Chapter 4, *Covered Activities and Associated Federal Actions*.

- Section 4.1.1, *History and Overview of the State Water Project and Central Valley Project.*
- Section 4.2.1.2, *State Water Project Facilities Operations and Maintenance.*
- Section 4.3.1, *Delta Cross Channel.*
- Section 4.3.4, *Central Valley Project Diversions.*
- Section 4.2.1.3, *Suisun Marsh Facilities Operations and Maintenance.*

The following paragraphs summarize the four existing facilities that would be operated to control flow criteria set by CM1: south Delta intakes, Delta Cross Channel gates, Suisun Marsh salinity control gates, and North Bay Aqueduct intake.

South Delta intakes. The existing south Delta diversions occur at the Banks Pumping Plant (SWP) and the Jones Pumping Plant (CVP). Banks Pumping Plant draws water into the Clifton Court Forebay, which is located in the south Delta along Old River. The forebay's intake draws water from three main sources: namely Old River downstream (north) of the intake, Middle River via Grant Line Canal, and Old River upstream of the intake. Jones Pumping Plant does not include a forebay but rather diverts water directly from Old River just upstream of the entrance to Clifton Court Forebay. The pumping plants generally divert much or all of the water coming from the San Joaquin River through Old River and Grant Line Canal, and draw the remainder of the pumping flow from Old and Middle River channels (north of the intakes) conveying Sacramento River water from the central

Delta. The pumping plants often cause net reverse flows (southward) in Old River and Middle River. Each pumping plant has an associated fish facility: the Skinner Fish Protective Facility for the Banks Pumping Plant and the Tracy Fish Collection Facility for the Jones Pumping Plant. The two fish facilities contain fish louvers (with 1-inch opening that create a behavioral barrier) that protect some fish from entrainment by the pumps. Those fish are collected and trucked to release points elsewhere in the Delta.

Delta Cross Channel. The Delta Cross Channel is an existing gated diversion channel between the Sacramento River (near Walnut Grove) and Snodgrass Slough. Flows into the Delta Cross Channel from the Sacramento River are controlled by large radial gates. When the gates are open, water flows from the Sacramento River through the cross channel to Snodgrass Slough and from there to channels of the lower Mokelumne River and into the central Delta. Once in the central Delta, the water is conveyed primarily via Old and Middle Rivers to the pumping plants as described above. Use of the Delta Cross Channel minimizes intake of brackish waters through the pumps by conveying fresh Sacramento River water to the forebay via a route that is little affected by tidal and flow-driven sources of saline water.

Suisun Marsh Salinity Control Gates. Suisun Marsh is currently managed largely to provide seasonal freshwater wetlands, primarily to support waterfowl habitat and recreation. Wetland managers flood their ponds in early October and drain them after the end of the waterfowl season in January. The Suisun Marsh Salinity Control Gates were originally installed and operated as a tidal pump to reduce salinity in the marsh: the one-way gates were opened on the ebb tide to allow freshwater from upstream to enter the slough and closed on the flood tide to prohibit saline water from entering the slough. Operation of the gates is based on tidal stage and triggered by high-salinity readings in the marsh. Gate operation results in a net flow of water from east to west. The salinity control structure (the gates and associated flashboards) alters local hydrodynamics and water quality conditions and can impede the migration and passage of various fish species when operated. The gates are operated, on average, 10 days per year, all during the period of early October through May (Burkhard pers. comm.). If necessary, coordination will occur with the Suisun Marsh Charter Principals Group over the term of the BDCP to seek amendments to the Suisun Marsh Plan that will provide for reducing the long-term operation of the Suisun Marsh Salinity Control Gates.

North Bay Aqueduct intake. The North Bay Aqueduct intake is located approximately 10 miles from the mainstem Sacramento River at the end of Barker Slough. The maximum pumping capacity is 175 cubic feet per second (cfs). During the last few years, daily pumping rates have ranged between 0 and 140 cfs. Each of the 10 North Bay Aqueduct pump bays is individually fitted with a positive-barrier fish screen consisting of a series of flat, stainless steel, wedge-wire panels with a slot width of 3/32 inch. This configuration is designed to exclude fish 25 millimeters or larger from being entrained. The bays tied to the two smaller units have an approach velocity of about 0.2 foot per second. The larger units were designed for an approach velocity of 0.5 foot per second, but actual approach velocity is about 0.44 foot per second.

3.4.1.2.3 Current Flow Management

The operations of the SWP and CVP are currently subject to the terms and conditions of D-1641, the USFWS (2008) and NMFS (2009a, 2011) BiOps, and the Section 2081 Incidental Take Permit for longfin smelt (California Department of Fish and Game 2009). The USFWS BiOp was remanded on March 29, 2011, and the NMFS BiOp on September 20, 2011; both are being revised. Water operations continue under the terms of the remanded BiOps. USFWS, NMFS, DWR, and the state and federal water contractors are petitioning the court to extend the deadline for the remanded BiOps by 3 years. This additional time would allow for flow experiments in the Delta similar to what is contemplated in this conservation measure to address key uncertainties. The results of these studies would then inform the remanded BiOps (and the BDCP). The new BiOps, when issued, are expected to remain in effect until the proposed north Delta intakes become operational. The BiOp issued by USFWS places restrictions on project operations intended to protect delta smelt; the BiOp issued by NMFS places other restrictions intended to protect Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and green sturgeon. All of the operational constraints included in these BiOps have been implemented and are included in the environmental baseline. Some actions required under the BiOps have been completed or are in place; these actions are incorporated in the environmental baseline described in Chapter 5, *Effects Analysis*. Other actions have not yet been completed, but will be in place prior to operation of the new north Delta intakes. These actions are required under the BiOps, and are not part of this Plan. Finally, some actions are ongoing and will be continued under the BDCP, or are not yet completed and will be completed under the BDCP; these actions are part of this Plan. Table 3.1-1 summarizes actions required by the BiOp but proposed for continuation under the BDCP. Most of these actions are components of CM1. Actions involving improvements in the Yolo Bypass are components of CM2, and actions involving restoration of natural communities and species habitat are components of other conservation measures (primarily CM3, CM4, CM5, CM6, CM7, and CM11).

3.4.1.3 Problem Statement

Operations of the south Delta SWP/CVP diversion facilities have been identified as primary factors in altering hydrodynamic conditions in Delta channels and associated fishery habitat (U.S. Fish and Wildlife Service 2008; Baxter et al. 2008). These operations contribute to local changes in water current patterns, water quality, and direct entrainment and losses of fish, macroinvertebrates, nutrients, phytoplankton, and zooplankton from the Delta environment (U.S. Fish and Wildlife Service 2008). The principal existing issues associated with flow management in the Delta, which CM1 is designed to address, include the following.

- Reverse flows in the Old and Middle Rivers.
- Entrainment, salvage, and predation effects of south Delta intakes.
- Delta Cross Channel effects on fish migration.
- Salinity, flow, and habitat in Suisun Marsh.
- Flow modification effects in the Sacramento River.
- Effects of reduced Delta outflows.
- Effects of climate change.

These issues are described below.

3.4.1.3.1 Reverse Flows in the Old and Middle Rivers

Most or all of the covered fish species (the juvenile and adult life stages of Chinook salmon, steelhead, delta smelt, longfin smelt, green and white sturgeon, Pacific and river lamprey, and Sacramento splittail) are expected to use hydrodynamic cues (e.g., channel flow direction and magnitude) to help guide their movement through the Delta. Reverse flows in Delta channels are thought to provide false attraction to migration cues, resulting in longer migration routes that may expose fish to varied sources of increased risk of mortality such as predation, exposure to seasonally elevated water temperatures, and increased vulnerability to entrainment at the south Delta intakes.

A variety of other impacts have also been attributed to reverse flows in the Old and Middle Rivers. During the winter months, there is a positive relationship between the magnitude of reverse flows within Old and Middle Rivers and the occurrence of prespawning adult delta smelt in SWP/CVP fish salvage (Kimmerer 2008; U.S. Fish and Wildlife Service 2008; Grimaldo et al. 2009). Also, particle tracking model simulations suggest that planktonic early life stages of covered fish species (e.g., larval delta smelt) may face a greater risk of vulnerability to entrainment at the SWP/CVP export facilities when reverse flows in Old and Middle Rivers increase.

Reverse flows within the channels of Old and Middle Rivers are also theorized to affect local and regional habitat conditions for covered fish and other aquatic species. Changes in channel velocity and flow patterns affect hydraulic residence time in the area and the production of phytoplankton and zooplankton that are important to the diet of covered fish. Channel velocities, scour, and deposition patterns affect habitat for benthic organisms and other macroinvertebrates. Changes in tidal hydrodynamics, especially channel velocity, affect habitat suitability for covered fish and other aquatic species in the area.

Relationships between the magnitude of reverse flows in Old and Middle Rivers and corresponding changes in salvage of various covered fish, such as juvenile Chinook salmon, steelhead, splittail, longfin smelt, lamprey, and sturgeon, are highly variable. Analyses and evaluations of the potential biological benefits of managing the south Delta intakes based on direct diversion rates or changes in the magnitude of reverse flows in Old and Middle Rivers are presented in Chapter 5, *Effects Analysis*. 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.

3.4.1.3.2 Entrainment, Salvage, and Predation Effects of South Delta Intakes

For decades, water has been diverted directly from the south Delta through SWP/CVP facilities to meet agricultural and urban water demands south and west of the Delta. These diversions create an artificial north-south flow of water through the Delta (as opposed to the general east-west flow pattern that existed before the diversions) and, as detailed above, have resulted in the development of reverse flows in major Delta channels that result in entrainment of fish, invertebrates, nutrients, and other organic material. Existing intake facilities are equipped with louvers that guide juvenile and larger fish into salvage facilities. Salvaged fish are subsequently transported to release locations on the lower Sacramento and San Joaquin Rivers, where there are high concentrations of predators (Miranda et al. 2010). Planktonic eggs, larvae, and small juveniles are not effectively salvaged and do not survive when carried into conveyance facilities. Smelt and juvenile salmonids that are drawn into Clifton Court Forebay are subject to high rates of predation from the large populations of predatory fish that are present there as well as from other sources of mortality (Gingras 1997; Clark et al. 2009; Castillo et al. 2009).

Construction and operation of the new north Delta intakes are expected to facilitate substantial reductions in entrainment and associated adverse effects associated with operation of the south Delta intakes. These outcomes are detailed in Appendix 5.B, *Entrainment*, and in Chapter 5, *Effects Analysis.*

3.4.1.3.3 Delta Cross Channel Effects on Fish Migration

When the Delta Cross Channel is open, fish move into the interior Delta with Sacramento River water (Brandes and McLain 2001). Survival of juvenile Chinook salmon, and likely other fish species, within the interior Delta is lower than survival in the mainstem Sacramento River (Baker and Morhardt 2001; Brandes and McLain 2001; CALFED Bay-Delta Program 2001; Perry and Skalski 2009; Perry et al. 2010), although it is unknown whether this reduced survival has a population-level effect on Chinook salmon (Manly 2008).

Current seasonal operations of the Delta Cross Channel gates are designed to minimize the migration of juvenile fish from the Sacramento River into the interior Delta through the Delta Cross Channel during the spring. However, adverse effects of an open Delta Cross Channel operation on anadromous fish, and other fish, occur outside of this closure period. Furthermore, open gates decrease velocities and increase bidirectional flows in the Sacramento River and its tributaries, slowing the migration of covered species and increasing their vulnerability to predation or mortality from poor habitat. Therefore, lengthening the closure period or operating on a tidal or daily cycle may improve survival of salmonids and other covered fish species.

Construction and operation of the new north Delta intakes are expected to entail relatively minor changes (average monthly changes of less than 10%; Appendix 5.C, Attachment 5.C.A, Section 5.C.A.4.6, *Delta Cross Channel and Georgiana Slough Flows*) in the frequency and volume of Sacramento River water flows into the Delta Cross Channel. Moreover, those flows will continue to be manipulated through the flow criteria and real-time operations discussed below, and are subject to future revision via adaptive management to minimize adverse effects on covered species and natural communities.

3.4.1.3.4 Salinity, Flow, and Habitat in Suisun Marsh

The Suisun Marsh Salinity Control Gates alter local current patterns and tidal hydrodynamics within Montezuma Slough, in large regions of Suisun Marsh, and in the main river channel between the control gate and Suisun Bay (California Department of Water Resources 1999). The gates have been identified as an impediment to migration and passage of species such as Chinook salmon, steelhead, and green sturgeon through Montezuma Slough (Fujimura et al. 2000). Operation of the control structure during the late fall in dry years can cause a significant upstream shift in X2 (the location, expressed in kilometers from the Golden Gate Bridge, at which channel-bottom water salinity is 2 ppt, a representative marker of the general area of the low-salinity zone), potentially increasing the risk of entrainment at the SWP/CVP export facilities for smelt and other species that are situated near X2 (Fullerton pers. comm.). These changes in environmental conditions are thought to have resulted in adverse effects on covered species and other aquatic resources in the area.

As levees are breached for tidal restoration under *CM4 Tidal Natural Communities Restoration*, salinity levels may increase through much of Suisun Marsh, complicating the feasibility of either discontinuing the operation of the salinity control gates, or eliminating the gates. First, rising salinity could negatively affect the managed wetlands of the remaining waterfowl hunting clubs. Secondly, salinity standards at the Suisun Marsh may have to be revised. Assuming that the Suisun Marsh's current salinity standards are maintained, tidal restoration would likely require increased operation of the salinity control gates (Chappell pers. comm.).

It is expected that the Suisun Marsh Salinity Control Gates would continue to be operated much as they currently are. However, that operation would be subject to modification via the adaptive management process (Section 3.6.5, *Adaptive Management Process*) to minimize adverse effects on covered species and natural communities.

3.4.1.3.5 Flow Modification Effects in the Sacramento River

The Sacramento River is the primary migration corridor and spawning/rearing habitat for Chinook salmon, Central Valley steelhead, sturgeon, and lamprey spawning in the Sacramento River watershed. Further, both delta smelt and longfin smelt are thought to spawn in the lower Sacramento River (Wang 1986; Bennett 2005).

The principal BDCP effects on the mainstem Sacramento River in the Plan Area will be associated with the reductions of flow caused by operation of the new north Delta diversions. The adverse effect of this flow reduction on covered species will be minimized by maintaining minimum instream flows past the intakes, called bypass flows. The following considerations were included in the development of the bypass flows.

Maintain adequate flows for covered fish species

Of particular interest are flow rates within Sutter and Steamboat Sloughs. These sloughs are existing channels that convey water from the Sacramento River in the general vicinity of Courtland downstream to approximately Rio Vista where they reenter the lower Sacramento River. Both channels currently have a hydraulic capacity greater than 500 cfs. Benefits to maintaining adequate flows in Sutter and Steamboat Sloughs include the following.

- Providing an alternative migration route for salmonids (Perry and Skalski 2008) and possibly splittail, sturgeon, and lamprey that circumvents the Delta Cross Channel and Georgiana Slough, thereby reducing the likelihood of covered fish species moving into the interior Delta where they may be exposed to higher predation pressure and entrainment into the south Delta pumps.
- Providing high-value juvenile rearing habitat. Both slough channels support substantially more woody riparian vegetation and greater habitat diversity (e.g., water depths, velocities, in-channel habitat) than is present along the mainstem Sacramento River between Courtland and Rio Vista.
- Providing high-value spawning habitat for splittail during dry periods without floodplain inundation.

Despite these anticipated benefits, Perry and Skalski (2009) and Perry et al. (2010) indicate that survival rates of juvenile Chinook salmon in Sutter and Steamboat Sloughs are highly variable relative to the mainstem Sacramento River. They have found that survival has been higher than, lower than, and similar to survival rates in the mainstem Sacramento River rates. Recent hydrodynamic modeling indicates that substantial habitat restoration in the Cache Slough Restoration Opportunity Area (ROA) (Section 3.4.3.2, *Problem Statement*), in combination with bypass flow requirements for the north Delta intakes, will enhance downstream flows in Sutter and Steamboat Sloughs substantially above those present under current conditions without the north Delta diversion facility (Munevar pers. comm.). Further, the BDCP will enhance channel margins (*CM6 Channel Margin Enhancement*) in Sutter and Steamboat Sloughs in part to create habitat that is unfavorable to nonnative predators that may be reducing survival of Chinook salmon, and likely other covered species, in these sloughs. Therefore, in combination with these other conservation measures, maintaining bypass flows is necessary to improve survival of salmonids, sturgeon, and splittail in Sutter and Steamboat Sloughs.

Maintain transport flows necessary for downstream movement of delta and longfin smelt

Downstream movement primarily occurs from April to July for delta smelt and December to June for longfin smelt. Newly hatched larval delta and longfin smelt, called yolk-sac larvae, have a yolk sac attached to them with an oil globule (Wang 1986). The yolk sac provides nourishment for delta smelt larvae for approximately 4 to 6 days (Bennett 2005); this is thought to be similar for longfin smelt. These larvae are very weak swimmers and drift downstream with flows from the Sacramento River to the low-salinity zone, where they can find suitable prey. To avoid starvation, this downstream movement must take place before the entire yolk sac is absorbed. Because downstream yolk-sac larval movement is driven nearly entirely by downstream flows, a minimum bypass flow criterion is necessary to allow this movement to occur.

Maintain downstream transport of food and organic material

The Sacramento River is used as a major corridor through which food and other organic material from upstream are transported downstream to the Delta and bays. The Delta and bays acquire production from upstream areas to support their ecosystems.

Maintain necessary attraction flows for upstream migration of adult Chinook salmon, steelhead, and sturgeon, including attraction flows through Sutter and Steamboat Sloughs

The timing of these flows varies between species; from September to June for the salmonids, and from February to November for the sturgeons.

Minimize tidally driven bidirectional flows near intakes, reducing the amount of time that covered fishes will be exposed to predators occupying habitat near the intakes

Flows past the intakes may also affect local current patterns and hydrodynamics, and this may affect fish entrainment or impingement, debris loading, and effectiveness of fish screen cleaning mechanisms.

3.4.1.3.6 Delta Outflow Effects

Fishery monitoring studies conducted by CDFW (Baxter et al. 1999) suggest that abundances of juvenile life stages of many fish (e.g., starry flounder, splittail, longfin smelt, and striped bass) and macroinvertebrates are a function of X2, a surrogate for the low-salinity zone during the late winter and spring (e.g., January through June [Kimmerer 2004]). For example, longfin smelt juvenile abundance indices increased as the X2 moved further downstream (west) within Suisun Bay (Kimmerer 2004). Recent analyses have suggested that previous relationships between X2 and fish abundance indices have changed, with overall abundance declining (Kimmerer 2004). The changes observed in these relationships have been hypothesized to be the result of the introduction and rapid colonization of Suisun Bay by the filter-feeding overbite clam (*Potamocorbula amurensis*) and its subsequent reduction of phytoplankton and zooplankton, reducing food supplies for juveniles within the upper estuary(Kimmerer 2004). Another change in this relationship has occurred since 2001 in conjunction with the pelagic organism decline, although the cause of this change is currently unknown (Baxter et al. 2008).

Factors that may contribute to the relationship between Delta outflow (including X2) and juvenile fish abundance are heavily debated, but may include increased productivity and availability of high-value habitat in Suisun Bay; downstream transport of fish, food, and organic matter; reduced temperature and/or toxics exposure; changes in nutrient composition; inundation of backwater and floodplains with high flows; and the distribution of early life stages of fish into habitats that are located further downstream with decreased vulnerability to direct and indirect effects of south Delta SWP/CVP export operations. Proposed changes to water operations under CM1 are intended to provide flexibility in managing outflow to benefit covered fish species.

3.4.1.3.7 Effects of Climate Change

Ongoing climate change is expected to have substantial effects on the Bay-Delta region (see recent review of projected climate changes by Cloern et al. 2011). Studies suggest that northern California will experience a continuing change from snow to rain in winter, leading to reduced snowpack, earlier snowmelt, and reduced river flows and reservoir storage in summer (Knowles and Cayan 2002; Miller et al. 2003; Mote et al. 2005). Air temperatures will continue to rise, increasing water temperatures and the movements of aquatic species in search of cool-water refuges. Accelerated rates of relative sea level rise will increase the intrusion of seawater into the upper estuary (Cayan et al. 2009). Sea level rise combined with an increase in coastal storms, storm surge, and river runoff will increase shoreline flooding and erosion. These physical changes are expected to be widespread and long-lasting, but the operational flexibility afforded under CM1 provides opportunities to adapt to these changes and minimize their harmful consequences. Those benefits are detailed in Chapter 5, Section 5.3.4, *Climate Change Adaptation*.

3.4.1.4 Implementation

CM1 focuses on several components of CVP and SWP water operations in the Plan Area that compose a flow regime intended to contribute to achieving the biological goals and objectives. These components include operations of the south Delta export facilities, a new Head of Old River operable gate, new north Delta intake facilities, Delta Cross Channel gates, the Suisun Marsh Salinity Control Gates, and a new North Bay Aqueduct intake. Each of these individual operations is proposed to interact and complement each other to provide important biological and water supply functions. Additionally, climate change effects in the Delta and in connected upstream areas were considered in the development of CM1. Operations under CM1 represent a substantial change in Delta flows, and in some instances real-time operations will be applied to minimize adverse biological and water supply effects. Two key drivers of Delta operations, Fall X2 and spring outflow, which are controlled in part by many of the individual operational components described above, are designed to respond to developing science and information that would be amassed between the time of permit issuance and operations under CM1. The process for determining these specific operations is outlined in a decision tree as described below. Upon commencing operations, adaptive management of CM1 would be used to further adjust and fine tune operations to maximize benefits and minimize adverse effects on biological resources and water supply.

During the initial years of BDCP implementation, flow management will be performed consistent with the current BiOps, as amended under court order, and any other regulatory or legal constraints that may be imposed in the future. Implementation of flow management under CM1 will be initiated when the new north Delta intakes become operational, thereby enabling joint management of north and south Delta diversions. This is estimated to occur beginning in year 10. CM1 implementation is discussed in the following sections.

- Section 3.4.1.4.1, *Proposed Water Facilities,* describes the primary proposed water facilities: north Delta intakes, an alternative North Bay Aqueduct intake, and a Head of Old River operable gate.

- Section 3.4.1.4.2, *Management Structure*, describes CM1 governance, particularly the monitoring, research, and adaptive management program and the interactions with related entities, especially those involved in real-time operations.
- Section 3.4.1.4.3, *Flow Constraints*, describes the seasonal flow constraints that have been used to estimate the biological effects of diversion operations. Operational flow constraints would be subject to real-time operations adjustments (Section 3.4.1.4.5), but would closely resemble the modeled constraints.
- Section 3.4.1.4.4, *Decision Trees*, describes the decision trees that would be used to set flow constraints with regard to two critical variables—spring outflow and fall outflow—and how they will be implemented.
- Section 3.4.1.4.5, *Real-Time Operational Decision-Making Process*, describes how operations will be managed to control the day-to-day or instantaneous operations of the diversions within the context of the flow constraints.
- Section 3.4.1.4.6, *Facility Maintenance Actions*, identifies actions needed for facility maintenance.

3.4.1.4.1 Proposed Water Facilities

Two new water control facilities will be constructed: three North Delta intakes with their associated conveyance and support facilities, and a new permanent Head of Old River operable gate.

Each of these facilities is described in Chapter 4, Section 4.2.1, *CM1 Water Facilities and Operation*. The locations of the new north Delta intakes and the existing Head of Old River barrier, which will be replaced by the Head of Old River Gate, are shown in Figure 1-1, *Plan Area Location* (Chapter 1).

North Delta Intakes

Three new north Delta intakes will be located along the Sacramento River (Figure 4-2, *Schematic Diagram of the Proposed North Delta Intake and Conveyance Facilities*, Figure 4-3, *Locations of the Proposed North Delta Intake and Conveyance Facilities*, and Figure 4-4, *Conceptual Intake Structure*, in Chapter 4). Each intake will have a capacity of up to 3,000 cfs and will be fitted with fish screens designed to minimize entrainment or impingement risk for all covered fish species. Diverted waters will be conveyed to a new regulating forebay, and then south to SWP/CVP canals, via a pipeline and tunnel system. Construction of the north Delta intakes will allow great flexibility in operation of both south and north Delta diversions, as well as operation of the Delta Cross Channel. Diversions at the north Delta intake would be greatest in wetter years and lowest in drier years, when south Delta diversions would provide the majority of the CVP and SWP south of Delta exports. This is a result of north Delta bypass flow requirements, which are described in more detail below. Actual Delta channel flows and diversions may be modified to respond to real-time operational needs such as those related to Old and Middle Rivers, Delta Cross Channel, or north Delta bypass flows. The north Delta intakes and conveyance system are described in detail in Chapter 4, Section 4.2.1.1, *North Delta Diversions Construction and Operations*.

Constraints incorporated in the design and operation of the north Delta intakes include the following.

- The new north Delta diversion facilities will consist of three separate intake units with a total, combined intake capacity not exceeding 9,000 cfs (maximum of 3,000 cfs per unit; details in Chapter 4, Section 4.2.1.1, *North Delta Diversions Construction and Operations*).

- Project conveyance is provided by a tunnel capacity sized to provide for gravity flow from an intermediate forebay to the south Delta pumping facilities (Chapter 4, Section 4.2.1.2, *State Water Project Facilities Operations and Maintenance*).
- The facility will, during operational testing and as needed thereafter, demonstrate compliance with the then-current NOAA and CDFW fish screening design and operating criteria, which govern such things as approach and passing velocities and rates of impingement. In addition, the screens will be operated to achieve the following performance standard and will be deemed to be out of compliance with permit terms if the standard is exceeded: Maintain survival rates through the reach containing new north Delta intakes (0.25 mile upstream of the upstream-most intake to 0.25 mile downstream of the downstream-most intake) to 95% or more of the existing survival rate in this reach. The reduction in survival of up to 5% below the existing survival rate will be cumulative across all screens and will be measured on an average monthly basis.
- The facility will precede full operations with a phased test period during which DWR, in close collaboration with NMFS and CDFW, will develop detailed plans for appropriate tests and use those tests to evaluate facility performance across a range of pumping rates and flow conditions. DWR will also implement operational constraints that minimize adverse impacts on covered fish species within that operational range, and demonstrate that biological performance standards are being achieved (Section 3.4.1.5, *Adaptive Management and Monitoring*). This phased testing period will include biological studies and monitoring efforts to enable the measurement of survival rates (both within the screening reach and downstream to Chipps Island), and other relevant biological parameters which may be affected by the operation of the new intakes.
- Operations will be managed at all times to avoid increasing the magnitude, frequency, or duration of flow reversals in Georgiana Slough.
- The fish and wildlife agencies (USFWS, NMFS, and CDFW) retain final authority over the operational criteria and constraints (i.e., which pumping stations are operated and at what pumping rate) during testing. The fish and wildlife agencies are also responsible for evaluating and determining whether the diversion structures are achieving performance standards for covered fishes over the course of operations. Consistent with the experimental design, the fish and wildlife agencies will also determine when the testing period should end and full operations consistent with developed operating criteria can commence. In making this determination, fish and wildlife agencies expect and will consider that, depending on hydrologies, it may be difficult to test for a full range of conditions prior to commencing full operations. Therefore, tests of the facility to ensure biological performance standards are met are expected to continue intermittently after full operations begin, to enable testing to be completed for different pumping levels during infrequently occurring hydrologic conditions.
- DWR will contract with the Delta Science Program to host an independent review of the engineering design and approach to meeting biological criteria, including lessons learned from other large screening programs.

Head of Old River Operable Gate

A new permanent, operable gate at the head of Old River (at the divergence from the San Joaquin River) would be constructed and operated to protect outmigrating San Joaquin River salmonids in the spring and to provide water quality improvements in the San Joaquin River in the fall. The temporary agricultural barriers (on Middle River and Old River near Tracy and Grant Line Canal) will continue to be installed. Operation of the Head of Old River gate can vary from completely open (laying flat on the channel bed) to completely closed (erect in the channel, prohibiting all flow from the San Joaquin River to Old River), with the potential for operations in between that would allow partial flow. The actual operation of the gate would be determined by real-time operations based on actual flows and/or fish presence.

3.4.1.4.2 Management Structure

Management structure for CM1 is presented in detail in Chapter 7, *Implementation Structure*. Additional details regarding management of the adaptive management program are presented in Section 3.6, *Adaptive Management and Monitoring*. The following is a summary of that structure.

- BDCP oversight is provided by the Authorized Entity Group and the Permit Oversight Group, which comprise representatives of the Permittees[2] and the fish and wildlife agencies. They are assisted in this effort by an advisory Stakeholder Council.
- BDCP administration is performed by the Implementation Office, overseen by the Program Manager and their designated Science Manager, both chosen by the Authorized Entity Group with approval by the Permit Oversight Group.
- Monitoring, research, and adaptive management decisions are primarily made by the Adaptive Management Team, chaired by the Science Manager; for further detail see Section 3.6.4.5, *Adaptive Management Team*.
- The annual water operations strategy for implementation of CM1 is developed jointly by DWR, CDFW, Bureau of Reclamation (Reclamation), USFWS, and NMFS.
- Real-time water operations under CM1 are determined by DWR, CDFW, Reclamation, USFWS, and NMFS; for further detail see Section 3.4.1.4.5, *Real-Time Operational Decision-Making Process*.

3.4.1.4.3 Flow Criteria

The flow parameters applied under CM1 are similar to those required under the BiOps and D-1641, but parameter values are different. The following six criteria are used to define the flow constraints:

- Old and Middle River flows
- Head of Old River barrier operations
- Delta outflow/X2
- North Delta bypass flows
- Export to inflow ratio
- Sacramento River flow at Rio Vista

These criteria are further described below and in Table 3.4.1-1. In addition, flow criteria also apply for the Delta Cross Channel gates and the Suisun Marsh Salinity Control Gates. Under the BDCP, these facilities would continue to be operated as they are now operated under the terms of the BiOps. For the Delta Cross Channel gates, the gates would be closed if fish are present in October and November, with closure decisions at that time reached through the real-time operations process

[2] DWR and the participating state and federal water contractors.

described in Section 3.4.1.4.5. The CALSIM II modeling assumed Delta Cross Channel operations as required by NMFS (2009) BiOp Action 4.1. In the modeling, Delta Cross Channel gates are closed for a certain number of days during October 1 through December 14 based on the Wilkins Slough flow, and the gates may be opened if the D-1641 Rock Slough salinity standard is violated because of the gate closure. Delta Cross Channel gates are assumed to be closed during December 15 through January 31. February 1 through June 15, Delta Cross Channel gates are operated based on D-1641 requirements. The Suisun Marsh Salinity Control Gates would continue to be closed up to 20 days per year from October through May.

In addition, BDCP operations criteria include a preference for south Delta pumping in July through September to provide limited flushing for improving general water quality conditions and reduced residence times. As part of the BDCP criteria, the location of where the D-1641 Emmaton salinity control requirement is proposed to be complied with is changed to Threemile Slough juncture. The changes to the Fremont Weir proposed under *CM2 Yolo Bypass Fisheries Enhancement* will affect the operations in the Delta, as well.

Old and Middle River Flows

This criterion chiefly serves to constrain the magnitude of reverse flows in the Old and Middle Rivers, also known as the "OMR flows," for entrainment protection and minimization of adverse indirect effects.

Head of Old River Barrier Operations

This criterion refers to the opening and closing of the operable gate on the Head of Old River barrier and thus influences Old and Middle River and San Joaquin River flows.

Delta Outflow/X2

Delta Outflow criterion allows provision of sufficient outflow to maintain a desirable salinity regime downstream of Collinsville during the spring and fall. The X2 criterion refers to the longitudinal location of the 2-ppt salinity line in the Delta (measured in kilometers upstream from the Golden Gate) and is used as a way to manage the low-salinity zone, as well as water quality in the Delta.

Export-to-Inflow Ratio

This criterion provides for the proportion of Delta inflows that can be diverted at the SWP and CVP south Delta export facilities. The criterion is consistent with the D-1641 requirements and refers to the limitation on combined export of the CVP Jones Pumping Plant and SWP Banks Pumping Plant using a percentage of 3-day running average Delta inflow. The percentages range from 35% to 45% during February depending on the January eight-river index, and 35% during March through June. For rest of the months, 65% of the Delta inflow is allowed to be exported.

Sacramento River Flow at Rio Vista

This criterion serves to maintain minimum flows for outmigrating salmonids and smelt. This criterion refers to maintaining a minimum instream flow of 3,000 cfs in Sacramento River at Rio Vista, during January through August. During September through December, the required minimum instream flow is per D-1641.

North Delta Bypass Flows

The objectives of the north Delta diversion bypass flow criteria include regulation of flows to: maintain fish screen sweeping velocities; reduce upstream transport from downstream channels; support salmonid and pelagic fish transport to regions of suitable habitat; reduce predation effects downstream; and maintain or improve rearing habitat in the north Delta.

To ensure that these objectives are met, diversions must be restricted at certain times of the year (more severely from December through June) when juvenile covered fish species are present. This is achieved by restricting the diversion to constant low level pumping during the seasonal high flows that coincide with the start of the winter rains (called *pulse flows*), when the juvenile fish begin their outmigration; followed by providing adequate flows during the remainder of the outmigration (called *post-pulse operations*). A process of determining when the pulse occurs is described below. The protections allowed during these pulses will achieve safe juvenile passage past the intakes to well downstream of lower Delta channels that might otherwise lead them away from the lower estuary. Additional but less restrictive requirements apply for the late spring to late fall period.

The initial pulse is a natural occurrence caused by the first substantial runoff event of the season. This can occur as early as October or as late as February, but usually happens in December. During the initial pulse, flows will be diminished only by constant low-level pumping to the extent allowed under the rules described below. If the initial pulse occurs prior to Dec 1, then an assessment will be made to decide when a second pulse is necessary. A flow condition will be categorized as an initial pulse based on real-time monitoring. The definition of the initial pulse for the purposes of modeling is provided below.

At the end of the initial pulse phase, post-pulse operations will apply. The conditions that trigger the transition from the initial pulse protection to post-pulse operations are described below, along with bypass operating rules for the post-pulse phase, which provide for restricted levels of pumping.

In July through September, the bypass rules are less restrictive, allowing for a greater portion of the Sacramento River to be diverted, as described in Table 3.4.1-2. In October through November the bypass amount is increased.

The north Delta diversion bypass flow criteria comprise three parameters that are applied to the Sacramento River: constant low-level pumping, initial pulse protection, and three levels of post-pulse operations. These parameters are summarized below.

- **Constant low-level pumping**. Diversions of up to 6% of total Sacramento River flow such that bypass flow never falls below 5,000 cfs. No more than 300 cfs can be diverted at any one intake. While referred to as “constant,” pumping would vary with flows at Freeport.
- **Initial pulse protection**. Low-level pumping is maintained through the initial pulse period. After the pulse period has ended, water operations will be guided by post-pulse bypass flows presented in Table 3.4.1-2. Actual water operations will be based on real-time monitoring of fish movement.

If the initial pulse period begins before December 1, the month of May bypass criteria must be initiated following the initial pulse period; the second pulse period would have the same protective operation as the initial pulse protection.

For the purpose of modeling, the initiation of the pulse is defined by the following criteria.

- Flow in the Sacramento River below Wilkins Slough increases by more than 45% over a 5-day period.
- Flows greater than 12,000 cfs as measured in the Sacramento River below Wilkins Slough.

Low-level pumping continues until: flows in the Sacramento River below Wilkins Slough return to pre-pulse flows (flow on first day of 5-day increase); flows decrease for 5 consecutive days; or flows are greater than 20,000 cfs for 10 consecutive days. Operationally, similar criteria are expected to be applied using real-time operations criteria (Section 3.4.1.4.5, *Real-Time Operational Decision-Making Process*), which entail the added consideration that a pulse is defined partly by the presence of substantial numbers of outmigrant juvenile salmonids.

- **Post-pulse water operations** (could apply during any month). After initial pulse(s), implement Level I post-pulse bypass rule (Table 3.4.1-2) until the occurrence of 15 total days of bypass flows above 20,000 cfs. Then implement Level II post-pulse bypass rule (Table 3.4.1-2) until 30 total days of bypass flows occur above 20,000 cfs. At this point, implement Level III post-pulse bypass rule (Table 3.4.1-2) so that bypass flows are sufficient to prevent any increase in duration, magnitude, or frequency of reverse flows at two points of control: Sacramento River upstream of Sutter Slough and Sacramento River downstream of Georgiana Slough. These points of control are used to prevent upstream transport toward the proposed intakes and to prevent any more upstream transport into Georgiana Slough than under existing conditions.

Application of Flow Criteria

Flow criteria are applied seasonally (month by month) and according to the following five water-year types. Under the observed hydrologic conditions over the 82-year period (1922–2003), the number of years of each water-year type is included below. The water-year type classification for the majority of the criteria mentioned here, unless noted differently, is based on the Sacramento Valley 40-30-30 Water Year Index defined under D-1641.

- Wet water year: the wettest 26 years of the 82-year hydrologic data record, or 32% of years.
- Above-normal water year: 12 years of 82, or 15%.
- Below-normal water year: 14 years of 82, or 17%.
- Dry water year: 18 years of 82, or 22%.
- Critical water year: 12 years of 82, or 15%.

Water operations under the BDCP are then constrained as shown in Table 3.4.1-1.

1 **Table 3.4.1-1. Water Operations Flow Criteria and Relationship to Assumptions in CALSIM Modeling**

Parameter	Criteria	Summary of CALSIM Modeling[a]
Old and Middle River/San Joaquin inflow-export ratio	• October, November: Flows will not be more negative than an average of −2,000 cfs during D-1641 San Joaquin River pulse periods, or −5,000 cfs during nonpulse periods. • 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 dry and 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 and dry year and -3,000 cfs during critical years. • April, May: Allowable flows depend on gaged flow measured at Vernalis, and will be determined by a linear relationship. The following values were used in the CALSIM II modeling. 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, allowable flows depend on gaged flow measured at Vernalis. However, 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 and up to 10,000 cfs, OMR flows will be at least 0 cfs. If Vernalis exceeds 10,000 cfs and up to 15,000 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.	• October, November: Assumed no south Delta exports during the D-1641 San Joaquin River 2-week pulse, no OMR restriction during 2 weeks prior to pulse, and −5,000 cfs in November after pulse. • December: −5,000 cfs only when the Sacramento River pulse based on the Wilkins Slough flow (same as the pulse for the north Delta diversion) occurs, if no OMR requirement was applied. If the USFWS (2008) BiOp Action 1 is triggered, after which −2,000 cfs requirement is assumed. • April, May: OMR requirement for the Vernalis flows falling between the specified flows were determined by linear interpolation. When Vernalis flow is between 5,000 cfs and 6,000 cfs, OMR requirement is determined by linearly interpolating between −2,000 cfs and +1,000 cfs. • January–March and July–September: Same as CM1 criteria
Head of Old River gate operations	• December, June 16 to September 30, and during the days in November 2 weeks after the D-1641 pulse: Operable gate will be open. • All other months: Operable gate will be partially or completely closed, via real-time	Assumed 50% open from January 1 to June 15, and during days in October prior to the D-

<table>
<tr><th>Parameter</th><th>Criteria</th><th>Summary of CALSIM Modeling[a]</th></tr>
<tr><td></td><td>operations, to minimize entrainment risk for outmigrant juvenile salmonids and/or manage San Joaquin River water quality. In determining the criteria for opening and closure of the Head of Old River gate, the fish andwildlife agencies' goal is to have the Head of Old River gate closed as much as possible from February 1 through June 15; however; the Head of Old River gate may be open subject to real-time operations for purposes of water quality, stage, and flood management considerations.
• Note to Reader: Prior to issuance of the final BDCP document, operational guidance will be developed for use by project operators in implementing these operational criteria.</td><td>1641 San Joaquin River pulse</td></tr>
<tr><td>Spring outflow</td><td>• March, April, May: As described in Section 3.4.1.4.4, Decision Trees, initial operations will be determined through the use of a decision tree. If at the initiation of dual conveyance, the Permit Oversight Group determines that 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 high outflow scenario would be to provide a March–May average outflow scaled to the 90% forecast of eight-river index for the water year, with scaling as summarized in the table below.

March–May Average Outflow Criteria for “High Outflow” Outcome of Spring Outflow Decision Tree
<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>17,200</td></tr>
<tr><td>70%</td><td>13,300</td></tr>
<tr><td>80%</td><td>11,400</td></tr>
<tr><td>90%</td><td>9,200</td></tr>
</table>
• March–May outflow targets are achieved using flow supplementation provided through an approved water transfer, by limiting CVP and SWP Delta exports to a total of 1,500 cfs, and finally, if these two water sources have been utilized, through releases from Oroville, with subsequent appropriate accounting adjustments between the SWP and the CVP.</td><td>• Same as CM1 criteria, assuming outflow from export reductions and Oroville releases</td></tr>
</table>

Parameter	Criteria	Summary of CALSIM Modeling[a]
	• 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 D-1641. • February, June: Flow constraints established under D-1641 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 operate to D-1641 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.	• Same as CM1 criteria.
Winter and summer outflow	• Flow constraints established under D-1641 will be followed.	• Same as CM 1 criteria.
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 Table 3.4.1-2.	• Same as CM1 criteria.
Export to inflow ratio	• Combined export rate is defined as the diversion rate of the Banks Pumping Plant and Jones Pumping Plant from the south Delta channels[b]. • 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. • Operation criteria are the same as defined under D-1641, subject to BDCP adaptive management.	• Same as CM1 criteria.

[a] See Table C.A-1, *CALSIM II Modeling Assumptions for Existing Conditions (EBC1), No Action Alternative (EBC2) and BDCP Operational Scenarios*, in Appendix 5.C, Attachment 5.C.A.

[b] It has not yet been determined whether the combined export rate will include the diversion rate of the new north Delta diversions.

OMR = Old and Middle Rivers

Flow criteria also apply for the Delta Cross Channel gates and the Suisun Marsh Salinity Control Gates. For the Delta Cross Channel gates, the gates would be closed if covered fish are present in October and November, with closure decisions at that time reached through the real-time operations process described in Section 3.4.1.4.5. The CALSIM II modeling assumed Delta Cross Channel operations as required by NMFS (2009) BiOp Action 4.1. In the modeling, Delta Cross Channel gates are closed for a certain number of days during October 1 through December 14 based on the Wilkins Slough flow, and the gates may be opened if the D-1641 Rock Slough salinity standard is exceeded because of the gate closure. From December 1 through December 14, the Delta Cross Channel gates would be closed except for water quality issues or to conduct approved experiments. The gates are assumed to be closed during December 15 through January 31. February 1 through June 15, Delta Cross Channel gates would be operated based on D-1641 requirements.

Under the BDCP, these facilities would continue to be operated as they are now under the terms of the BiOps and D-1641. The Delta Cross Channel gates would be closed if juvenile salmonids are present in October and November, with closure decisions at that time reached through the real-time operations process described in Section 3.4.1.4.5. The Suisun Marsh Salinity Control Gates would continue to be closed up to 20 days per year from October through May.

Table 3.4.1-2. Flow Criteria for North Delta Diversion Bypass Flows

Constant Low-Level Pumping (December–June)								
Diversions up to 6% of river flow such that bypass flows remain equal to or 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								
If Sacramento River at Freeport flow is over…	But not over…	The bypass is…	If Sacramento River at Freeport flow is over…	But not over…	The bypass is…	If Sacramento River at Freeport flow is over…	But not over…	The bypass is…
December–April								
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
May								
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

If Sacramento River at Freeport flow is over…	But not over…	The bypass is…	If Sacramento River at Freeport flow is over…	But not over…	The bypass is…	If Sacramento River at Freeport flow is over…	But not over…	The bypass is…
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								
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
July–September								
The bypass flow is 5,000 cfs			The bypass flow is 5,000 cfs			The bypass flow is 5,000 cfs		
October–November								
The bypass flow is 7,000 cfs			The bypass flow is 7,000 cfs			The bypass flow is 7,000 cfs		

3.4.1.4.4 Decision Trees

Over the past decades, there has been considerable disagreement over the causes and the relative importance of various factors contributing to the decline of many aquatic species in the Delta. There is agreement, however, that much additional insight can be gained through more focused science in the Delta.

Two key areas of uncertainty for the BDCP are the importance of fall outflow in achieving abundance and habitat objectives for delta smelt and the importance of spring outflow for achieving the longfin smelt abundance objective. Because of the scientific uncertainty concerning the volume of Delta outflow that is necessary to contribute to the biological goals and objectives for these species, the role and contribution of fall and spring outflow for the smelt species will be aggressively investigated in a collaborative decision-tree process.

In general, a decision tree is an analytical process to compare alternatives or hypotheses and through the structured comparison identify the strategy or strategies most likely to reach the defined goal. Here, the decision-tree process is a focused form of adaptive management that will be used to determine the volume of fall and spring outflow prior to initiating CM1 operations. Other covered fish species, including salmonids and sturgeon, are affected by outflow. Their outflow needs will also be investigated as part of the decision-tree process.

This decision tree and the BDCP must account for several important and distinct timing issues. First, in the near-term at the time of permitting, the fish and wildlife agencies must make decisions based on the best scientific and commercial data available at that time. Second, in the time between permitting and the initiation of CM1 operations, all the parties, including the fish and wildlife agencies, expect to gain more knowledge and have better information to guide decisions involving fall and spring outflow prior to north Delta operations.

The parties understand and appreciate these timing issues. For permitting purposes, the applicants propose a project with operational and flow criteria intended to achieve the biological goals and objectives, which, among other things, include the range of operational and flow criteria for the high-outflow and low-outflow scenarios. It is expected that USFWS, CDFW, and NMFS will issue a permit for the proposed project, which may include as permit terms and conditions the operational and flow criteria related to the high-outflow scenario in the application.

However, all of the parties, including USFWS, NMFS, and the CDFW, agree that future science and improved information will be used as described herein to determine fall and spring outflow criteria applicable when the conveyance facilities become operational. USFWS, CDFW, and NMFS will make the final decision about criteria that will be applicable when the conveyance facilities become operational pursuant to the decision-tree process described herein, and the dispute procedure described in Chapter 7, Section 7.1.7, *Elevation and Review of Implementation Decisions*.

CM1 includes two decision trees, one for fall outflow and one for spring outflow, that specify potential alternative outcomes for each criterion. Because each decision tree identifies two possible outcomes, the decision trees lay out four potential outcomes in outflow criteria when the spring and fall outflow components are combined, as described in Table 3.4.1-1. These four outcomes will be aggressively investigated through the decision-tree process. Project operating criteria will be subject to a new determination by the fish and wildlife agencies, consistent with the adaptive management process for the BDCP, based on best available science developed as described below, specifying what the spring and fall outflow criteria will be at the time CM1 operations begin. The parties anticipate that these adjustments will be made under the terms of the authorized program, without amending the permit.

Under the decision-tree process, hypotheses supporting each criterion will be tested in detail during the years before CM1 operations commence. The information gained during this period will be used to conduct a reevaluation of the initially specified criteria, based on all new scientific information, to decide what criteria will be selected for implementation at the beginning of CM1 operations. The decision-tree process will involve the following steps.

1. Clearly articulate scientific hypotheses designed to reduce uncertainty about what outflow criteria are needed to achieve the biological objectives for covered smelt species, salmonids, and sturgeon.
2. Develop and implement a science plan and data collection program based on the decision-tree management alternatives to test the hypotheses and reduce uncertainties.
3. At the time CM1 operations begin, the fish and wildlife agencies identify spring and fall outflow criteria sufficient to meet the biological objectives for covered fish species.

Once CM1 operations begin, the decision-tree process will end. Thereafter, the adaptive management and monitoring program will continue as the primary process for adjusting all aspects of the conservation strategy, including spring and fall outflow operating criteria for CM1 operations for all covered species.

Spring Outflow Decision Tree

Current science indicates that the decline in longfin smelt abundance has been a result of foodweb changes and reductions of winter-spring outflow from the Delta. Studies dating as far back as the 1980s suggest that spring (March–May) outflow is an important driver of longfin smelt abundance. Investigations related to the relationship between food, flow, and longfin smelt abundance continue in many venues; meanwhile, uncertainty exists regarding the mechanism through which higher Delta outflow improves the production and survival of early life stages of longfin smelt. Results of these investigations, including those directly related to the decision-tree process, will continue to be reviewed and considered in the coming years, in making management decisions regarding the contribution of winter-spring Delta outflow to meeting the population growth and abundance objectives for longfin smelt (Objectives LFSM1.1 and LFSM1.2, Section 3.3.7.2.3, *Species-Specific Goals and Objectives*).

Fall Outflow Decision Tree

How fall outflow affects delta smelt abundance and habitat quality is an active area of research, and understanding of these effects is expected to improve in the coming years. That improved understanding is likely to materially affect the conservation measures developed to achieve Objective DTSM2.1 (Section 3.3.7.1.3, *Species-Specific Goals and Objectives*)—which concerns availability of delta smelt habitat and is defined in terms of habitat area with a specific range of salinities, turbidities, flows, and other features—and Objective DTSM1.3—which concerns increasing delta smelt abundance through management of Fall X2. Under the USFWS (2008) BiOp, it is hypothesized that the fall habitat objective will be achieved by providing fall (September–November) flows necessary to position X2 in or near Suisun Bay in wet or above-normal years. This hypothesis is currently being tested in the FLaSH studies (Delta Stewardship Council 2010) and informed by annual reviews of USFWS (2008) BiOp effectiveness (Anderson et al. 2012); it will continue to be evaluated in the decision-tree process. Alternatively, it is hypothesized that new shallow-water habitat areas created through restoration of tidal natural communities (CM4) could accomplish this objective with lower outflow during the fall. If restoration of habitat for delta smelt is successful, there may be no need to provide the fall outflows prescribed under the high-outflow scenario (Table 3.4.1-1) to meet the biological objectives for this species. Collaborative scientific research to test each of these hypotheses will be conducted before initial operations of the north Delta facility.

3.4.1.4.5 Real-Time Operational Decision-Making Process

Note to reader: At the time of this Public Draft, the applicants and Reclamation are continuing to coordinate with the permitting agencies on the details of the real-time operations procedures to be consistent with the operations of the SWP and CVP. This section is therefore preliminary. The final BDCP document will describe operational criteria to guide project operations.

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. RTOs would be implemented on a timescale practicable for each affected facility and are part of the water operating criteria for CM1, which will be periodically evaluated and possibly modified through the adaptive management program (Section 3.6). The RTOs will satisfy Water Code, section 85321:

> 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.

As part of the BDCP, an RTO Team, comprising one representative each from USFWS, NMFS, CDFW, Reclamation, and DWR, will be assembled. The RTO Team will also include one representative of the state water contractors and one representative of the federal water contractors, who will serve as nonvoting members. The RTO Team may be expanded after further consideration of additional participants and appropriate ground rules. The RTO Team[3] will be responsible for evaluating real-time hydrology, operations, and fish data, and will use that information to make adjustments in operations. The RTO representatives will utilize technical teams (e.g., Smelt Working Group, Delta Operations for Salmonids and Sturgeon) and/or a subset of technical teams comprising PWA members and other interested parties (e.g., Delta Conditions Team) to provide and help evaluate the necessary information to assist them in their decision making. When developing adjustments to CM1 operations, in real-time, the RTO Team will consider the following.

- 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.

[3] The RTO Team will develop its operating procedures and any other details of its governance structure.

- 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.

Consistent with Chapter 6, Section 6.3.2, *Annual Delta Water Operations Plan*, the RTO team will work with DWR and Reclamation to inform development of the Annual Delta Water Operations Plan. Prospectively, and consistent with the criteria establish in CM1 and the considerations enumerated above, the RTO Team will identify for the coming water year estimates of the potential adjustments to planned operations. These estimates will include the likely relative priority of different responses that the RTO Team might bring into play during RTOs and key tools that may be used to choose among them, the intended benefits for covered fish species, any expected effects on water supply, and the monitoring and analysis protocols in place to track potential adjustments. During the course of the year, the RTO Team will track operational adjustments as they occur and account for the effects on covered fish species and water supply resulting from the adjustment to planned operations. Accounting for the effects of an adjustment must consider other relevant factors that are potentially affecting planned operations, such as changing hydrology, operational failures, or obligations to meet the State Water Resource Control Board's water quality standards. Retrospectively, the RTO Team will report the tracking and accounting information to describe for each operational adjustment the environmental conditions that triggered the adjustment, the specific adjustment(s) that were made to planned operations, and the effects of the adjustments on water supply and covered fish species. This information will be used by the RTO Team to review the efficacy of adjustments made to improve future decisions and inform development of subsequent Annual Delta Water Operations Plans.

The RTO Team will provide a publicly available website or other electronic medium to post information considered by the RTO Team, which may include real-time hydrology, operations, and fish data, and the operational changes made in response to these conditions. Posted information will be provided to the Implementation Office for inclusion in the Annual Report.

If the RTO Team cannot decide on an acceptable action, a decision will be made by the Regional Director of the relevant fish agency(s), given that the Director of the project agency concurs that the change is within their authority (Chapter 7, Section 7.1, *Program Manager*).

RTOs are expected to be needed during at least some part of the year at the Delta Cross Channel gates, Head of Old River gate, north and south Delta diversions, Fremont Weir Operable Gate(s), and the nonphysical barriers. Covered facilities and activities not described here will not be subject to RTOs, unless deemed necessary through the adaptive management program, and these components of the system will be operated pursuant to the criteria described in Section 3.4.1.4.3, *Flow Criteria*. The RTO Team in making operational decisions will take into account upstream operational constraints, such as coldwater pool management, instream flow, and temperature requirements.

Delta Cross Channel gates. The gates will be managed under RTOs from October 1 to November 30. The gates will be closed for a prescribed duration (i.e., a variable number of days during October through November) when juvenile salmonids are emigrating past the gates.

Head of Old River gate. The gate will be managed under RTOs from January 1 through June 15, and October 1 through November 30, based on real-time monitoring for the presence/absence of covered fishes, hydrologic conditions, and species risk. In determining the opening and closure of the Head of Old River gate, the fish and wildlife agencies' goal is to have the gate closed as much as possible in February through June 15; however, the gate may be open subject to RTO for purposes of water quality, stage, and flood control considerations. The final BDCP document will provide operational guidance for use by project operators in implementing these provisions.

North Delta diversions. Bypass flow operations will be managed under RTOs from December through June based on the presence of covered fish species and basin hydrology in order to improve survival past the diversions. The exact triggers and responses for RTO at the north Delta diversions are still under development. The various levels of pumping under CM1 are designed to protect salmonids during the expected presence of runs based on hydrology and expected migration timing. During operations, adjustments may be made to improve water supply and/or migratory conditions for fish by making real-time adjustments to the pumping levels at the north Delta diversions. Generally, RTOs will do the following.

- Manage north Delta diversion bypass flows within a preset range when juvenile salmonids are emigrating downstream past the intakes.
- Manage north Delta diversion bypass flows within a preset range when adult sturgeon are migrating upstream.
- Manage north Delta diversion bypass flows within a preset range to avoid an increase in frequency and magnitude of reverse flows (and entrainment) at Georgiana Slough compared to baseline. (Real-time adjustments to avoid reverse flows are primarily the responsibility of DWR operators with occasional input from RTO team as appropriate.)
- Manage the distribution of pumping activities among the three north Delta and two south Delta intake facilities to maximize survival of covered fish species in the Delta and water supply.

South Delta diversions. The south Delta diversions will be managed under RTO to achieve OMR criteria described in CM1 throughout the year based on fish protection triggers (e.g., salvage density, calendar, species distribution, entrainment risk, turbidity, and flow based triggers [Table 3.4.1-3]). Increased restrictions as well as relaxations of the OMR criteria may occur as a result of observed physical and biological information. Additionally, as described above for the north Delta diversions, RTO would also be managed to distribute pumping activities amongst the three north Delta and two south Delta intake facilities to maximize both survival of covered fish species in the Delta and water supply.

Table 3.4.1-3. Salvage Density Triggers for Old and Middle River Flow Adjustments January 1 to June 15

First Stage Trigger
(1) Daily SWP/CVP older juvenile Chinook salmon[b] loss density (fish per TAF) is greater than incidental take limit divided by 2,000 (2% WR JPE ÷ 2,000), with a minimum value of 2.5 fish per taf, or (2) Daily SWP/CVP older juvenile Chinook salmon loss is greater than 8 fish per TAF multiplied by volume exported (in TAF), or (3) CNFH CWT LFR or LSNFH CWT WR cumulative loss is greater than 0.5% for each surrogate release group, or (4) Daily loss of wild steelhead (intact adipose fin) is greater than 8 fish per TAF multiplied by volume exported (in TAF).[c] Response: • Reduce exports to achieve an average net OMR flow of -3,500 cfs for a minimum of 5 consecutive days. The 5-day running average OMR flows will be no more than 25% more negative than the targeted flow

level at any time during the 5-day running average period (e.g., -4,375 cfs average over 5 days). • Resumption of -5,000 cfs flows is allowed when average daily fish density is less than trigger density for the last 3 days of export reduction.[c] Reductions are required when any one criterion is met.
Second Stage Trigger
(1) Daily SWP/CVP older juvenile Chinook salmon loss density (fish per TAF) is greater than incidental take limit (2% of WR JPE) divided by 1,000 (2% of WR JPE ÷ 1,000), with a minimum value of 2.5 fish per TAF, or (2) Daily SWP/CVP older juvenile Chinook salmon loss is greater than 12 fish per TAF multiplied by volume exported (in TAF), or (3) Daily loss of wild steelhead (intact adipose fin) is greater than 12 fish per TAF multiplied by volume exported (in TAF). Response: • Reduce exports to achieve an average net OMR flow of -2,500 cfs for a minimum 5 consecutive days. Resumption of -5,000 cfs flows is allowed when average daily fish density is less than trigger density for the last 3 days of export reduction. Reductions are required when any one criterion is met.
End of Triggers
• Continue action until June 15 or until average daily water temperature at Mossdale is greater than 72°F (22°C) for 7 consecutive days (1 week), whichever is earlier. Response: • If trigger for end of OMR regulation is met, then the restrictions on OMR are lifted.
[a] Salvage density triggers modify project operations only within the ranges modeled. Triggers will not be implemented in a manner that reduced water supplies in amounts greater than modeled outcomes [b] *Older juvenile Chinook salmon* is defined as any Chinook salmon that is above the minimum length for winter-run Chinook salmon, according to the Delta Model length-at-date table used to assign individuals to race. [c] Three consecutive days in which the loss numbers are below the action triggers are required before the OMR flow reductions can be relaxed to -5,000 cfs. A minimum of 5 consecutive days of export reduction are required for the protection of listed salmonids under the action. Starting on day 3 of the export curtailment, the level of fish loss must be below the action triggers for the remainder of the 5-day export reduction to relax the OMR requirements on day 6. Any exceedance of a more conservative trigger restarts the 5-day OMR action response with the 3 consecutive days of loss monitoring criteria. TAF = thousand acre-feet.

Fremont Weir operable gate(s). The Fremont Weir operable gate(s) may be subject to RTOs from November 10 through May 15, when Sacramento River flow is high enough to support the diversion of water into the Yolo Bypass. Up to 500 cfs may be diverted into the bypass during May 16 to November 9 only for purposes of providing fish passage. Additional detail is provided in *CM2 Yolo Bypass Fisheries Enhancement* (Section 3.4.2.3, *Implementation*).

It is anticipated that the operating parameters that are implemented pursuant to RTOs will be similar to those described in the Annual Water Operations Plan. If a review indicates that actual operating parameters are higher or lower than those described in the Annual Water Operations Plan for 2 successive years, an adjustment to the prescribed range of that parameter(s) may be made, if recommended by the Adaptive Management Team, through the adaptive management process, as described in Section 3.6, subject to the adaptive management resources described in Section 3.4.23.

3.4.1.4.6 Facility Maintenance Actions

Facility maintenance actions serve to maintain the conservation benefits provided by use of flow management facilities, and thus have conservation value. Facility maintenance actions include periodic cleaning of the diversion screens and episodic in-water work to remove accumulated sediment and debris, which is typically an issue in the aftermath of a high-flow event such as a flood. These actions are further described in Chapter 4, *Covered Activities and Associated Federal Actions*.

3.4.1.5 Adaptive Management and Monitoring

Implementation of CM1 will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

3.4.1.5.1 Compliance and Effectiveness Monitoring

Compliance and effectiveness monitoring provisions are listed in Table 3.4.1-4. Effectiveness monitoring will be conducted to evaluate progress toward advancing the biological objectives discussed below in Section 3.4.1.6, *Consistency with the Biological Goals and Objectives*.

Table 3.4.1-4. Compliance and Effectiveness Monitoring Actions for CM1

Action Type	Monitoring Action	Timeframe
Compliance	Construction: Document compliance with fish screen design criteria.	Prior to construction and as-built
Compliance	Document compliance with the operational criteria with reference to existing environmental monitoring programs including: • IEP Environmental Monitoring Program: Continuous Multi-parameter Monitoring, Discrete Physical/ Chemical Water Quality Sampling) • DWR and Bureau of Reclamation: Continuous Recorder Sites • Central Valley Regional Water Quality Control Board: NPDES Self Monitoring Program • U.S. Geological Survey: Delta Flows Network and National Water Quality Assessment Program	Start prior to construction of water diversion facilities and continue for the duration of the permit term.
Compliance	Document compliance with the operational criteria using flow monitoring and models implemented by the Implementation Office. [*Details of monitoring to be developed; must be consistent with data structures supporting real-time operations.*]	Start prior to completion of water diversion facilities and continue for the duration of the Plan.
Compliance	Hydraulic field evaluations to measure velocities over a designated grid in front of each screen panel. Repeat as necessary to set initial baffle positions and confirm compliance with design criteria. This monitoring will be conducted at diversion rates close to maximum diversion rate. Locations of monitoring points, monitoring technology, and frequency/duration of monitoring are to be determined after baffling design is complete but prior to facility operations (same as postconstruction study 1, *Hydraulic Screen Evaluations to Set Baffles* [Fish Facilities Technical Team 2013]).	Initial studies require approximately 3 months beginning with initial facility operations.

Action Type	Monitoring Action	Timeframe
Compliance	Confirm screen operation produces approach velocities no greater than 0.33 foot per second (fps) in daytime and 0.2 fps at night when delta smelt are present [*indicator of smelt presence to be determined*]. Confirm screen operation produces sweeping velocities greater than or equal to approach velocities. Measure flow velocities within refugia. Approach and sweeping velocities will be measured within 12 inches outside of the screen face to account for boundary effects. This monitoring should be performed to evaluate the range of river stages accounting for the majority of total flow variability and should evaluate both clean and dirty screens at a representative range of river stages. Once compliance has been demonstrated, monitoring may cease. Monitoring should be repeated following any changes to the screens (other than cleaning) that the Adaptive Management Team determines may alter approach or sweeping velocities (seems to be same as postconstruction study 2, *Long-term Hydraulic Screen Evaluations*, combined with study 4, *Velocity Measurement Evaluations* [Fish Facilities Technical Team 2013]).	Approximately 6 months beginning with initial facility operations.
Effectiveness	Perform visual inspections (diver and/or camera) to evaluate effectiveness of cleaning mechanism and screen integrity. Determine whether cleaning mechanism is effective at protecting the structural integrity of the screen and maintaining uniform flow distribution through the screen. Adjust cleaning intervals as needed to meet requirements. (same as postconstruction study 3, *Periodic Visual Inspections* [Fish Facilities Technical Team 2013]).	Initial study to occur during first year of facility operation with periodic re-evaluation over life of project.
Effectiveness	Monitor refugia to evaluate effectiveness relative to design expectations. Method is likely to entail use of a Didson camera to observe fish behavior within refugia, but more specific monitoring protocols and performance metrics are to be developed once refugia design has been completed, and prior to facility operation. Monitoring will evaluate refugia operation at a range of river stages and with regard to target species or agreed proxies. Once compliance has been demonstrated, monitoring may cease. Monitoring will be repeated following any changes to the refugia that may be prescribed in the course of adaptive management (same as postconstruction study 5, *Refugia Effectiveness* [Fish Facilities Technical Team 2013]).	Approximately 6 months beginning with initial facility operations.
Effectiveness	Observe fish activity at screen face (using Didson cameras or other technology to be determined prior to facility operations) and use mark/recapture study of salmonid and smelt proxy fishes to evaluate impingement injury rate. Performance metrics to be determined prior to study initiation (same as postconstruction study 7, *Evaluation of Screen Impingement* [Fish Facilities Technical Team 2013]).	Study to be performed at varied river stages and diversion rates, during first 2 years of facility operation.
Effectiveness	Determine overall impact on survival of juvenile salmonids throughout the diversion reach related to the operation of the new facilities. Use mark/recapture and acoustic telemetry studies (or other technology to be determined prior to facility operations) to evaluate any impacts of facility operations on juvenile salmonids, under various pumping rates and flow conditions, to insure that the survival objectives for juvenile salmonids traversing the diversion reach are being met.	Study to be performed at varied river flows and diversion rates, during first 2 to 5 years of facility operation.
Effectiveness	Measure entrainment rates at screens using fyke nets located behind screens. Identify species and size of entrained organisms. Use trawl surveys in channel to calibrate density of entrained organisms. Performance metrics to be determined prior to study initiation (same as postconstruction study 8, *Screen Entrainment* [Fish Facilities Technical Team 2013], but with addition of trawl surveys).	Study to be performed at varied river stages and diversion rates, during first 2 years of facility operation.

Table 3.4.1-5 lists key uncertainties associated with CM1 and proposed research actions to resolve those uncertainties.

Table 3.4.1-5. Key Uncertainties and Potential Research Actions Relevant to CM1

Key Uncertainty	Proposed Research Actions	Timeframe
Are the initial spring outflow criteria (listed in Table 3.4.1-1) necessary, in conjunction with other conservation measures in the Plan, to achieve the biological objectives for covered fish species?	[Studies necessary to evaluate this uncertainty, which is the root of the spring outflow decision tree, have not yet been determined.]	Completion prior to initial operation of north Delta diversions
Is the USFWS Reasonable and Prudent Alternative (RPA) action for Fall X2 (listed in Table 3.4.1-1) necessary, in conjunction with other conservation measures in the Plan, to achieve the delta smelt biological objectives?	[Studies necessary to evaluate this uncertainty, which is the root of the fall outflow decision tree, have not yet been determined.]	Completion prior to initial operation of north Delta diversions
Relationship between proposed intake design features and expected intake performance relative to minimization of entrainment and impingement risks.	• Develop physical hydraulic model(s). If intake screen locations differ significantly in terms of river flow conditions or structure geometry, then more than one physical model study is needed. A physical model provides the capability to optimize hydraulics and sedimentation in the chosen river reach. Differences between the average channel velocity in the river and sweeping velocity adjacent to the screen face will be identified. Neutrally buoyant particles will be tracked to provide information on larval fish movement (same as preconstruction study 1, *Site Locations Lab Study* [Fish Facilities Technical Team 2013]).	6 to 12 months per model study depending on model scope of work and lab availability; needed prior to final design
Evaluation of tidal effects and withdrawals on flow conditions at screening locations	• Develop computational fluid dynamics model to provide information on how tidal changes and flow withdrawals affect flow conditions and sweeping velocities at screening locations. Results can be used in "Site Locations Lab Study" to set boundary conditions and validate physical model results (same as preconstruction study 2, *Site Locations Numerical Study* [Fish Facilities Technical Team 2013]).	6 months depending on model detail and complexity; needed prior to final design
Design of refugia areas (macro, micro, and base refugia)	Develop a physical hydraulic model to measure hydraulics and observe fish behavior in a controlled environment. Size/shape of refugia areas can be modified to optimize fish usage. Predators can be added to examine predation behavior near refugia (same as preconstruction study 3, *Refugia Lab Study* [Fish Facilities Technical Team 2013]).	6 to 9 months depending on model scope of work and lab availability; needed prior to final design
Examination of refugia at future fish screens.	Perform field evaluation of one or more existing (or soon-to-be-completed) fish screening facilities using fish refugia. Use these data to develop understanding of expected effectiveness of fish refugia and to identify areas for improvement (same as preconstruction study 4, *Refugia Field Study* [Fish Facilities Technical Team 2013]).	1 year; needed prior to final design

Key Uncertainty	Proposed Research Actions	Timeframe
Examination of refugia at future fish screens.	Perform field evaluation of one or more existing (or soon-to-be-completed) fish screening facilities using fish refugia. Use these data to develop understanding of expected effectiveness of fish refugia and to identify areas for improvement (same as preconstruction study 4, *Refugia Field Study* [Fish Facilities Technical Team 2013]).	1 year; needed prior to final design
Characterize the water velocity distribution at river transects within the proposed intake reaches for differing river flow conditions.	Perform field study to measure water velocity distribution across river transects using acoustic Doppler current profiler and to define velocity conditions at channel boundary. Differences between the average channel velocity in the river and sweeping velocity adjacent to the screen locations need to be identified to properly design the screen for sweeping velocity. Water velocity distributions in intake reaches will identify how hydraulics change with flow rate and tidal cycle (same as preconstruction study 7, *Flow Profiling Field Study* [Fish Facilities Technical Team 2013]).	1 year; needed prior to final design
What are the effects of deep-water screens on hydraulic performance	Use computational fluid dynamics model to assist development of baffling systems or other elements to address vertical velocity variations at the screen face (same as preconstruction study 8, *Deep Water Screens Study* [Fish Facilities Technical Team 2013]).	6 months depending on model detail and complexity; needed prior to final design
How will the new north Delta intakes affect survival of juvenile salmonids in the affected reach of the Sacramento River?	Perform mark-and-recapture studies, acoustic telemetry studies, and/or fyke net studies in proposed intake river reaches and control river reaches. Need to collect baseline data at 2 to 3 proposed screen locations and 2 to 3 control reaches. Following initiation of project operations, continue studies using same methodology and same locations. Identify the change in survival rates due to construction/operation of the intakes (same as preconstruction study 10, *Baseline Juvenile Salmon Survival Rates*, and postconstruction study 10, *Post-Construction Juvenile Salmon Survival Rates* [Fish Facilities Technical Team 2013]).	Start studies to collect multiple data sets; must be completed before construction begins. Postconstruction study to cover at least 3 years, sampling during varied river flows and diversion rates.
How will the new north Delta intakes affect Delta and longfin smelt density and distribution in the affected reach of the Sacramento River?	Use literature search, then trawling, trapping, and beach seining to collect data on delta and longfin smelt density and distribution within the intake reaches. Also collect data directly upstream and downstream of the intakes and in close proximity to sloughs and channels. Following initiation of diversion operations, continue sampling using same methods and at same locations. Compare to baseline catch data. Identify potential changes due to construction of intakes (same as preconstruction study 11, *Baseline Fish Surveys*, and postconstruction study 11, *Post-Construction Fish Surveys* [Fish Facilities Technical Team 2013]).	On-going study during months when delta and longfin smelt are expected to occur in the area. Important to start studies as soon as possible to capture seasonal data; studies completed prior to construction. Post-construction studies to be performed for duration of project operations, with timing and frequency to be determined.

Key Uncertainty	Proposed Research Actions	Timeframe
What is the relationship between Delta Cross Channel gates operations, covered fish movement and survival, and tidal flows?	Document effects of Delta Cross Channel gates operations on hydrodynamics and fish migration.	To be determined

3.4.1.5.2 Adaptive Management of Water Operations

CM1 may be adjusted according to the process described in Section 3.6, *Adaptive Management and Monitoring Program*, to achieve the relevant biological objectives, provided these adjustments are made consistent with Plan commitments and budget estimates described in Chapter 8, *Implementation Costs and Funding Sources*. Similarly, biological objectives may be adjusted by the same process. Strategies for making adaptive management changes will include the following.

- Changes in approach to implementing conservation measures.
- Shifting resources from less effective to more effective conservation measures.
- Adding new conservation measures consistent with the scope and budget of the Plan.
- Adjusting biological objectives.
- Other approaches, as described below.

The adaptive management commitments of the Permittees, including the specific commitments of the participating state and federal water contractors, are described in this section, in Section 3.4.23, *Resources to Support Adaptive Management,* and in Table 8-41, *BDCP Funding Provided by Participating State and Federal Water Contractors* (Chapter 8).

Operations of the new water facilities described in this conservation measure may be adjusted through two separate processes for the purpose of further minimizing impacts on covered fish species and advancing the biological objectives.

- The real-time operations process described in Section 3.1.4.5 that would occur on a monthly, weekly, and sometimes daily basis.
- The adaptive management process, in which the annual water operations planning process would be used to inform proposed changes to CM1 (Chapter 6, Section 6.3.4, *Annual Water Operations Report*).

Water facility operating criteria will be comprehensively reevaluated every 5 years as part of the program-level assessment conducted by Implementation Office, as described in Chapter 6, Section 6.3.5, *Five-Year Comprehensive Review*. Adjustments made through the adaptive management process to provide supplemental water to benefit covered fish species will be offset by one or more of the following sources to ensure that average annual water deliveries are consistent with the CM1 operations, including the decision tree. In the event that changes to CM1 are adopted through the adaptive management process, the resources needed to implement such changes are described in Section 3.4.23, *Resources to Support Adaptive Management*.

3.4.1.6 Consistency with the Biological Goals and Objectives

CM1 will advance the biological goals and objectives as identified in Table 3.4.1-6. The rationale supporting these conclusions is based on the analysis developed in Chapter 5, *Effects Analysis*, and its supporting appendices. By helping to restore a more natural flow regime and enabling restoration of some attributes of a natural flood disturbance regime, CM1 also provides an indirect contribution to many other goals and objectives that are directly served by habitat protection and restoration actions; these goals and objectives are not specifically listed below, but are addressed in detail in CM2 through CM11. The rationale for each of the goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.1-6. Biological Goals and Objectives Addressed by CM1

Biological Goals or Objective	How CM1 Advances a Biological Objective
Goal L3: Capacity for movement of native organisms and genetic exchange among populations necessary to sustain native fish and wildlife species in the Plan Area.	
Objective L3.2: Promote connectivity between low-salinity zone habitats and upstream freshwater habitats and availability of spawning habitats for native pelagic fish species.	A shift from the current north-south flow pattern through the Delta to a more east-west dominated flow pattern will facilitate connectivity within delta smelt habitat and thus facilitate access to spawning habitat.
Objective L3.3: Provide flows that support the movement of juvenile life stages of native fish species to downstream rearing habitats.	Flexibility provided by dual conveyance operations allows pulse flows to expedite downstream passage of larval delta and longfin smelt. Use of the north Delta diversions reduces unfavorable north-south flows in the interior Delta that expose outmigrant juveniles to unfavorable habitats and high predation risk. See discussion in text, below.
Objective L3.4: Provide flows that support the movement of adult life stages of native fish species to natal spawning habitats.	Use of the north Delta diversions yields a relative increase in attraction flows from the San Joaquin River, thus reducing the incidence of returning adults being exposed to unfavorable habitats and migration delays. This entails a concomitant reduction in Sacramento River flows, but bypass flow criteria ensure outflow at rates that maintain attraction flows in this stream. See discussion in text, below.
Goal L4: Increased habitat suitability for covered fish species in the Plan Area.	
Objective L4.2: Manage the distribution of covered fish species to minimize movements into areas of high predation risk in the Delta.	Reduced negative Old and Middle River flows will reduce covered fish exposure to predation in and near Clifton Court Forebay. This is achieved by use of the north Delta diversions, which may create a predation hazard near the intakes. *CM15 Localized Reduction of Predatory Fishes* is included in the conservation strategy partly to compensate for this effect.
Objective L4.3: Reduce entrainment losses of covered fish species.	Entrainment and related losses will be reduced in the south Delta by reducing use of the south Delta diversions. Entrainment and related losses will be minimized in the north Delta by appropriately screening the north Delta diversions and adhering to the bypass flow criteria. See discussion in text, below.
Goal DTSM1: Increased end of year fecundity and improved survival of adult and juvenile delta smelt to support increased abundance and long-term population viability.	
Objective DTSM1.2: Limit	The north Delta intakes will be located upstream of the primary

Biological Goals or Objective	How CM1 Advances a Biological Objective
entrainment mortality associated with operations of water facilities in the south Delta.[a]	geographic distribution of delta smelt. This will reduce the spatial overlap of diversion intakes and delta smelt occurrence, thereby reducing the risk of entrainment.
Objective DTSM1.3: Achieve an improved Recovery Index.[a]	Improved capacity for movement (Goal L3 above) and reductions in delta smelt entrainment (Objective DTSM1.2 above) will tend to reduce delta smelt mortality, supporting increased values of the Recovery Index.
Goal DTSM2: Increased quality and availability of habitat for all life stages of delta smelt and increased availability of high-quality food for delta smelt. The habitat objective can be met through a combination of Delta outflow and/or physical habitat restoration suitable for delta smelt.	
Objective DTSM2.1: Increase the extent of suitable habitat.[a]	This objective is described in terms of habitat area at a range of salinities, turbidities, and other features, achieved by providing flows that position low-salinity habitat in or near Suisun Bay. It is uncertain whether these benefits can be provided by means other than augmenting flow. This possibility is being tested in the FLaSH experiments (Delta Stewardship Council 2010) and will continue be evaluated in the decision tree process.
Goal LFSM1: Increased fecundity and improved survival of adult and juvenile longfin smelt to support increased abundance and long-term population viability.	
Objective LFSM1.1: Achieve longfin smelt population growth.[a]	Increasing the flexibility in the overall management of flow and export operations by relocating the primary point of diversion to the north Delta and reducing the spatial overlap of intakes and longfin smelt is expected to reduce water diversions within the tidal region of the Delta and is thus reduce the risks of entrainment and salvage at the south Delta export facilities. Relocating the primary point of diversion will also contribute to a reduction in the occurrence of reverse flows in Old and Middle Rivers, which influence entrainment at the south Delta export facilities. It is expected that these changes will contribute to an increase in the survival and abundance of larval and adult longfin smelt in the Plan Area, and thus contribute to longfin smelt population growth.
Objective LFSM1.2: Limit entrainment mortality associated with operation of water facilities.[a]	See Objective LFSM1.1 above.
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.	
Objective WRCS1.1: Improve through-Delta survival.[a]	The north Delta intakes will be operated so as to not increase the incidence of reverse flows in the Sacramento River at the Georgiana Slough junction, thereby limiting the potential for covered salmonids to inadvertently migrate into the interior Delta, where survival of juvenile salmonids has generally been shown to be lower when compared to the mainstem Sacramento River.
Goal WRCS3: No degradation of aquatic habitat conditions for winter-run Chinook salmon upstream of the water facilities.	
Objective WRCS3.1: Avoid impairing PCEs of designated critical habitat.[a]	The PCEs of salmonid designated critical habitat (i.e., sites for spawning, rearing, and migration) all occur upstream of the Plan Area (migration and rearing habitat also occur within the Plan Area). Managing water operations through CM1 is intended to ensure that operations do not degrade conditions upstream of the Plan Area.

Biological Goals or Objective	How CM1 Advances a Biological Objective
Objective WRCS3.2: Support a wide range of life-history strategies.[a]	Real-time operational decisions are expected to allow water facility operations to be implemented in a way that will support a wide range of life-history strategies within a species and cover 95% of the life stages present in the Plan Area (i.e., adult migration, juvenile outmigration), to ensure that beneficial and/or potential negative effects of operations do not affect a particular life-history strategy over another (i.e., late-migrant vs. early-migrant).
Goal SRCS1: Increased spring-run Chinook salmon abundance.	
Objective SRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.
Goal SRCS3: No degradation of aquatic habitat conditions for spring-run Chinook salmon upstream of water facilities.	
Objective SRCS3.1: Avoid impairing PCEs of designated critical habitat.[a]	See Objective WRCS3.1 above.
Objective SRCS3.2: Support a wide range of life-history strategies.[a]	See Objective WRCS3.2 above.
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.	
Objective FRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.
Goal FRCS3: No degradation of aquatic habitat conditions for fall-run/late fall–run Chinook salmon upstream of water facilities.	
Objective FRCS3.1: Avoid impairing upstream habitat within the Plan Area.[a]	See Objective WRCS3.1 above.
Objective FRCS3.2: Support a wide range of life-history strategies.[a]	See Objective WRCS3.2 above.
Goal STHD1: Increased steelhead abundance.	
Objective STHD1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.
Goal STHD3: No degradation of aquatic habitat conditions for steelhead upstream of the water facilities.	
Objective STHD3.1: Avoid impairing PCEs of designated critical habitat.[a]	See Objective WRCS3.1 above.
Objective STHD3.2: Support a wide range of life-history strategies.[a]	See Objective WRCS3.2 above.
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.	
Objective GRST1.1: Increase juvenile and adult survival.[a]	Reduced entrainment (Objective L4.4 above) is expected to improve green sturgeon survival by reducing entrainment-related mortality.
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.	
Objective WTST1.1: Increase juvenile and adult survival.[a]	See GRST1.1 above.

PCEs = primary constituent elements

[a] Summarized objective statement; full text presented in Table 3.3-1.

3.4.1.6.1 Juvenile Migration and Rearing (Objective L3.3)

Juvenile life stages of all covered fish species use habitat in the Plan Area for both migration and rearing, often with both activities occurring in the same area. Juvenile salmonids, for instance, forage throughout their outmigration, spending up to several months in the Plan Area. Pacific lamprey ammocoetes may forage for many years in the Plan Area before beginning to metamorphose and migrate towards the sea. CM1 supports migration and foraging by juveniles of each of the covered fish species, primarily by four mechanisms: pulse flows, preferred migration corridors, reduced north-south flows, and synergies involving habitat restoration areas.

Proposed bypass flow criteria allow pulse flows that would provide a period of relatively rapid downriver flows in the Sacramento River and westward. This would be achieved by minimizing diversions, especially at the Delta Cross Channel gates and the south Delta intakes, at times that would allow delta and longfin smelt larval transport to foraging habitat in the low-salinity zone (noting that migration timing differs for the two species). Expediting their migration in this way would allow them to complete outmigration before they deplete their yolk sac; it also reduces the time during migration that they are exposed to other stressors such as predation. Providing pulse flows requires coordinated timing of both reservoir releases and diversion volumes as described in Section 3.4.1.4, *Implementation*.

CM1 works in concert with *CM16 Nonphysical Barriers*, to facilitate salmonid migration. Under current conditions, north-south flows predominate much of the time in channels leading to the south Delta export facilities and in the Delta Cross Channel. Depending on tidal state and hydrologic stage, they can also occur in certain channels hydraulically connected to these waterways. Such artificial flow patterns are thought to attract outmigrating juvenile salmonids to these channels, which leads to increased entrainment at the SWP/CVP pumps and areas of the interior Delta where greater instances of adverse conditions exist.

Dual conveyance operations will allow modification of the south Delta diversions, and potentially those of the Delta Cross Channel, so as to reduce the frequency and magnitude of flows causing migrating fish to enter the interior Delta. This, in turn, will allow juvenile outmigrants to follow a downstream course into more tidally-influenced portions of the estuary, thereby having a more rapid migration with briefer exposure to predation; it will also reduce the proportion of fish entering the interior Delta, where survival of juvenile Chinook salmon (and presumably other salmonids) is lower (Baker and Morhardt 2001; Brandes and McLain 2001; CALFED Bay-Delta Program 2001; Perry and Skalski 2009; Perry et al. 2010). Reducing the reliance on through-Delta conveyance via the Delta Cross Channel and intakes in the south Delta will also substantially reduce the effects of existing flow anomalies such as weak flows or reverse flows on salmonids in the San Joaquin River system and tributaries, Mokelumne River, and other eastside tributaries. Although there is some increased entrainment exposure for Sacramento River salmonids due to the presence of the new north Delta diversions, these effects are intended to be minimized by fish screen and sweeping and approach velocity criteria, and other operational parameters such as bypass flows.

Restoration actions benefiting fish habitat, such as channel margin enhancement and channel-floodplain reconnections, will preferentially be sited in areas projected for heavier use by covered fish species under the altered CM1 flow conditions. Thus, synergistic benefits may be derived from the coincidence of altered flow benefits with improved habitat condition. For instance, because channel margin enhancement will be targeted to juvenile salmonid migration corridors, there should be a disproportionately higher use of those habitats by migrant juvenile salmon.

3.4.1.6.2 Adult Migration (Objective L3.4)

Operation of the north Delta intakes is expected to reduce reliance on through-Delta conveyance via the Delta Cross Channel and diversions in the south Delta. Locally, this will reduce the occurrence and magnitude of flow changes driven by the south Delta diversions on salmonids and sturgeon in the San Joaquin River system and tributaries, Mokelumne River, and other east-side tributaries. Such artificial flow patterns are thought to confuse the upstream migration cues of adults, reducing the probability that they will enter the eastside tributaries or causing delays in migration.

For salmonids and sturgeon migrating up the Sacramento River, seasonal closure or restriction of Delta Cross Channel gates is expected to maintain operational restrictions set under the BiOps, which provide migration cues for returning adults, and avoid false cues.

3.4.1.6.3 Entrainment and Related Losses (Objective L4.4)

Entrainment has long been recognized as a frequently fatal risk associated with the existing south Delta diversions. This risk has been reduced and is partly remediated by existing fish screen and salvage facilities described in Section 3.4.1.4.1 *Proposed Water Facilities*. Additionally, reductions in exports under the recent requirements of the BiOps have further reduced entrainment risks. Nonetheless opportunities remain to further reduce entrainment and its associated risks, which include stress/injury related to salvage operations, and prescreening and postscreening losses to predation.

The location of the existing south Delta export facilities is within the influence of all covered fish species for at least part of the year. Reducing diversions in the south Delta is expected to reduce the risk of entrainment mortality of salmonids, smelt, splittail, sturgeon and Pacific and river lamprey, and the risk of predation mortality of salmonids, smelt, lamprey, and splittail associated with the export facilities. (Fish that do become entrained into Clifton Court Forebay will have predation risk reduced through measures described in *CM15 Localized Reduction of Predatory Fishes.*)

The new north Delta intakes will be equipped with fish screens designed to minimize the risk of entrainment or impingement for all covered fish species, including relatively weak swimmers such as the delta smelt; moreover, the population centers of resident estuarine species, particularly delta and longfin smelts, are downstream of the reach of the Sacramento River where the north Delta intakes would be installed (Wang 1986; Bennett 2005). These screens will be engineered to provide appropriate approach and sweeping velocities to minimize risk to covered fish species when fish are within the vicinity of intakes. Multiple intakes will reduce the distance fish must travel past each fish screen, allowing individuals to rest between intakes. There will also be an aggressive predator control program at the north Delta intakes, as described in *CM15 Localized Reduction of Predatory Fishes*. These measures are expected to minimize the contribution to entrainment and predation caused by operation of the north Delta diversions. Use of these diversions, in turn, enables a substantial reduction in entrainment and predation risk associated with the south Delta diversions.

Because the north Delta diversions do not require a fish salvage facility, their operation is expected to reduce mortality of covered fish species associated with collection, handling, transport, and release of salvaged fish from the existing export facilities and predation within these facilities.

3.4.2 Conservation Measure 2 Yolo Bypass Fisheries Enhancement

Under *CM2 Yolo Bypass Fisheries Enhancement*, the Implementation Office will modify the Yolo Bypass to increase the frequency, duration, and magnitude of floodplain inundation, and will conduct a diverse suite of further actions in the area intended to achieve beneficial outcomes for covered fish species. The conservation measure will improve passage and habitat conditions for Sacramento splittail, Chinook salmon, green and white sturgeon, Pacific and river lamprey, and possibly steelhead. The increased floodplain inundation and water surface will increase the regional supply of invertebrates that fish prey upon, which is expected to contribute to an increase in fish and other aquatic species (Sommer et al. 2004). This increased productivity will also potentially benefit other areas as it is transported off the floodplain and downstream within Cache Slough and the Sacramento River.

CM2 will be implemented in four phases (Section 3.4.2.3.3, *Timing and Phasing*), starting upon issuance of final permit and continuing to approximately 2063. Refer to Chapter 6, *Plan Implementation*, for additional details on the timing and phasing of CM2. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented during construction activities to ensure that effects of CM2-related actions on covered species will be avoided or minimized.

Other planning actions are also proposed within the Yolo Bypass, including those proposed in the *2012 Central Valley Flood Protection Plan* and the *Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan*. The *Central Valley Flood Protection Plan* (California Department of Water Resources 2012a) is a comprehensive new framework for system-wide flood management and flood risk reduction in the Sacramento and San Joaquin Basins. The actions covered in CM2 overlap with elements of this plan; therefore, DWR incorporated ecosystem enhancement activities into the plan.

The actions covered by the *Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan* (Bureau of Reclamation and California Department of Water Resources 2012) are intended to address two of the Reasonable and Prudent Alternative (RPA) actions outlined in the NMFS (2009) BiOp: RPA Action I.6.1 and RPA Action 1.7. RPA Action I.6.1 (Restoration of Floodplain Rearing Habitat) requires increased seasonal inundation in the lower Sacramento River Basin, and RPA Action I.7 (Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass) requires multispecies fish passage improvements and assessment of their performance. While there are some differences in the requirements of the NMFS (2009) BiOp and CM2, both RPA actions are intended to be covered under Conservation Measure CM2.

The integration of these separate but overlapping processes will occur formally once the BDCP has been approved. Until that time, coordination will occur through the Yolo Bypass Fishery Enhancement Planning Team. This team provides a forum to discuss and coordinate the integration of these and other ongoing planning efforts in the Yolo Bypass.

The adverse and beneficial effects of CM2 are evaluated in Appendix 5.C, *Flow, Passage, Salinity, and Turbidity*; Appendix 5.D, *Contaminants*; Appendix 5.E, *Habitat Restoration*; Appendix 5.F, *Biological Stressors on Covered Fish*; and Appendix 5.H, *Aquatic Construction and Maintenance Effects*. This information supports Chapter 5, *Effects Analysis*.

3.4.2.1 Purpose

The primary purpose of CM2 is to meet or contribute to achieving the biological goals and objectives related to the survival, migration, distribution, and reproduction of covered fish species and to enhance natural ecological processes. CM2 will enhance the floodplain function of Yolo Bypass and improve connectivity to the Sacramento River for covered fish species by increasing the frequency, magnitude, and duration of floodplain inundation. CM2 will also improve fish passage at the Fremont Weir for covered fish species through structural and topographic modifications.

Increased frequency of inundation will enhance existing connectivity between the Sacramento River and Yolo Bypass floodplain habitat. Also, it can increase production of zooplankton and dipteran larvae (prey resources for covered fish species), mobilization of organic material, and primary production, with conditions suitable for spawning, egg incubation, and larval stages for covered fish species such as Sacramento splittail (if inundation is greater than 30 days). Seasonal flooding in the bypass will occur when it will be most effective at supporting native fish species (i.e., when it is in synchrony with the natural timing of seasonally occurring hydrologic events in the watershed).

Increased magnitude of inundation has the potential to increase primary and secondary aquatic productivity. Flooding increases the volume of water (areal extent and depth) in the photic zone, allowing for conditions that can result in increases in phytoplankton biomass. Increased biomass may lead to an increase in the abundance of zooplankton and planktivorous fish. This increase in primary and secondary productivity in the foodweb is expected within the immediate Yolo Bypass area, but may also be exported downstream with the phytoplankton and zooplankton.

Increased duration of inundation is expected to increase production of zooplankton and dipteran larvae (prey resources for covered fish species), mobilization of organic material, and primary production. Inundation lasting more than approximately 30 days between March 1 and May 15 is expected to benefit Sacramento splittail spawning and juvenile production. Short-duration inundation (less than 30 days) events are expected to result in a lesser benefit to juvenile salmon growth when compared to inundation that extends longer than 30 days (BDCP Integration Team 2009).

Improved fish passage is anticipated through modifications to topography and weirs, which are expected to improve fish passage and reduce the risk of migration delays and stranding of adult fish. Stranding of fish and subsequent predation by birds and piscivorous fish have been identified as sources of mortality for juvenile salmon rearing within the floodplain habitat (Sommer et al. 2001b, 2005; BDCP Integration Team 2009). Illegal harvest of covered fish species may also be a source of mortality that could be exacerbated by existing migration delays, low flows, and stranding caused by shorter inundation periods.

Specifically, this conservation measure will advance the following benefits.

- Provide access to additional spawning habitat for Sacramento splittail (Sommer et al. 2001a, 2002, 2007a, 2008; Moyle 2002; Moyle et al. 2004; Feyrer et al. 2006). Because splittail are primarily floodplain spawners, successful spawning is predicted to increase with increased floodplain inundation.
- Provide additional juvenile rearing habitat for Chinook salmon, Sacramento splittail, and possibly steelhead (Sommer et al. 2001a, 2001b, 2002, 2007a, 2008; Moyle 2002; Moyle et al. 2004; Feyrer et al. 2006). Growth and survival of larval and juvenile fish can be higher within

the inundated floodplain compared to those rearing in the mainstem Sacramento River (Sommer et al. 2001b).

- Improve downstream juvenile passage conditions for Chinook salmon, Sacramento splittail, river lamprey, and possibly steelhead and Pacific lamprey. An inundated Yolo Bypass is used as an alternative to the mainstem Sacramento River for downstream migration of juvenile salmonids, Sacramento splittail, river lamprey, and sturgeon; rearing conditions and protection from predators are believed to be better in this area. Sommer et al. (2003, 2004) found that, other than steelhead and Pacific lamprey, juveniles from all of these species inhabit the Yolo Bypass during periods of inundation. The expected increased habitat and productivity resulting from increased inundation of Yolo Bypass are likely to also provide some benefits to covered species, including steelhead and lamprey.

- Improve adult upstream passage conditions of migrating fish using the bypass such as Chinook salmon, steelhead, sturgeon, and lamprey. An inundated Yolo Bypass is used as an alternative route by upstream migrating adults of these species when Fremont Weir is spilling. Increasing the frequency and duration of inundations will provide these improved conditions for more covered species over longer portions of their migrations. However, the increased use of the bypass could put more fish at risk, if stranding conditions occur when flows are reduced. The overall benefits of providing additional flow in the bypass will be assessed through adaptive management (Section 3.6, *Adaptive Management and Monitoring Program*). Monitoring for fish stranding will also be implemented, and fish salvage and rescue operations will be carried out, as necessary, to avoid stranding and migration delays for covered fish species.

- Increase food for rearing salmonids, Sacramento splittail, and other covered species on the floodplain (Sommer et al. 2001a, 2001b, 2002, 2004, 2007a, 2008; Moyle 2002; Moyle et al. 2004; Feyrer et al. 2006). During periods when the bypass is flooded, a relatively high production of zooplankton and macroinvertebrates serves, in part, as the forage base for many of the covered fish species (Benigno and Sommer 2008; Moyle et al. 2004).

- Increase the availability and production of food in the Delta, Suisun Marsh, and bays downstream of the bypass, including restored habitat in Cache Slough, for delta smelt, longfin smelt, and other covered species, by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into the Delta (Schemel et al. 1996; Jassby and Cloern 2000; Mitsch and Gosselink 2000; Lehman et al. 2008).

- Increase the duration of floodplain inundation and the amount of associated rearing habitat and increase migration pathways during periods that the Yolo Bypass is receiving water from both the Fremont Weir and the westside tributaries (e.g., Cache and Putah Creeks).

- Reduce losses of adult Chinook salmon, sturgeon, and other fish species to stranding and illegal harvest by improving upstream passage at the Fremont Weir (*CM17 Illegal Harvest Reduction*) and monitoring for fish stranding below Fremont Weir as flow into Yolo Bypass from the Sacramento River recedes. As necessary, implement fish salvage and rescue operations to avoid stranding and migration delays for covered fish species.

- Reduce the exposure and risk of juvenile fish migrating from the Sacramento River into the interior Delta through the Delta Cross Channel and Georgiana Slough, by decreasing the number of fish passing through these areas (Brandes and McLain 2001).

- Reduce the exposure of outmigrating juvenile fish to entrainment or other adverse effects associated with the proposed north Delta intakes and the proposed Barker Slough Pumping

Plant facilities by passing juvenile fish into and through the Yolo Bypass upstream of the proposed intakes.

- Improve fish passage, and possibly increase and improve seasonal floodplain habitat availability, by retrofitting Los Rios Check Dam with a fish ladder, or creating another fish-passable route by which water from Putah Creek can reach the Toe Drain.

Increasing the frequency, magnitude, and duration of inundation in the Yolo Bypass is the largest opportunity for enhancing seasonally inundated floodplain that serves as habitat for covered species in the Central Valley. The Yolo Bypass is the only floodplain in the Plan Area that can be managed for habitat and species benefits without the restoration of historic floodplains that have been disconnected and/or developed for year-round land uses.

3.4.2.2 Problem Statement

For descriptions of the ecological implications and current condition of the Yolo Bypass fisheries, see Chapter 2, *Existing Ecological Conditions,* and Section 3.3.7, *Species Biological Goals and Objectives*. Section 3.3.7 also describes the need for fisheries enhancements as a component of the conservation strategies for aquatic communities and associated covered species, based on the existing conditions and ecological values of these resources.

The discussion below describes conditions that will be improved through implementation of CM2.

3.4.2.2.1 Flow Management in the Yolo Bypass

The Yolo Bypass is the largest contiguous floodplain on the lower Sacramento River. The bypass is a central feature of the Sacramento River Flood Control Project, which conveys floodwaters from the Sacramento and Feather Rivers and their tributary watersheds. Unlike conventional flood control systems that frequently isolate rivers and ecologically essential floodplain habitat, the Yolo Bypass has been engineered to allow Sacramento Valley floodwaters to inundate a broad floodplain.

The primary input to the Yolo Bypass is through the Fremont Weir[4]. Flow pulses in the Sacramento River are first diverted into Sutter Bypass, an 18,000-acre agricultural floodplain with many similarities to the Yolo Bypass; the Sacramento River immediately upstream of Fremont Weir has a relatively low channel capacity (28,250 cubic feet per second [cfs]), so Sutter Bypass flooding is often initiated in modest flow pulses (Sommer et al. 2001b). When the combined flow of Sutter Bypass and the Sacramento and Feather Rivers raises water levels at Fremont Weir to an elevation of 32.8 feet National Geodetic Vertical Datum of 1929, which typically occurs when combined total flow from these sources surpasses 55,000 cfs (Sommer et al. 2001b), flows begin to enter Yolo Bypass. Water entering the Yolo Bypass due to an overtopping of the Fremont Weir occurs in approximately 70% of water years (California Department of Water Resources 2012b)[5]. Complete

[4] The Fremont Weir, located between river miles 81.7 and 83.4, is a fixed concrete weir constructed by USACE. It is 9,120 feet long, with an earthfill section dividing it into two parts. The crest of the concrete weir section is at elevation 33.5 feet (no vertical datum given), and the crown of the earthfill section is at an elevation of 47.0 feet (no vertical datum given) (U.S. Army Corps of Engineers 1955).

[5] This frequency is based on gage data from 1935 to 2012. Digital data are only available online for the period 1985–2012. Using only this data, the frequency of overtopping of the Fremont Weir is approximately 60%; using only data from the years after the completion of the Shasta Dam (1945–2012), the frequency of overtopping at the Fremont Weir is 69%.

inundation of the Yolo Bypass floodplain (which is 59,000 acres, or 92 square miles) typically occurs during significant flooding events, not from a typical overtopping event. Typical overtopping events do not result in complete inundation of the Yolo Bypass. When the Yolo Bypass is completely inundated during a significant flooding event, the area of inundation approximately doubles the wetted area of the Delta.

Floodwaters entering over Fremont Weir initially flow through scour channels to the Tule Pond, then into the Tule Canal, a perennial channel north of the Sacramento Weir, and the Toe Drain, a perennial channel south of the Sacramento Weir on the eastern edge of the bypass. Floodwaters then spill onto the floodplain when discharge in the Toe Drain exceeds the channel capacity, at approximately 2,000 to 3,000 cfs. The floodplain is considered inundated when the stage of the Toe Drain at Lisbon Weir exceeds just over 8 feet National Geodetic Vertical Datum of 1929. In major storm events, additional water enters from the east via Sacramento Weir, adding flow from the American and Sacramento Rivers (Sommer et al. 2001b). Flow also enters the Yolo Bypass from several small westside streams: Knights Landing Ridge Cut, Cache Creek, Willow Slough Bypass, and Putah Creek. These tributaries can substantially augment the Sacramento River Basin floodwaters or cause localized floodplain inundation before Fremont Weir spills occur (Sommer et al. 2001b).

Management of the Fremont Weir is considered passive, because the weir was designed to overtop at a specific stage and allow inundation of the Yolo Bypass floodplain. The Fremont Weir has no facilities to adjust the flow entering the Yolo Bypass. The Sacramento Weir is a needle dam, the top portion of which is manually operated to selectively change the flow split between the Sacramento River mainstem and the Yolo Bypass.

3.4.2.2.2 Floodplain Habitat

Yolo Bypass is important in terms of agricultural production, wildlife and aquatic habitat, recreation (e.g., waterfowl hunting and bird or wildlife viewing), and educational opportunities. Seasonal inundation of the Yolo Bypass limits the types of crops that can be grown. Orchards and winter crops are not viable, nor are long-term ventures such as alfalfa. Agricultural crops grown in the bypass include rice (both wild and conventional), tomatoes, corn, millet, wheat, milo, and safflower. Cattle grazing occurs on approximately 8,000 acres of the bypass (California Department of Fish and Game 2008a).

Yolo Bypass provides aquatic habitat for 42 fish species, 15 of which are native (Sommer et al. 2001a). The bypass seasonally supports several covered fish species, including delta smelt (typically found in the lower bypass, in the Cache Slough area), Sacramento splittail, steelhead, and spring-run and winter-run Chinook salmon. Typical winter and spring spawning and rearing periods for native Delta fish coincide with the timing of the flood pulse (Sommer et al. 2001b). The majority of the floodplain habitat is seasonally dewatered and is less likely to be dominated by nonnative fish species except in perennial waters.

Sommer et al. (2003) noted that floodplain inundation during high-flow years may favor several aquatic species in the estuary. The Yolo Bypass is an important nursery for young fish, and may help to support the foodweb of the San Francisco Estuary. Adult fish use the Yolo Bypass as a migration corridor (i.e., Chinook salmon and sturgeon) and for spawning (i.e., Sacramento splittail) (Harrell and Sommer 2003).

Physical structures in the bypass such as the Fremont Weir have been identified as impediments and potential barriers to successful upstream passage. Two primary passage issues exist.

- Passage impediments caused by existing structures within Yolo Bypass, which impede fish when Sacramento River water is flowing over the Fremont Weir.
- Flow attraction caused by westside tributary flows and the Cache Slough Complex tidal exchange when no water is flowing over the Fremont Weir and upstream passage is not possible.

3.4.2.2.3 Sacramento Splittail

Sacramento splittail migrate upstream and spawn in seasonally inundated floodplain margin habitat associated with flooded vegetation (Sommer et al. 2001a; Moyle 2002; Moyle et al. 2004). Splittail typically spawn in late winter to spring, depositing adhesive eggs on submerged vegetation and other substrates. After hatching, the larvae and early juveniles forage and rear along the inundated floodplain prior to moving downstream into the estuary as waters recede.

Adult Sacramento splittail spawn in the Plan Area on inundated floodplains of the Yolo Bypass and along the Cosumnes River, as well as within Sutter Bypass (outside the Plan Area, but within the Study Area[6]) (Sommer et al. 1997, 2001a, 2002; Crain et al. 2004; Moyle et al. 2004). Limited collections of ripe adults and early-stage larvae indicate Sacramento splittail spawn in shallow water (less than 2 meters deep) over flooded vegetated habitat (cockle burr, other annual terrestrial vegetation, and perennial vegetation like willow) with a detectable water flow (Moyle et al. 2004). Floodplain inundation activates dormant larvae of an aquatic fly (chironomid) that oversummer in floodplain sediment, which as late-stage larvae or pupae are an important food of late-stage larval Sacramento splittail (Kurth and Nobriga 2001). Relatively warm water temperatures and an abundance of food allow young Sacramento splittail to grow and develop rapidly on floodplains, physically preparing them to leave the floodplains when water levels recede. Accordingly, increasing water temperatures and declining water levels may cue floodplain emigration of juveniles.

3.4.2.2.4 Chinook Salmon

Juvenile Chinook salmon currently rear in the Yolo Bypass when the Fremont Weir is overtopped by the Sacramento River (Sommer et al. 2001a; Moyle 2002; Harrell and Sommer 2003; BDCP Integration Team 2009). Sommer et al. (2001a) noted several benefits for juvenile Chinook salmon that rear in Yolo Bypass as opposed to the mainstem Sacramento River, including the availability of low-velocity habitats, more abundant food, and warmer water temperatures, all of which can result in increased growth rates by reducing energy expenditures, increasing energy inputs, and increasing metabolic rates, respectively.

Results of coded wire tag studies and beach seine and rotary screw trap sampling within the Yolo Bypass showed that residence time for juvenile salmon in the inundated bypass was approximately 30 days on average, although substantially shorter (4 days) and longer residence times (greater than 50 days) were also observed. These results suggest that, although a few days of inundation may be sufficient to trigger incubation and emergence of dipteran larvae and stimulate primary production, longer periods of inundation (3 weeks or more) may be required to provide sufficient

[6] The Study Area is the area where physical changes attributable to the BDCP have the potential to affect covered fish species. It includes the Sacramento River upstream to Keswick Dam, the San Joaquin River upstream to the Stanislaus River, tributaries downstream of SWP and CVP dams (Clear Creek, Feather River, American River, and Stanislaus River), and the Plan Area.

time for fish such as juvenile Chinook salmon to take advantage of increased prey availability, thereby achieving improved growth rates and size, when compared to those continuing to rear in the Sacramento River and the Delta (BDCP Integration Team 2009). It is also possible that these benefits vary among Chinook salmon populations; studies to date have not distinguished between the various runs of juvenile Chinook salmon that may rear in the bypass. However, the timing of bypass inundation, which primarily floods in January and occasionally in December, but rarely in November, correlates well with juvenile fall-run and, to a lesser extent, winter-run Chinook salmon densities in the adjacent reach of the Sacramento River. These densities are generally greatest between January and April, and November and February, respectively. Their peak emigration rates are closely tied to peaks in Sacramento River flow, which can occur from January 1 until April 15 (BDCP Integration Team 2009).

3.4.2.2.5 Sturgeon

Adult white sturgeon have been observed using the Yolo Bypass as an upstream migration corridor (BDCP Integration Team 2009; Harrell and Sommer 2003), and green sturgeon have been rescued from the Yolo Bypass at the Fremont Weir. In 2006, CDFW rescued 23 sturgeon (no species identification given) over the course of rescue operations at the Fremont Weir (Roberts pers. comm.). In 2011, 14 green sturgeon (and 19 white sturgeon) were rescued at the Fremont Weir (Healey and Vincik 2011). Thus, it appears that both species use the Yolo Bypass as a migration route (California Department of Fish and Game 2011). A recent set of studies provides design and operational criteria for sturgeon passage at Fremont Weir (California Department of Water Resources 2007; Webber et al. 2007). These criteria will provide guidance for developing anticipated modifications to the Fremont Weir to facilitate the Yolo Bypass Fisheries Enhancement Plan (YBFEP) and improve passage for adult sturgeon to reduce passage delays and stranding and related negative impacts.

Passage issues delay migration and increase the risk of adult mortality. Observations at the Fremont Weir have shown that adult fish are vulnerable to increased legal and illegal harvest when they accumulate in the concrete apron of the weir and in the area immediately downstream of the weir. Efforts are currently underway to identify the design and operation of improved fish passage facilities that would reduce delays and the mortality risk associated with these delays. The design and operations of fish passage facilities will be integral components of modifications to the Fremont Weir.

3.4.2.2.6 Other Covered Fish Species

Juvenile delta smelt, longfin smelt, and sturgeon, while not likely to use the Yolo Bypass as rearing habitat, could benefit directly or indirectly from increased aquatic production exported downstream from the bypass to the Delta and bays. The co-occurrence of suitable food supplies (zooplankton) and various life stages of delta smelt is an important factor affecting delta smelt survival and abundance (Feyrer et al. 2007; Miller 2007). Increased frequency, duration, and area of Yolo Bypass inundation is anticipated to increase aquatic primary production in the Yolo Bypass. Export of this organic matter from the bypass to areas downstream is expected to benefit delta and longfin smelt and sturgeon. Although both smelt species also seasonally occur in Yolo Bypass (Sommer et al. 2004), they are unlikely to substantially use habitat beyond the floodplain's perennial channel (i.e., seasonal habitat).

The extent to which juvenile steelhead rear in the Yolo Bypass is unknown, but steelhead smolts may use the bypass to a limited extent as rearing habitat (Bureau of Reclamation 2008). The extent to which steelhead use the Yolo Bypass as a migration corridor and how that affects their migration are unknown, but it is assumed that steelhead do migrate through the Yolo Bypass.

Lamprey may also enter the Yolo Bypass, but to what extent is unknown.

3.4.2.2.7 Covered Wildlife Species

Giant garter snakes in the Yolo Bypass are part of the Yolo Basin/Willow Slough subpopulation addressed in the recovery plan for this species (U.S. Fish and Wildlife Service 1999). This population centers on the western Yolo Bypass levee with the majority of reported occurrences west of the bypass, and along the western side of the interior of the bypass. Possible reasons for fewer giant garter snakes on the eastern side of the bypass include more frequent and longer-duration inundation events due to lower elevations on the east side, and the potential for predation along the Toe Drain.

Giant garter snakes forage and find cover in rice fields, wetlands, and adjacent uplands during their active season (early spring through mid-fall) and remain in underground burrows during their hibernation period (mid-fall through early spring). Giant garter snakes that have been observed in the Yolo Bypass during their active season could lie dormant in burrows in the bypass during the inactive season; however, the existing flood regime probably either precludes use of the bypass during their inactive period or displaces snakes during flood events.

Other covered terrestrial species that use or are expected to use the Yolo Bypass include Swainson’s hawk, greater sandhill crane, and western burrowing owl. Periodic inundation in the Yolo Bypass would limit the use of that area by these species.

3.4.2.3 Implementation

3.4.2.3.1 Enhancement Actions

Yolo Bypass fisheries enhancement will be achieved with site-specific component projects to construct fish passage improvements and facilities to introduce and manage additional flows for seasonal floodplain habitat. Prior to construction of each project, necessary preparatory actions will include interagency coordination, feasibility evaluations, site or easement acquisition, coordination related to any required modifications to agricultural practices, development of site-specific plans, and regulatory compliance.

Projects proposed under CM2 are in many cases analogous to similar projects that DWR and cooperating agencies have completed or are constructing elsewhere in the Central Valley. For instance, in the Lower Butte Creek area and Sutter Bypass DWR has been a partner in projects to upgrade weirs with movable gates, upgrade culverts, replace poorly functioning fish ladders, and install fish screens on the Sutter Bypass pumping plants. Projects of this type serve as a proof-of-concept for the types of improvements proposed in Yolo Bypass under CM2.

Actions to be implemented as part of CM2 fall into one of three categories.

- Category 1 actions are generally small in scale, address a known problem and can be implemented relatively easily, or will provide an interim solution until a more permanent solution can be implemented. Category 1 actions will proceed immediately after BDCP permits are issued and before the YBFEP is completed.

- Category 2 actions are larger in scale and may require further evaluation, research, design, and coordination with the fish and wildlife agencies and stakeholders to refine the action to provide the greatest biological benefit while also addressing stakeholder concerns and accommodating stakeholder needs. Category 2 Actions will be further defined in the YBFEP, and will not proceed until the YBFEP is completed.
- Category 3 actions may affect stakeholders or may be controversial and/or substantially change the existing conditions of the Yolo Bypass. Category 3 actions will also be defined within the YBFEP, but will proceed only after an environmental impact report /environmental impact statement (EIR/EIS) for the YBFEP is completed and the record of decision/notice of determination (ROD/NOD) is signed (i.e., CEQA/NEPA compliance) and all permits have been received.

3.4.2.3.2 Yolo Bypass Fisheries Enhancement Plan and EIR/EIS

The YBFEP will propose a sustainable balance among important uses of the Yolo Bypass with consideration of existing conservation easements. Important uses of the Yolo Bypass include flood protection, agriculture, threatened and endangered terrestrial species habitat, fisheries habitat, the Yolo Natural Heritage Program, and managed wetlands habitat, as described in existing state and federal land management plans associated with the Yolo Bypass Wildlife Area and existing conservation easements on private land.

With stakeholder and scientist input, the YBFEP will further refine CM2 and the component projects that will be evaluated. The YBFEP and an associated YBFEP EIR/EIS will be completed by year 4. During their development, the component projects will be evaluated, individually or grouped as alternatives, to ensure that they will provide the greatest biological benefit to the covered fish species, consistent with the goals of this measure and the biological goals and objectives of the Plan. Projects must also minimize impacts on other uses of the Yolo Bypass, such as flood control, agriculture, waterfowl use and hunting, and habitat for covered and noncovered species. Project design and environmental compliance documentation will be completed, including the YBFEP EIR/EIS.

The component projects that are expected to achieve the desired biological outcomes of CM2 will be further developed and implemented. If the YBFEP evaluation does not support implementation of one or more of the component projects, they will not be implemented. Reasons that implementation may not be supported by the YBFEP include, but are not limited to the following

- The action will not be effective.
- The action is not needed because of the effectiveness of other actions.
- The action will have unacceptable negative effects on flood control.
- The action will have unacceptable negative effects on land use or species (both covered and noncovered native species).
- Landowner agreement to implement the action cannot be obtained.

Selected component projects that do not trigger EIR/EIS-level evaluation (Category 2 actions) will not be implemented until after completion of the YBFEP. Selected component projects that do trigger EIR/EIS-level evaluation under CEQA/NEPA (Category 3 actions) will be brought to a preliminary level of design for the YBFEP EIR/EIS. Permitting and the remainder of engineering design will begin after the YBFEP EIR/EIS is complete. Component projects requiring USACE Section 408 permissions may require that any real estate transactions have been completed, and Section 408 permissions may delay finalization of the ROD/NOD until USACE accepts final design.

Completion of the YBFEP and associated EIR/EIS is anticipated to take 3 to 4 years. Full engineering design and permitting of multiple component projects are anticipated to take up to 3 additional years, depending on the scope and scale of component projects. Preparing and letting construction contracts, and constructing the component projects within appropriate work windows are anticipated to span approximately 2 years.

Specifically, the YBFEP will address the following elements.

- Evaluate alternative actions to improve fish passage and reduce stranding, and provide enhanced access to floodplain rearing habitat for fish. Actions include, but are not limited to, physical modifications to the Fremont Weir and Yolo Bypass to manage the timing, frequency, and duration of inundation of the Yolo Bypass (Figure 3.4-1) with gravity flow from the Sacramento River; and fish passage improvements at Fremont and Lisbon Weirs.
- Evaluate alternative actions to increase the duration and frequency of floodplain inundation and increase the complexity of the inundated floodplain habitat to provide the greatest biological benefit for the covered fish species within the constraints that exist in the Yolo Bypass.
- Identify actions that will be implemented and the sequence in which they will be implemented, based on the alternatives evaluation.
- Identify applicable BDCP biological objectives, performance goals, and monitoring metrics.
- Demonstrate plan compatibility with the flood control functions of the Yolo Bypass as well as habitat management, agricultural uses, and waterfowl use and hunting.
- Identify specific funding sources from the BDCP funding commitments.
- Identify and describe a process to address regulatory and legal constraints.
- Provide an implementation schedule with milestones for key actions.

The Implementation Office will consult with the USACE, CDFW, NMFS, and USFWS to develop the YBFEP, and will also coordinate with Yolo and Solano Counties, affected reclamation districts, other flood control entities, and the Yolo Bypass Fisheries Enhancement Planning Team, as well as coordinate, through the Yolo Bypass Working Group, with entities that are planning and/or implementing actions within the Yolo Bypass, such as the Bureau of Reclamation and their Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan (Bureau of Reclamation 2012). The Implementation Office will develop a public outreach strategy before the YBFEP process starts, which will establish a timeline and identify opportunities for stakeholder involvement, including a process by which stakeholder comments will be addressed in—or rejected from—the YBFEP. During implementation of CM2, the Implementation Office will coordinate with USACE, Reclamation, the California Department of Water Resources (DWR), reclamation districts, and other flood control entities, as appropriate, to ensure that fish passage improvements, bypass improvements, and Fremont Weir improvements and operations are constructed in accordance with the YBFEP and are compatible with the flood control functions of the Yolo Bypass.

3.4.2.3.3 Timing and Phasing

CM2 actions are proposed for implementation in four phases:

- Phase 1: year 1 to year 5
- Phase 2: year 6 to year 10
- Phase 3: year 11 to year 25
- Phase 4: year 26 to year 50

The discussion below identifies and describes the various conceptual component projects that will be implemented as part of CM2 and identifies which projects are currently considered Category 1, 2, or 3 actions.

Phases 1 and 2: Year 1 to Year 10

The timeline below is preliminary; however, the Implementation Office is committed to taking the component projects to construction as soon as possible. Site numbers in parentheses correspond with locations on Figure 3.4-1.

- **Component Project 1: Fish Rescue.** This component project will provide funding to accelerate fish rescue and improvements to fish stranding assessments. Monitoring to detect fish stranding at the Fremont Weir State Wildlife Area and known passage impediments will be implemented on an annual basis beginning immediately after BDCP permit issuance. Monitoring will occur after periods when the Fremont Weir has been overtopped from the Sacramento River and flow begins to recede. Such monitoring will continue until fish passage measures are implemented and demonstrated to be successful, and DWR and the fish and wildlife agencies determine that monitoring is no longer necessary. Fish captured behind Fremont Weir, in the large pool at the base of Fremont Weir, and at isolated pools and channels in the Fremont Weir State Wildlife Area will be released within the mainstem Sacramento River; all fish captured and released will be recorded and reported annually to the fish and wildlife agencies. Additionally, all sturgeon and adult salmon captured will be tagged and their movements monitored following release back to the Sacramento River. Reports to the fish and wildlife agencies will record the number of each species of fish captured/rescued, and describe the condition of each fish at the time of release. Fish rescue operations will be conducted by CDFW. Funding will be provided by BDCP to facilitate fish rescue and monitoring operations. To minimize stress to each fish, handling will be kept to the minimum necessary to capture, tag, transport, and release the fish back into the mainstem Sacramento River (site 1 on Figure 3.4-1) (Phase 1, Category 1 action).
- **Component Project 2: Monitoring and Research.** Monitoring and research under CM2 are described below in Section 3.4.2.4, *Adaptive Management and Monitoring* (Phase 1, Category 1 or 2 action).
- **Component Project 3: Fish-Rearing Pilot Project at Knaggs Ranch (not to exceed 10 acres).** This component project shares facets of the Westside Concept[7] that relate to evaluating

[7] The term "Westside Concept" has been used to describe a range of ideas for how to bring water into the Yolo Bypass, bring juvenile fish into the bypass, distribute water through the bypass, manage floodplain habitat and develop opportunities for enhanced water supply in the bypass, and reduce reliance on pumping water from the Delta north through the Toe Drain. The Westside Concept can be understood as either a stand-alone action or an

the use of water from Knights Landing Ridge Cut to solely provide or supplement flows, and evaluating the effectiveness of applying water pond by pond, rather than across a contiguously inundated, heterogeneous floodplain (site 3 on Figure 3.4-1) (Phase 1 or before, Category 1 action). This project is being hosted by an interested landowner, employing practices within the normal range of agricultural operations.

- **Component Project 4: Fish Rearing Studies at Knaggs Ranch.** This is a pilot project to investigate fish rearing with supplemental or sole flows from Knights Landing Ridge Cut over multiple years (site 4) (Phase 1 or 2, Category 3 action).
- **Component Project 5: Fish Ladder Operations Study at Fremont Weir.** This component project will experiment with different approaches to operating the existing ladder, such as removing wooden baffles and monitoring fish passage (site 5 on Figure 3.4-1) (Phase 1 or before, Category 1 or 2 action).
- **Component Project 6: Experimental Sturgeon Ramps at Fremont Weir.** This component project will construct and study up to four experimental ramps at the Fremont Weir to test whether they can provide effective passage for adult sturgeon and lamprey from the Yolo Bypass over the Fremont Weir to the Sacramento River when the river overtops the weir by approximately 3 feet (Figure 3.4-2). The species-specific biological goals and objectives for both green and white sturgeon include the reduction of stranding at the Fremont Weir. Developing effective passage through experimental sturgeon ramps will contribute toward reducing stranding at Fremont Weir. Studies of sturgeon swimming speeds and types of structures (i.e., ramps, ladders) that provide sturgeon passage have been performed (Cheong et al. 2006; Webber et al. 2007; and Anderson et al. 2007) and will provide insight into design considerations for passage of green and white sturgeon at Fremont Weir. Feasibility and specific design criteria for the ramps have not yet been determined. Monitoring technologies will be used to collect information on fish passage to evaluate the ramps' efficacy at passing adult fish (site 6 on Figure 3.4-1) (Phase 1, Category 3 action).
- **Component Project 7: Auxiliary Fish Ladders at Fremont Weir.** This component project will construct up to three sets of auxiliary fishways. At least one set of auxiliary fishways will serve the western length of Fremont Weir. Because the Fremont Weir is nearly 2 miles long and is constructed in two distinct lengths, these auxiliary fishways will help fish pass the weir regardless of where they approach it from. Figure 3.4-3 shows a concept for a facility to prevent fish stranding in the western length of Fremont Weir. At least one of the fish ladders will replace, and possibly increase the width of, the existing Fremont Weir fish ladder. Figure 3.4-4 shows a concept for substantially improving the existing fish ladder. At least one multistage, multispecies fishway will be placed adjacent to, or incorporated within the main gated seasonal floodplain inundation channel (in its ultimate location) to provide passage when velocities or partially opened gates would otherwise be impassable or provide poor fish passage. Figure 3.4-5 shows a concept for providing multistage, multispecies fish passage. Fish ladder placement will result in positive drainage from the stilling basin, with very little, if any, additional work on the stilling basin (site 7 on Figure 3.4-1) (Phase 1 or 2, Category 3 action).
- **Component Project 8: Fish Screens for Small Yolo Bypass Diversions.** If determined appropriate, this component project will construct fish screens on small Yolo Bypass diversions

auxiliary action similar to those described in other elements of CM2. This range of ideas will be explored further in the YBFEP, and actions that support the goals of the YBFEP will be incorporated.

(Phase 2, Category 2 action). Such work would be applied toward the 100 cfs per year remediation target identified in *CM21 Nonproject Diversions*.

- **Component Project 9: New or Replacement Impoundment Structures and Agricultural Crossings at the Tule Canal and Toe Drain.** This component project will replace agricultural crossings of the Tule Canal and Toe Drain with fish-passable structures such as flat car bridges or earthen crossings with large, open culverts. Construct new or replacement operable check-structures to facilitate continued agriculture in the Yolo Bypass while promoting fish passage in season (site 9 on Figure 3.4-1) (Phase 1, Category 3 action).

- **Component Project 10: Lisbon Weir Improvements.** This component project will replace the Lisbon Weir with a structure that improves fisheries management and maintains the ability to impound water for irrigation, while reducing maintenance (site 10 on Figure 3.4-1) (Phase 1, Category 3 action).

- **Component Project 11: Lower Putah Creek Improvements.** This component project will realign Lower Putah Creek to improve upstream and downstream passage of Chinook salmon and steelhead. If feasible, this action will also include floodplain habitat restoration to provide benefits for multiple species on existing public lands. The realignment will be designed so that it will not create stranding or migration barriers for juvenile salmon (site 11 on Figure 3.4-1) (Phase 1, Category 3 action)[8]. This action will be covered in the YBFEP.

- **Component Project 12: Water Supply Improvement for the Yolo Bypass Wildlife Area.** This component project will improve Yolo Bypass Wildlife Area water supply at Lisbon Weir to support wildlife management in the Yolo Bypass Wildlife Area (by reducing reverse flows in the Toe Drain) and potentially benefit the aquatic foodweb and downstream fish. Other actions not yet fully defined or developed will be considered. These may include a subsidy of Yolo Bypass Wildlife Area pumping costs or procurement of additional water from western tributary sources. This project incorporates goals of the Westside Concept (site 12 on Figure 3.4-1) (Phase 1 or 2, Category 3 action).

- **Component Project 13: Use of Supplemental Flow through Knights Landing Ridge Cut.** This component project will evaluate the desirability of using supplemental flows through Knights Landing Ridge Cut, introduced via redesign of Colusa Basin Drain Outfall Gates, increased operation of upstream unscreened pumps, or other means. If currently unscreened pumps were to be used for more than a pilot period, the pumps would need to be screened or replaced with fish-friendly pumps. This project incorporates goals of the Westside Concept (site 13 on Figure 3.4-1) (Phases 1 and 2, Category 3 action).

- **Component Project 14: Flood-Neutral Fish Barriers.** This component project will construct and test flood-neutral fish barriers to prevent fish from straying into Knights Landing Ridge Cut and the Colusa Basin Drain. These barriers will be most effective when employed in association with attraction flows to a location, such as at Fremont Weir, that is fish-passable and leads to the mainstem Sacramento River. This project incorporates goals of the Westside Concept (site 14 on Figure 3.4-1) (Phase 2, Category 3 action).

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[8] Improvements to Upper Putah Creek outside of the Plan Area will be included as part of the YBFEP. Improvements to Upper Putah Creek will support fish passage, water quality, and spawning habitat improvements in Putah Creek upstream of the Yolo Bypass Wildlife Area and downstream of Solano Diversion Dam (site 11 on Figure 3.4-1) (Phase 1).

- **Component Project 15: Gated Seasonal Floodplain Inundation Channel Past Fremont Weir.** This component project will modify a section of the Fremont Weir to enable introducing managed flows to the Yolo Bypass at times when Fremont Weir is not overtopping. The Fremont Weir would continue to passively overtop when the Sacramento River stage exceeds the height of the weir. In Chapter 5, *Effects Analysis*, it is assumed that a section of the Fremont Weir will be lowered to 17.5 feet NAVD88. Lower elevations may be considered, if necessary, to satisfy inundation targets or fish passage needs. Because the Fremont Weir is perched on the natural levee that bounds the Yolo Basin, including the northern edge of the Yolo Bypass (Figure 3.4-1), it will be necessary to excavate through that area of higher ground to hydraulically connect the Sacramento River to the Yolo Bypass at these lower flow stages. Thus, the new section of gates will replace the former section of Fremont Weir, and also extend below it, to govern flows in the channel that will be excavated. The new section of operable gates will allow for controlled flow into the Yolo Bypass when the Sacramento River stage at the weir exceeds approximately 17.5 feet NAVD88, leaving the remaining portion of Fremont Weir to overtop passively when the Sacramento River stage is higher than the top of the weir (32.8 feet NAVD88). The seasonal floodplain inundation flows will attract fish migrating upstream. Therefore, the gates and the fishways immediately adjacent to them will be designed so that, when they are operated to provide seasonal floodplain inundation flows, they also allow efficient upstream and downstream passage of sturgeon and salmonids between the Yolo Bypass and the Sacramento River. If additional work to ensure positive drainage of the entire length of Fremont Weir is required, it will be completed as part of this project (site 15 on Figure 3.4-1) (Phase 2, Category 3 action).

- **Component Project 16: Nonphysical or Physical Barriers to Attract Juvenile Salmon into the Yolo Bypass.** If it is deemed necessary to enhance capture of juveniles into Yolo Bypass through the gated seasonal floodplain inundation channel (described in Component Project 15), this component project will construct and operate nonphysical or physical barriers in the Sacramento River. Examples of such barriers include bubble curtains or log booms (site 16 on Figure 3.4-1) (Phase 2 or 3, Category 3 action).

- **Component Project 17: Support Facilities.** This component project will construct associated support facilities (e.g., operations buildings, parking lots, access facilities such as roads and bridges) throughout the Yolo Bypass necessary to provide safe access for maintenance, monitoring, and fish rescue (Phase 2, Category 3 action).

- **Component Project 18: Levee Improvements.** This component project will improve levees adjacent to the Fremont Weir Wildlife Area, as necessary, to maintain existing level of flood protection, or to beneficially reuse excavated earth (Phase 2, Category 3 action).

- **Component Project 19: Yolo Bypass Modifications to Direct or Restrain Flow.** Through modeling and further concept development, this component project will determine which of the following actions are necessary to improve the distribution (i.e., wetted area) and hydrodynamic characteristics (i.e., residence times, flow ramping, and recession) of water moving through the Yolo Bypass: grading; removal of existing berms, levees, and water control structures (including inflatable dams); construction of berms or levees; reworking of agricultural delivery channels; and earthwork or construction of structures to reduce Tule Canal and Toe Drain channel capacities. The project will include modifications that will allow water to inundate certain areas of the bypass to maximize biological benefits and reduce stranding of covered fish species in isolated ponds, minimize effects on terrestrial covered species, including giant garter snake, and accommodate other existing land uses (e.g., wildlife, public, recreation, and agricultural use areas). Necessary lands will be acquired in fee-title or through conservation or flood easement (Phase 2, Category 3 action).

Phase 3: Year 11 to Year 25

Final permissions/permits from the permitting agencies for construction of the component projects directly affecting flood control structures (Fremont Weir, Sacramento Weir, and Colusa Basin Drain Outfall Gates, if affected, as well as project levees) not obtained in Phase 1 or 2 will be received by Phase 3 at the latest. Those component projects that are not able to obtain permits and be constructed during Phases 1 or 2 will do so in Phase 3. Full buildout is estimated to be completed in years 10, 11, or 12, at which time operations of these component projects will begin.

Phase 3 will encompass project operation, monitoring, and continued adaptive management (Section 3.6, *Adaptive Management and Monitoring Program*). A matrix of criteria will be developed and tested prior to Phase 3, and operations will be adjusted accordingly. For example, if results of monitoring and studies indicate that shorter or earlier gate operations within the adaptive management range yield equivalent or better fish benefits, operation of the gated channel at Fremont Weir will be modified accordingly. If scientific results indicate that the wetter, later end of the adaptive management range is more biologically effective, operations will shift accordingly within existing or additional easements.

The following project will be designed, permitted, and, if feasible, constructed in Phase 3.

- **Component Project 20: Sacramento Weir Improvements.** At a minimum, modifications will be made to reduce leakage at the Sacramento Weir and thereby reduce attraction of fish from the Yolo Bypass to the weir where they cannot access the Sacramento River and could become stranded. The YBFEP will review the benefits and necessity of constructing fish passage facilities at the Sacramento Weir to improve upstream adult fish passage and positive drainage to reduce juvenile fish stranding. This action may require excavation of a channel to convey water from the Sacramento River to the Sacramento Weir and from the Sacramento Weir to the Toe Drain; construction of new gates at all or a portion of the weir; and modifications to the stilling basin (site 20 on Figure 3.4-1) (Phase 3, Category 3 action).

Phase 4: Year 26 to Year 50

Phase 4 will encompass project operation, monitoring, and continued adaptive management (Section 3.6, *Adaptive Management and Monitoring Program*). Similar to Phase 3, the matrix of criteria developed and tested prior to Phase will continue to be used, and operations will be adjusted accordingly.

3.4.2.3.4 Operation Scenarios for Fremont Weir

Proposed modifications to the Fremont Weir will increase the biological benefit of the Yolo Bypass across a range of water-year types, while accommodating other uses of the Yolo Bypass such as management for agriculture, waterfowl, wetlands, and fish. Table 3.4.2-1 summarizes the operations patterns of the proposed Fremont Weir gated channel (the "notch") to manage the timing, frequency, and duration of inundation of the Yolo Bypass with inflow from the Sacramento River, and identifies additional operational considerations related to fisheries, agriculture, and waterfowl. These operations were developed for discussion and illustration at the BDCP Yolo Bypass Fisheries Enhancement stakeholder group. They are expected to be typical of, but not necessarily identical to, actual operational guidelines that will be developed in the course of subsequent project-specific design, planning, and environmental documentation. The intent is to inundate the floodplain during periods of importance to the covered fish species, primarily from mid-November through April, with limited operations outside of this period sufficient to ramp down inundation in such a way as to avoid and minimize potential stranding of native fish, but control populations of nonnative fish.

Maintenance of Fremont Weir and Yolo Bypass Improvements

Routine maintenance of the Fremont Weir and Yolo Bypass is also a covered activity. Vegetation maintenance activities may include mowing, discing, livestock grazing, dozing, spraying and/or hand-cutting of young willow groves, cottonwoods, arundo, brush, debris, and young selected oak trees. Trees with a trunk diameter of 4 inches or greater may be pruned up to 6 feet from the ground. Clearing of areas will be done in strips to open areas for water flow and to avoid islands and established growth. On a periodic basis, sediment will be removed from the Fremont Weir area using graders, bulldozers, excavators, dump trucks, or other machinery. Outside of the new channel, removal of approximately 1 million cubic yards of sediment within 1 mile of the weir can be reasonably expected to occur on an average of approximately every 5 years based on recent maintenance history. Primarily inside the new channel, an additional 1 million cubic yards of sediment removal is anticipated every other year as a conservative estimate of sediment management. Where feasible, work will be conducted under dry conditions; some dredging along the deepest part of the channel may be necessary to maintain connection for fish passage. Where agreements can be made with landowners, sediment may be disposed of on properties in the immediate vicinity of the Fremont Weir; it may also be used as source material for levee or restoration projects, or otherwise beneficially reused.

Maintenance activities will extend from the Sacramento River to the Fremont Weir, the Fremont Weir to the southern end of the Yolo Bypass, and along and between the associated levees.

Actions to Reduce Effects on Giant Garter Snake and Other Terrestrial Covered Species

Increased periodic inundation in the Yolo Bypass could affect giant garter snakes overwintering in areas ranging from an estimated 520 acres of upland habitat (during 1,000-cfs flows through the gated channel) to an estimated 1,255 acres of upland habitat (during 4,000-cfs flows through the gated channel (Chapter 5, Section 5.6.18.1.2, *Periodic Inundation*). Project-associated inundation of areas that would not otherwise have been inundated is expected to occur in no more than 30% of all years, since Fremont Weir is expected to overtop the remaining estimated 70% of all years, and during those years operations of the gated channel will not typically affect the maximum extent of inundation. However, duration of inundation could be increased in all years, and this could adversely affect covered terrestrial species. In more than half of all years under existing conditions, an area greater than the project-related inundation area already inundates during the snake's inactive season. Additionally, the reduction in rice lands as a result of spring flooding could diminish the amount of available habitat for giant garter snake during the active season (Appendix 5.J, Attachment 5J.E, *Estimation of BDCP Impact on Giant Garter Snake Summer Foraging Habitat (Acreage of Rice) in the Yolo Bypass*). As described under *CM3 Natural Communities Protection and Restoration* (Table 3.4.3-1), a giant garter snake reserve with a mosaic of upland and aquatic habitats will be established adjacent to the Yolo Basin/Willow Slough subpopulation to reduce effects on giant garter snake that would result from habitat loss and increased periodic inundation in the Yolo Bypass. The reduction in rice production will be offset through restoration or protection of rice land or equivalent-value habitat at a 1:1 ratio.

1 **Table 3.4.2-1. Potential Operations Pattern for Fremont Weir Gated Channel and Other Considerations**

		Before Nov 10	Nov 10–30	Dec 1–15	Dec 16–31	Jan 1–15	Jan 16–31	Feb 1–15	Feb 16–28	Mar 1–15	Mar 16–31	Apr 1–10	Apr 11–30	May 1–15	After May 15
Potential Operations Pattern for Fremont Weir Gated Channel															
If Yolo Bypass is not flooded (YBY Gauge <3,000 cfs)	**Operations Concept: When Sacramento River Conditions Allow**	**No Fremont Weir gate operations** except to provide fish passage **(up to 500 cfs**, if appropriate**).**	Initiate Fremont Weir flows up to 6,000 cfs (only if harvest is complete or if westside tributaries are already flooding).	Initiate Fremont Weir flows up to 6,000 cfs to provide seasonal floodplain habitat.						Initiate Fremont Weir flows up to 6,000 cfs to provide seasonal floodplain habitat when a large proportion of juvenile salmon are detected upstream. Initiate ramping flows March 24, so that flows are in bank by April 10, unless the Yolo Bypass floods.			**No Fremont Weir gate operations** except to provide fish passage (**up to 500 cfs**, if appropriate).		**No Fremont Weir gate operations** except to provide fish passage **(up to 500 cfs**, if appropriate**).**
										Operate Fremont Weir gate (if necessary) in conjunction with existing flooding to meet Objective SAST1.1 (7,000 acres of continuous floodplain habitat less than 2 meters deep for 30 days, at least once every 5 years). Operations will not target objective for 3 years after it is achieved.					
If Yolo Bypass is flooded (YBY Gauge >3,000 cfs)	**Operations Concept: When Sacramento River Conditions Allow**	**No Fremont Weir gate operations** except to provide fish passage **(up to 500 cfs**, if appropriate**).**	Initiate Fremont Weir flows up to 6,000 cfs (only if harvest is complete or if westside tributaries are already flooding).	Initiate Fremont Weir flows up to 6,000 cfs to provide seasonal floodplain habitat.						Initiate Fremont Weir flows up to 6,000 cfs to provide seasonal floodplain habitat.					**No Fremont Weir gate operations** except to provide fish passage **(up to 500 cfs**, if appropriate**).**
										Operate Fremont Weir gate (if necessary) in conjunction with existing flooding to meet Objective SAST1.1 (7,000 acres of continuous floodplain habitat less than 2 meters deep for 30 days, at least once every 5 years). Operations will not target objective for 3 years after it is achieved.					
Footprint Targets		Out-of-bank flows not created by project (zero or negligible).	Small inundation footprint (operations would target 7,000–10,000 acres).												Out-of-bank flows not created by project (zero or negligible).
				Large inundation footprint (operations would target 17,000 acres). Operate the notch prior to, during, and following natural flooding events (Fremont Weir overtopping or other tributary inputs) to prolong duration and provide continuity between natural flooding events. Ramp flows down to small footprint by March 1.											
Fishery Enhancement	**Winter-Run Chinook**		Provide seasonal floodplain habitat for winter-run Chinook salmon (initial emigration period is correlated to first pulse flow of ~12,000+ cfs at Wilkins Slough).												
	Spring-Run Chinook			Provide seasonal floodplain habitat for spring-run Chinook salmon.											
	Fall-Run Chinook					Provide seasonal floodplain habitat for fall-run Chinook salmon.									
	Late Fall–Run Chinook		Provide seasonal floodplain habitat for yearling late fall–run Chinook salmon (floodplain rearing habitat benefits for yearling Chinook salmon are unknown).									Provide seasonal floodplain habitat for young-of-year late fall–run Chinook salmon.			
	Steelhead					Provide seasonal floodplain habitat for steelhead (floodplain rearing habitat benefits for steelhead are unknown).									
	Splittail					Improve conditions for adults staging to spawn and spawning.				Provide seasonal floodplain habitat for splittail spawning and rearing.					
	Adult Fish Passage	Improve passage for covered fish species, particularly adult salmonids and sturgeon, through Fremont Weir gate and additional fish passage structures.													

	Before Nov 10	Nov 10–30	Dec 1–15	Dec 16–31	Jan 1–15	Jan 16–31	Feb 1–15	Feb 16–28	Mar 1–15	Mar 16–31	Apr 1–10	Apr 11–30	May 1–15	After May 15
Other Considerations														
Agriculture (conservation easements or fee-title may be required for all inundation on agricultural land)		Harvest is usually finished during this time period.	No impacts on agriculture during this period. Willows and marsh plants must be managed to allow for subsequent crop planting.					Inundation during this period is expected to cause **zero to some yield impacts on affected lands** (Howitt et al. 2013).		Inundation during this period is expected to cause **some to high yield impacts on affected lands** (Howitt et al. 2013).		May 10 is expected to be the final day for planting without yield impacts (Howitt et al. 2013). Final cessation of inundation during this period could be too late to allow successful land preparation and planting by June 10, the reported last possible day to plant (with high yield impacts) (Howitt et al. 2013).		Cessation of inundation by May 15 is expected to be too late to prepare land to plant by June 10, the last possible day to plant (with high yield impacts) (Howitt et al. 2013).
Waterbird and Wetland Management	Seasonal wetland flooding begins early September, full flood-up by late November. Flood harvested rice fields as early as possible after harvest.	Continue to flood new wetland habitat and maintain optimal water levels for foraging (<30 centimeters). Continue flooding rice fields, harvest completed.	Circulate water in wetlands and rice fields to maintain optimal levels for foraging (<30 centimeters). Water levels in most rice fields typically are drawn down in late February in anticipation of field preparation. Peak winter duck populations in the bypass in February.						Drawdown of wetland fields throughout this time period depending on target seed plants. Private clubs start draining in early March, and the Yolo Bypass Wildlife Area starts draining 2 to 4 weeks later. Prolonged delays on drawdown dates may result in less seed production and undesirable vegetation. Duck nesting in adjacent uplands begins during the latter half of this time period.			Peak nesting period for resident ducks (uplands) and shorebirds (wetlands/rice). Maintain some permanent wetlands for brood/chick habitat. Rice fields in the second half of this time period provide forage and habitat for breeding waterbirds.		Maintain some wetlands for breeding waterbirds and broods. Waterbird nesting increases in rice fields, and brood use continues until end of July. Fallow rice fields (Yolo Bypass Wildlife Area) flooded for shorebirds (July/August).
Hunting, Wildlife Viewing and Environmental Education	The hunting season for waterfowl begins in late October and extends until late January. Private duck clubs can hunt daily, while hunting on the Yolo Bypass Wildlife Area is limited to Wednesdays, Saturdays, and Sundays.													
	The Yolo Basin Foundation provides environmental education on the Yolo Bypass Wildlife Area to students year-round during the school year. The Yolo Bypass Wildlife Area provides public access to wildlife viewing year-round, although the peak viewing time is when waterfowl are present.													

3.4.2.4 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will be performed as required in project plans and permitting documents for each action covered in this conservation measure. Additional compliance monitoring actions required under the BDCP concern both project construction and operation and are identified in Table 3.4.2-2. Monitoring needs associated with implementation of avoidance and minimization measures may be required for each component project; see *CM22 Avoidance and Minimization Measures* and Appendix 3.C, *Avoidance and Minimization Measures*, for details of how these measures would be implemented and what types of monitoring are required.

Table 3.4.2-2. Compliance Monitoring Actions under CM2

ID #	Compliance Monitoring Action	Metric	Success Criteria	Timing/Duration
CM2-1	Construction: Document in design and as-built reports compliance with Fremont Weir design criteria.	Design criteria are documented.	Fremont Weir modifications meet design criteria post construction.	Prior to construction and as-built
CM2-2	Construction: Document in design and as-built reports compliance with experimental sturgeon ramps.	Design criteria are documented.	Experimental sturgeon ramps meet design criteria post construction.	Prior to construction and as-built
CM2-3	Construction: Document in design and as-built reports compliance with Tule Canal/Toe Drain improvements plan.	Design criteria are documented.	Tule Canal/Toe Drain improvements meet design criteria post construction.	Prior to construction and as-built
CM2-4	Construction: Document in design and as-built reports compliance with Sacramento Weir fish passage modification plan.	Design criteria are documented.	Sacramento Weir modifications meet design criteria post construction.	Prior to construction and as-built
CM2-5	Construction: Document in design and as-built reports compliance with proposed modifications to berms, levees, and water control structures.	Design criteria are documented.	Berms, levees and water control structures meet design criteria post construction.	Prior to construction and as-built
CM2-6	Construction: Document in design and as-built reports compliance with realignment of Lower Putah Creek plan.	Design criteria are documented.	Realignment of Lower Putah Creek meets design criteria per the Lower Putah Creek Plan post construction.	Prior to construction and as-built
CM2-7	Operation: Document that flow over Fremont Weir meets flow requirements (details in Chapter 6, *Plan Implementation*).[a]	Flow	Flow conditions over Fremont Weir meet requirements necessary for floodplain inundation (extent, duration and frequency)	During overflow at Fremont Weir and periods when Fremont Weir is designed to flood, for the duration of the BDCP

ID #	Compliance Monitoring Action	Metric	Success Criteria	Timing/Duration
CM2-8	Operation: Document that flow in Tule Canal/Toe Drain meets operational requirements (details in Chapter 6, *Plan Implementation*).	Flow	Flow within the Tule Canal/Toe Drain meets operational requirements.	Prior to completion of the modifications to the facilities for duration of the BDCP.
CM2-9	Plankton and invertebrate sampling	Plankton and invertebrate abundance	Increases in plankton and invertebrate abundance, and transport of plankton and invertebrates off of Yolo Bypass to areas occupied by delta smelt	Every 5 years after modifications to Fremont Weir are completed
CM2-10	Site-Level Assessment	Use of Yolo Bypass by covered fish species	Detection of use by adult and juvenile covered fish species within the flooded portions of Yolo Bypass.	Monthly seine/net surveys between November 10 and May 15 through year 15
CM2-11	Upstream and downstream fish passage at Fremont Weir	Fish passage	Upstream and downstream passage of covered fish species (i.e., adults and juveniles)	Pit tag and other suitable techniques/ studies of covered juvenile fish (primarily salmonids as well as lamprey) downstream migration past Fremont Weir, as well as upstream passage of covered adult fish past Fremont Weir (primarily salmonids, sturgeon and lamprey). Monitoring to occur for a period of 5 years, once Fremont Weir modifications are completed. Monitoring will track adult juvenile migration through Yolo Bypass, between Fremont Weir and Cache Slough.

[a] The existing California Department of Water Resources river stage monitoring gages program is important and directly related to the biological goals and objectives and is included in the cost assumptions.

Effectiveness and status and trend monitoring will also be performed as required in project plans and permitting documents for each action covered in this conservation measure. Effectiveness monitoring actions include the following.

- Annually assess passage delays and the effectiveness of efforts to reduce them in Yolo Bypass and other anthropogenic barriers and impediments (i.e., Sacramento and Stockton Deep Water Ship Channel, Delta Cross Channel) using methods such as Dual-Frequency Identification Sonar

(DISDON) or other suitable method to observe fish behavior at barriers. Begin monitoring upon final BDCP permit authorization and continue on an annual basis through year 15, to cover the range of hydrologic conditions (i.e., wet years and dry years). Report results in annual progress report.

- Annually assess juvenile salmonid through-Delta survival and/or continue conducting studies assessing juvenile growth rates using hatchery origin juvenile salmonids. Begin monitoring upon final BDCP permit authorization and continue through year 15. Report results in annual progress report.
- Annually assess the abundance of Sacramento splittail as part of the Fall Midwater Trawl and evaluate the response of the population to habitat restoration actions, particularly CM2, *CM4 Tidal Natural Communities Restoration*, and *CM5 Seasonally Inundated Floodplain Restoration*. At year 15, assess whether the objective has been met and present the agencies with the plan for continued monitoring (annual, every-other-year, every 5 years). Report results in annual progress report.

There are two key uncertainties regarding how CM2 will affect conditions in the Yolo Bypass and the ecosystems, natural communities, and species within it. Table 3.4.2-3 lists these key uncertainties and related research actions that the Adaptive Management Team will consider to resolve the uncertainties.

Table 3.4.2-3. Key Uncertainties and Potential Research Actions Relevant to CM2

Key Uncertainty	Potential Research Actions
Do the modifications at Yolo Bypass function as expected, and if so, how effective are they?	• Evaluate the effectiveness of the fish passage gates at Fremont Weir. • Evaluate the effectiveness of the sturgeon ramps. • Determine whether stilling basin modification has reduced stranding risk for covered fishes. • Determine whether Sacramento Weir improvements have benefited fish passage and minimized stranding risk. • Determine effectiveness of Tule Canal/Toe Drain and Lisbon Weir improvements to reduce the delay, stranding, and loss of migrating salmon, steelhead, and sturgeon. • Determine growth rates of juvenile salmonids that have entered the Yolo Bypass during Fremont Weir operation. • Document Sacramento splittail spawning and spawning success in the Yolo Bypass during Fremont Weir operation. • Evaluate whether the Lower Putah Creek realignment has improved upstream and downstream passage by covered fish. • Determine severity of predation effects on covered fish using the Yolo Bypass.
Do the increased frequency and duration of flooding in Yolo Bypass affect the health and vigor of elderberry shrubs and other valley/foothill riparian vegetation in the Yolo Bypass?	• Monitor key indices of plant health and vigor for elderberry shrubs and other riparian species at selected sites prior to implementation of CM2, and at regular intervals following improvements that lead to increased inundation frequency and duration in the bypass.

3.4.2.5 Consistency with the Biological Goals and Objectives

CM2 will advance the biological goals and objectives identified in Table 3.4.2-4. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.2-4. Biological Goals and Objectives Addressed by CM2 and Related Monitoring Actions

Biological Goal or Objective	How CM2 Advances a Biological Objective	Monitoring Action(s)
Goal L1: A reserve system with representative natural and seminatural landscapes consisting of a mosaic of natural communities that is adaptable to changing conditions to sustain populations of covered species and maintain or increase native biodiversity.		
Objective L1.3: Restore and protect 65,000 acres of tidal natural communities and transitional uplands to accommodate sea level rise. Minimum restoration targets for tidal natural communities in each ROA are 7,000 acres in Suisun Marsh ROA, 5,000 acres in Cache Slough ROA, 1,500 acres in Cosumnes/Mokelumne ROA, 2,100 acres in West Delta ROA, and 5,000 acres in South Delta ROA.	Increasing the frequency, magnitude, and duration of inundation in the Yolo Bypass floodplain will enhance primary productivity and the extent of suitable and viable spawning and rearing habitat within the Plan Area.	Compliance monitoring
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.		
Objective L2.5: Maintain or increase the diversity of spawning, rearing, and migration conditions for native fish species in support of life-history diversity.	Increasing frequency of inundation will enhance existing connectivity between the Sacramento River, its floodplain, and the Delta.	CM2-9, CM2-10
Objective L2.8: Provide refuge habitat for migrating and resident covered fish species.	Seasonal inundation of floodplain will contribute to an increase in off-channel habitat with conditions suitable for salmon and splittail.	CM2-10
Objective L2.9: Increase the abundance and productivity of plankton and invertebrate species that provide food for covered fish species in the Delta waterways.	Seasonal inundation of floodplain habitat will increase the input of terrestrial biota and aquatic primary and secondary productivity, contributing to the foodweb supporting covered fish species. This will work in tandem with the flooded shallow water to contribute to an increase in growth rate for juvenile fish rearing in the bypass.	CM2-9
Goal L4: Increased habitat suitability for covered fish species in the Plan Area.		
Objective L4.2: Manage the distribution of covered fish species to minimize movements into areas of high predation risk in the Delta.	Providing flows to attract or direct covered fish species to floodplain habitat may reduce predation mortality.	CM2-10, CM2-11

Biological Goal or Objective	How CM2 Advances a Biological Objective	Monitoring Action(s)
Goal DTSM1: Increased end of year fecundity and improved survival of adult and juvenile delta smelt to support increased abundance and long-term population viability.		
Objective DTSM1.1: Increase fecundity over baseline conditions.[a]	CM2 will contribute to a significant increase in the extent, duration, and frequency of floodplain inundation. This is anticipated to increase primary and secondary productivity, which may seasonally increase the abundance of food available to delta smelt. An increase in food may contribute to an increase in size and thus an increase in per capita fecundity of delta smelt.	CM2-9
Objective DTSM1.3: Achieve an improved Recovery Index.[a]	CM2 will contribute to a significant increase in the extent, duration, and frequency of floodplain inundation. This is anticipated to increase primary and secondary productivity, which may increase the abundance of food available to delta smelt. An increase in food may contribute to an increase in survival, thereby contributing to achieving the Recovery Index metrics.	CM2-9
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.		
Objective WRCS1.1: Improve through-Delta survival.[a]	CM2 is expected to contribute to an increase in through-Delta survival by providing an alternate migration route that may provide improved survival (compared to the mainstem Sacramento River). Further, juvenile Chinook salmon that migrate through the Yolo Bypass will bypass Georgiana Slough, which leads to the interior Delta. Studies indicate that juvenile survival decreases when migrating through the interior delta than for fish migrating via the Sacramento River (Perry et al. 2010). CM2 is also expected to contribute to increased growth of juvenile Chinook salmon that rear within Yolo Bypass. Katz (2012) found that growth rates for caged juvenile Chinook salmon reared within flooded agricultural fields in Yolo Bypass were among the highest recorded in freshwater Central Valley habitats. Increased growth is also expected to contribute to increased through-Delta survival.	CM2-10
Objective WRCS1.2: Create a viable alternate migratory path through Yolo Bypass.[a]	CM2 will directly contribute to achieving this objective through modifications to the Fremont Weir to promote juvenile salmonid passage into Yolo Bypass and provide conditions conducive to juvenile rearing and migration within Yolo Bypass.	CM2-11

Biological Goal or Objective	How CM2 Advances a Biological Objective	Monitoring Action(s)
Goal WRCS2: Substantial reduction of passage delays (to contribute to increased migration and spawning success, and thus abundance) at human-made impediments for adult winter-run Chinook salmon migrating through the Delta.		
Objective WRCS2.1: Limit adult winter-run Chinook salmon passage delays in the Yolo Bypass to fewer than 36 hours by year 15.	CM2 will directly contribute to achieving this objective through modifications to the Fremont Weir that promote upstream passage of adults and reduce passage delays at the Fremont Weir for those adults attracted to the Yolo Bypass from the mainstem Sacramento River.	CM2-11
Goal SRCS1: Increased spring-run Chinook salmon abundance.		
Objective SRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM2-11
Objective SRCS1.2: Create a viable alternate migratory path through Yolo Bypass.[a]	See Objective WRCS1.2 above.	CM2-11
Goal SRCS2: Substantial reduction of passage delays (to contribute to increased migration and spawning success and thus abundance) at human-made impediments for adult spring-run Chinook salmon migrating through the Delta.		
Objective SRCS2.1: Limit adult passage delays in the Yolo Bypass and at other human-made barriers and impediments in the Plan Area.[a]	See Objective WRCS2.1 above.	CM2-11
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.		
Objective FRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above	CM2-11
Objective FRCS1.2: Create a viable alternate migratory path through Yolo Bypass.[a]	See Objective WRCS1.2 above.	CM2-11
Goal FRCS2: Substantial reduction in passage delays (to contribute to increased migration and spawning success and thus abundance) at human-made impediments for adult fall-run/late fall–run Chinook salmon migrating through the Delta.		
Objective FRCS2.1: Limit adult passage delays in the Yolo Bypass and at other human-made barriers and impediments in the Plan Area.[a]	See Objective WRCS2.1 above.	CM2-11
Goal STHD1: Increased steelhead abundance.		
Objective STHD1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM2-11
Objective STHD1.2: Create a viable alternate migratory path through Yolo Bypass.[a]	See Objective WRCS1.2 above.	CM2-11
Goal STHD2: Substantial reduction in passage delays (to contribute to increased migration and spawning success and thus abundance) at human-made impediments for adult steelhead migrating through the Delta.		
Objective STHD2.1: Limit adult passage delays in the Yolo Bypass and at other human-made barriers and impediments in the Plan Area.[a]	See Objective WRCS2.1 above.	CM2-11
Goal SAST1: Increased abundance of Sacramento splittail in the Plan Area.		
Objective SAST1.1: Improve splittail index of abundance in the Plan Area.[a]	CM2 will directly contribute toward achieving this objective by increasing the frequency that suitable splittail spawning and rearing habitat is available in Yolo Bypass, which is expected to contribute to an increase in splittail abundance.	CM2-10

Biological Goal or Objective	How CM2 Advances a Biological Objective	Monitoring Action(s)
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.		
Objective GRST1.1: Increase juvenile and adult survival.[a]	CM2 is expected to contribute toward achieving this objective by increasing primary and secondary productivity, which may contribute to an increase in food important to juvenile and adult sturgeon. Additionally, reducing passage delays at Fremont Weir may contribute to a reduction in stress, which may increase survival of adult sturgeon.	CM2-9, CM2-10, CM2-11
Goal GRST2: Improved connectivity that facilitates timely passage and reduces stranding of adult green sturgeon.		
Objective GRST2.1: Eliminate adult stranding by year 15, and minimize stranding until this time.[a]	CM2 will directly contribute to achieving this objective by modifying the Fremont Weir, which is expected to eliminate passage delays at the Fremont Weir and the scour pools directly below Fremont Weir. Other modifications to the Tule Canal will be implemented to eliminate any passage delays that may occur within the canal.	CM2-11
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.		
Objective WTST1.1: Increase juvenile and adult survival.[a]	See Objective GRST1.1 above.	CM2-9, CM2-10, CM2-11
Goal WTST2: Improved habitat connectivity that facilitates timely passage and reduces stranding of adult white sturgeon.		
Objective WTST2.1: Eliminate adult stranding by year 15, and minimize stranding until this time.[a]	See Objective GRST2.1 above.	CM2-11
Goal PRL1: Improved habitat connectivity that facilitates timely passage for Pacific and river lamprey within the Plan Area.		
Objective PRL1.1: Reduce passage delays for lamprey adults migrating upstream within the Yolo Bypass by year 15.	CM2 will directly contribute to achieving this objective by implementing modifications at the Fremont Weir to improve fish passage performance. Additionally, modifications to the Yolo Bypass may result in further reductions in passage delays that may occur elsewhere within the Yolo Bypass.	CM2-11
Objective PRL1.2: Improve downstream passage conditions for lamprey ammocoetes and macropthalmia at the Fremont Weir by year 15.	CM2 will directly contribute to achieving this objective by implementing modifications at the Fremont Weir to improve fish passage performance, including passage of juvenile covered fish species.	CM2-11

[a] Summarized objective statement; full text presented in Table 3.3-1.

3.4.3 Conservation Measure 3 Natural Communities Protection and Restoration

Under *CM3 Natural Communities Protection and Restoration*, the Implementation Office will establish a system of protected lands in the Plan Area, called a reserve system, by acquiring lands for protection and, in some cases, restoration. Such a system is needed to meet natural community and species habitat protection objectives described in Section 3.3, *Biological Goals and Objectives*. See Chapter 6, Section 6.1.2, *Maintaining Rough Proportionality*, for provisions to ensure that protection and restoration occur in rough proportionality with natural community loss. The reserve system will be assembled over the BDCP permit term to accomplish the following aims.

- Protect and enhance areas of existing natural communities and covered species habitat.
- Protect and maintain occurrences of selected covered plant species with limited distributions.
- Provide sites suitable for restoration of natural communities and covered species habitat (some restoration would occur on lands already publicly owned).
- Provide habitat connectivity among the lands in the reserve system and connectivity to existing conservation lands (Figure 3.2-14) inside and outside of the Plan Area.

This section describes the purpose of the reserve system, the means by which CM3 will advance the biological goals and objectives, and opportunities for protecting and restoring natural communities throughout the Plan Area. Procedures for land acquisition and restoration planning are described in Section 3.4.3.3.1, *Land Protection*, and Section 3.4.3.4, *Natural Communities* Restoration, respectively, including requirements related to the extent of land acquisition, site selection criteria and reserve design, preacquisition surveys, and development of site-specific plans for restoration projects. Restoration requirements that are not related to any of the other conservation measures but are necessary to meet biological objectives for covered species are addressed in this section. Additional requirements for restoration of each natural community type are provided in CM4 through CM10.

The Implementation Office may purchase credits from approved mitigation or conservation banks for incorporation into the reserve system. Credits used to address conservation targets must be from approved banks that have service areas that include all or part of the Plan Area.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM3. This conservation measure is not expected to result in adverse effects on natural communities or covered species. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM3 on covered species will be avoided or minimized.

3.4.3.1 Purpose

The purpose of CM3 is to protect high-value natural communities and covered species habitats, and to achieve the land protection necessary to meet or contribute to the biological goals and objectives as identified in Section 3.4.3.6, *Consistency with the Biological Goals and Objectives*. Additional land may need to be protected to achieve the restoration target of 83,679 acres (Objective L1.1), some of which will be on public land. This conservation measure provides for protection of existing natural communities and covered species habitat, and for protection of lands necessary for restoration (Objective L1.2).

3.4.3.2 Problem Statement

For descriptions of the ecological values and current condition of natural communities in the Plan Area, see Chapter 2, *Existing Ecological Conditions,* and Section 3.3, *Biological Goals and Objectives*. Section 3.3 also describes the need for natural communities protection and restoration as a component of the conservation strategies for natural communities and associated covered species, based on the existing conditions and ecological values of these resources.

Natural communities in the Plan Area have been lost, fragmented, and degraded primarily as a result of agricultural conversion, flood control, and urban development. The protection and restoration of natural communities will eliminate future loss, fragmentation, and degradation within the reserve system, and natural communities restoration will reverse past loss, fragmentation, and degradation. As shown in Table 3.3-2, there is an abundance of unprotected land in the Plan Area (85%), providing opportunities to build the reserve system off of and link existing conservation lands within and adjacent to the Plan Area. The following discussion describes existing conditions and natural community protection opportunities in each of the conservation zones[9].

3.4.3.2.1 Conservation Zone 1

Conservation Zone 1 is located in Solano County north of Montezuma Hills and west of Yolo Bypass (Figure 3.4-6). This conservation zone provides opportunities for protecting and restoring grasslands and associated vernal pool and alkali seasonal wetland complexes, for tidal marsh restoration at the Cache Slough ROA[10], and for cultivated lands protection. Approximately 8% of the conservation zone (4,446 of 54,061 acres) is currently protected. Opportunities exist to link the reserve system with existing conservation lands. Key existing conservation lands in this zone are portions of Jepson Prairie Preserve and Calhoun Cut Ecological Reserve, south and west of Lindsey Slough.

Conservation Zone 1 includes some of the largest contiguous expanses of grasslands and associated vernal pool complex in the Plan Area. Grasslands and associated vernal pool complex in this zone are located between conserved grassland landscapes immediately adjacent to the Plan Area (e.g., portions of Jepson Prairie Preserve) and tidal marsh in the Cache Slough ROA. Grasslands in this zone provide, or have the potential to provide, foraging habitat for the tricolored blackbird, western burrowing owl, Swainson's hawk, and white-tailed kite; upland habitat for the giant garter snake and western pond turtle; breeding and upland habitat for the California tiger salamander; and habitat for vernal pool fairy shrimp, vernal pool tadpole shrimp, alkali milk-vetch, San Joaquin spearscale, dwarf downingia, Boggs Lake hedge-hyssop, Heckard's peppergrass, legenere, heartscale, brittlescale, delta button celery, and Carquinez goldenbush.

Sufficient cultivated lands are present in Conservation Zone 1 to achieve a substantial proportion of the overall cultivated lands conservation target acreages (Table 3.3-2) established for the Plan Area. Cultivated lands in this zone provide foraging habitat for tricolored blackbird, Swainson's hawk, and other species associated with cultivated lands.

Conservation Zone 1 includes tidal, grassland, and vernal pool restoration opportunities. It includes a portion of the Cache Slough ROA, which is suitable for tidal natural communities restoration as

[9] See Chapter 12, *Glossary*, for definition of conservation zones.

[10] See Chapter 12, *Glossary*, for definition of restoration opportunity areas (ROAs).

described in *CM4 Tidal Natural Communities Restoration*. This conservation zone also contains lands suitable for grassland restoration to increase connectivity among currently fragmented patches of grassland and seasonal wetlands (both within Conservation Zone 1 and with adjacent lands to the southwest that, in turn, connect with Conservation Zone 11) and to provide upland wildlife refugia adjacent to restored tidal marsh plains. Additionally, Conservation Zone 1 contains lands that were historically vernal pool complexes that have since been highly degraded, but which are suitable for vernal pool restoration.

3.4.3.2.2 Conservation Zone 2

Conservation Zone 2 consists of the Yolo Bypass and associated lands to the south and west, and overlaps with the Yolo County HCP/NCCP area (Figure 3.4-7). Cultivated land is the predominant community type in this zone; thus, it provides opportunities for protecting cultivated foraging habitats. This conservation zone also provides opportunities for protecting and restoring grassland and associated seasonal wetlands, and for restoration of tidal and associated riparian natural communities and nontidal wetlands. Conservation Zone 2 includes a portion of the Cache Slough ROA, which is suitable for tidal natural communities restoration as described in *CM4 Tidal Natural Communities Restoration.*

Approximately 58% (39,700 of 68,904 acres) of Conservation Zone 2 consists of existing conservation lands. Ample opportunities exist to protect cultivated lands and associated natural communities in large blocks connected to existing conservation lands, both within this zone and with adjacent lands to the southwest and southeast in Conservation Zones 1 and 4, respectively. Yolo Bypass Wildlife Area and other conservation lands owned by CDFW are present in the central and northern portions of Conservation Zone 2, while Liberty Island, owned by the Trust for Public Lands, and other lands owned by USACE and DWR are present at the southern end.

Conservation Zone 2, which hosts the majority of rice lands and other cultivated lands in the Plan Area, supports a sufficient amount of these lands to achieve a substantial proportion of the overall cultivated lands conservation target acreages (Table 3.3-2) established for the Plan Area. These cultivated lands support foraging habitat for tricolored blackbird, Swainson's hawk, giant garter snake, and other species associated with cultivated lands. This conservation zone includes one of two giant garter snake subpopulations in the Plan Area (the Yolo Basin/Willow Slough subpopulation).

3.4.3.2.3 Conservation Zone 3

Conservation Zone 3 is located between the Yolo Bypass and the Sacramento River (Figure 3.4-8), and consists primarily of cultivated lands and natural and artificial channels with narrow strips of associated riparian vegetation. This conservation zone provides opportunities to protect foraging habitat for Swainson's hawk and greater sandhill crane. Protection of cultivated lands and associated irrigation channels may also provide opportunities to establish giant garter snake habitat connectivity between the Yolo Basin/Willow Slough subpopulation in Conservation Zone 2 and the Coldani Marsh/White Slough subpopulation in Conservation Zone 4. Only 0.6% (460 of 83,246 acres) of this conservation zone consists of existing conservation lands, providing few opportunities to build the reserve system off of existing conservation lands.

3.4.3.2.4 Conservation Zone 4

Conservation Zone 4 is located along the eastern edge of the Plan Area, and overlaps with the plan area for the *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan* (San Joaquin County MSHCP) (Figure 3.4-9). This conservation zone provides opportunities to restore tidal and associated riparian natural communities and nontidal wetlands, and to protect cultivated lands. It includes tidal natural communities restoration opportunities in the Cosumnes/Mokelumne ROA, at the confluence of the Cosumnes and Mokelumne Rivers.

Approximately 41% (20,013 of 48,832 acres) of Conservation Zone 4 consists of existing conservation lands, providing ample opportunities to link the reserve system with existing conservation lands. Stone Lakes National Wildlife Refuge and Cosumnes Preserve occupy most of the land in the northern half of Conservation Zone 4. The Stone Lakes National Wildlife Refuge project area (Figure 3.3-6) is the area surrounding the existing refuge that has been federally approved for acquisitions on a willing-seller basis to add lands to the refuge. This provides opportunities to develop a conservation strategy that will build off of the existing wildlife refuge (i.e., these lands could be acquired through the BDCP and donated to the refuge for protection and management). In the central portion of the conservation zone are lands held by The Nature Conservancy, including Bean Ranch, Crump Ranch, Fitzgerald, Beacon Farms, and Cowell Ranch. Lands publicly owned by BLM, the City of Sacramento, and DWR are also present in the central portion of Conservation Zone 4. Woodbridge Ecological Reserve (CDFW-owned), White Slough Wildlife Area (DWR-owned), and the City of Lodi water treatment plant are present in the southern half of Conservation Zone 4.

Cultivated lands in Conservation Zone 4 provide habitat for tricolored blackbird, Swainson's hawk, greater sandhill crane, and giant garter snake. This conservation zone contains the Coldani Marsh/White Slough subpopulation of giant garter snake, and provides opportunities for marsh restoration to protect and expand this subpopulation and provide connectivity with giant garter snake habitat in the Stone Lakes area in Conservation Zone 4.

3.4.3.2.5 Conservation Zone 5

Conservation Zone 5 extends from the central Delta eastward, to encompass lands along the eastern edge of the Plan Area (Figure 3.4-10). This zone includes cultivated lands that provide habitat for tricolored blackbird, Swainson's hawk, greater sandhill crane, and giant garter snake. It includes lands suitable for tidal natural communities restoration in the West Delta ROA, providing habitat for Mason's lilaeopsis, Suisun Marsh aster, and delta mudwort, and for the creation of sandhill crane roosting sites.

Approximately 25% (30,919 of 123,679 acres) of Conservation Zone 5 consists of existing conservation lands, providing opportunities to link the reserve system with existing conservation lands. Existing conservation lands in this zone include Sherman Island and Twitchell Island, owned by DWR, Staten Island owned by The Nature Conservancy, and Lower Sherman Island and Woodbridge Ecological Reserves owned by CDFW. Other existing conservation lands in Conservation Zone 5 include portions of Stone Lakes National Wildlife Refuge and Cosumnes Preserve, and East Bay Regional Park lands.

3.4.3.2.6 Conservation Zone 6

Conservation Zone 6 encompasses deeply subsided islands of the Delta that are predominately under cultivation and generally support only small, fragmented patches of habitat that are not associated with cultivated land (Figure 3.4-11). The zone provides opportunities for tidal habitat restoration in the West Delta ROA providing habitat for Mason's lilaeopsis, Suisun Marsh aster, and delta mudwort. Cultivated lands in Conservation Zone 6 provide Swainson's hawk foraging habitat and greater sandhill crane foraging and roosting habitats, thereby providing opportunities for cultivated lands protection to help provide for the conservation and management of these species.

Approximately 11% (11,940 of 110,771 acres) of Conservation Zone 6 consists of existing conservation lands. These include the Franks Tract State Resource Area owned by California Department of Parks and Recreation, Dutch Slough owned by DWR, and numerous relatively small areas consisting of Delta islands owned by CDFW and DWR.

3.4.3.2.7 Conservation Zone 7

Conservation Zone 7 is located at the southern end of the Plan Area and includes the San Joaquin and Stanislaus Rivers and their tributaries with associated cultivated lands and natural communities (Figure 3.4-12). This zone overlaps with the San Joaquin County MSHCP. Conservation Zone 7 provides the best opportunities in the Plan Area for restoring seasonally inundated floodplain. The riparian natural community in Conservation Zone 7 supports riparian brush rabbit and provides suitable habitat for riparian woodrat, least Bell's vireo, yellow-breasted chat, white-tailed kite, Swainson's hawk, and valley elderberry longhorn beetle. Cultivated lands in this zone provide habitat for Swainson's hawk other covered species associated with cultivated lands.

Only approximately 2% (2,685 of 116,734 acres) of Conservation Zone 7 consists of existing conservation lands, providing limited opportunities for building a reserve system off of existing conservation lands. However, opportunities exist to connect with conservation lands to the south of the Plan Area, including adjacent portions of San Joaquin National Wildlife Refuge. Conservation lands in this zone include portions of San Joaquin National Wildlife Refuge and several small protected areas including Vernalis Riparian Habitat Preserve and Dos Reis Preserve owned by CDFW and lands owned by the State Lands Commission.

3.4.3.2.8 Conservation Zone 8

Conservation Zone 8 is in the southwestern portion of the Plan Area and overlaps with the East Contra Costa County HCP/NCCP area (Figure 3.4-13). The predominant natural communities in this conservation zone are grasslands and associated vernal pool and alkali seasonal wetland complexes, which provide habitat for San Joaquin kit fox, tricolored blackbird, western burrowing owl, Swainson's hawk, white-tailed kite, western pond turtle, California red-legged frog, California tiger salamander, vernal pool fairy shrimp, vernal pool tadpole shrimp, alkali milk-vetch, San Joaquin spearscale, heartscale, brittlescale, and delta button celery. Tidal natural communities provide habitat for Mason's lilaeopsis and delta mudwort. Conservation Zone 8 provides opportunities for protecting these natural communities and the associated covered species.

Approximately 9% (3,169 of 35,776 acres) of Conservation Zone 8 consists of existing conservation lands. Conservation lands in this conservation zone include Clifton Court Forebay and Byron Conservation Bank owned by CDFW.

3.4.3.2.9 Conservation Zone 9

Conservation Zone 9 consists primarily of urban lands (e.g., Brentwood and Discovery Bay); nonurban areas are predominately cultivated lands (Figure 3.4-14). Cultivated lands in this conservation zone provide foraging habitat for Swainson's hawk. This conservation zone provides opportunities for protecting cultivated lands. Habitats not associated with cultivated lands occur in small patches that are disconnected from other natural habitats.

Approximately 5% (1,631 of 30,426 acres) of Conservation Zone 9 consists of existing conservation lands. These include lands owned by East Bay Regional Park District and several relatively small areas owned by the City of Brentwood.

3.4.3.2.10 Conservation Zone 10

Conservation Zone 10 encompasses the city of Antioch and consists almost entirely of urban lands (Figure 3.4-15). There are few or no protection or restoration opportunities in this zone. Approximately 8% of this zone (511 of 6,356 acres) consists of existing conservation lands. These include lands owned by East Bay Regional Park District and several relatively small areas owned by the Cities of Oakley, Antioch, and Pittsburg. Antioch Dunes National Wildlife Refuge is in this zone.

3.4.3.2.11 Conservation Zone 11

Conservation Zone 11 is located in the Suisun Marsh area, and predominately consists of tidal natural communities and managed wetlands surrounded by an upland fringe of grasslands and associated vernal pools and alkali seasonal wetland complexes (Figure 3.4-16). The grasslands and associated vernal pools and alkali wetlands provide habitat for the tricolored blackbird, western burrowing owl, Swainson's hawk, white-tailed kite, California tiger salamander, vernal pool fairy shrimp, and vernal pool tadpole shrimp, alkali milk-vetch, San Joaquin spearscale, dwarf downingia, Boggs Lake hedge-hyssop, Heckard's peppergrass, legenere, heartscale, brittlescale, and Carquinez goldenbush. The tidal marsh and managed wetlands provide habitat for the salt marsh harvest mouse, Suisun shrew, tricolored blackbird, Suisun song sparrow, California black rail, California clapper rail, western pond turtle, Suisun thistle, soft bird's-beak, Delta tule pea, Suisun Marsh aster, and Mason's lilaeopsis. Conservation Zone 11 provides opportunities to protect and restore all of these natural communities and to provide for the conservation and management of the associated covered species.

Approximately 52% (55,470 of 107,339 acres) of Conservation Zone 11 consists of existing conservation lands. These include Grizzly Island Wildlife Area (CDFW-owned), Hill Slough Wildlife Area (CDFW-owned), and Rush Ranch (Solano Land Trust–owned).

3.4.3.3 Natural Communities Protection Implementation

All lands in the reserve system will be managed consistent with the BDCP for the duration of the permit term and will be protected *in perpetuity*. Lands will be owned in fee-title or via easement to guarantee protection *in perpetuity*. Lands not owned by BDCP will be managed cooperatively with the landowner. Cooperative management agreements will be concluded with each landowner to ensure management consistent with the BDCP. See Chapter 7, Section 7.3.1, *Implementation of the Habitat Protection and Restoration Conservation Measures*, for more details on the establishment of the reserve system.

The land protection commitments for natural communities are presented in Table 3.3-2 in the "Protected by BDCP" column and in Table 3.4.3-1. Acquisition of these lands will also fulfill the acreage requirements for each of the covered species, as shown in Table 3.4.3-1. These commitments represent the extent of land that will be acquired to meet preservation requirements; the actual extent that will be acquired will likely be greater, because acquired parcels will include excess amounts of target and nontarget natural communities.

3.4.3.3.1 Land Protection

The Implementation Office will secure reserve system lands through a variety of mechanisms that will include, but will not be limited to, the following.

- Purchase in fee-title.
- Purchase or application of permanent conservation easements (on public or private lands).
- Change of federal- or state-owned lands to more protective land use designation.
- Permanent agreements with state, federal, and local agencies (e.g., flood control agencies) that commit the parties to the restoration, enhancement, and management public lands in the reserve system in a manner supporting the biological goals and objectives.
- Purchase of suitable mitigation credits from approved private mitigation banks.

The Implementation Office may acquire lands in partnership with other conservation organizations or through grants of land from participating entities where such lands will serve to achieve the biological goals and objectives. The reserve system will comprise conservation areas (lands that are under direct management of the Implementation Office or an Authorized Entity), lands protected through permanent conservation easements.

It is anticipated that lands used for habitat restoration actions will primarily be those that are currently in public ownership or those that are acquired in fee-title, because restoration activities have a high potential to preclude other land uses. Lands acquired for the protection and maintenance of existing habitat functions may be acquired through conservation easements that specify permitted land uses and practices in sufficient detail to maintain the intended habitat functions of the acquired lands, although enhancements may also be implemented on conservation easement lands as opportunities arise.

Overlap of the Plan Area with Other Habitat Conservation Plan Areas

The Plan Area overlaps with the planning areas of six regional HCPs (Figure 1-2, *Plan Area in Relation to Neighboring Conservation Plan Boundaries*, in Chapter 2). Two of these plans, the *South Sacramento Habitat Conservation Plan* (South Sacramento HCP) and San Joaquin County MSHCP, present potential land use conflicts: each plan has potentially competing demands with the BDCP for protection of cultivated lands in the overlap area. Cultivated land is dominant within these overlap areas, is important to several species covered under the overlapping plans (e.g., Swainson's hawk, greater sandhill crane, tricolored blackbird), and has relatively large acquisition requirements for the three plans. The BDCP must acquire 48,625 acres of cultivated land, and the South Sacramento HCP and San Joaquin County MSHCP may need to acquire as much as an estimated 6,000 and 36,000 acres within their areas of overlap with the Plan Area, respectively. The South Sacramento HCP may also have limited opportunities for protection of wetland land cover types, presenting potentially competing demands for these land cover types in the overlap area.

Because the mitigation and conservation goals of the plans are similar, the conservation strategies of all plans will be coordinated in the overlap areas to ensure that all three plans can meet their respective needs and the conservation values of mitigation and conservation is maximized. To ensure that all three plans will be able to meet their acquisition requirements for cultivated lands, special provisions will be made for the overlap areas. The BDCP will evaluate conservation acquisitions every 5 to years and make adjustments, if conflicts occur with either of these two overlapping HCPs. This adaptive approach will include the following process to allow swaps of easements with the South Sacramento HCP or San Joaquin County MSHCP.

- If during the permit terms of the South Sacramento HCP or San Joaquin County MSHCP, either plan is unable to meet its mitigation requirements for cultivated land or wetland land cover types due to a lack of willing sellers and due in part to acquisition by the BDCP of cultivated land or wetland land cover types in the overlap area, a credit swap of easement(s) will be initiated.
- Determination that the first criterion has been met will be made jointly by CDFW, USFWS, the Implementation Office, and the South Sacramento HCP or San Joaquin County MSHCP implementing entity.
- Cultivated land or wetland land cover types owned by the Authorized Entities or Supporting Partners in the overlap area in fee-title or conservation easements will be identified for their applicability to the South Sacramento HCP or San Joaquin County MSHCP conservation strategy.
- The South Sacramento HCP or San Joaquin County MSHCP will acquire conservation easements or fee-title on land outside of the overlap area with equivalent or greater conservation value to the BDCP as the land identified in the criteria above. This land acquired must be within the Plan Area but may be outside Sacramento or San Joaquin Counties.
- As an alternative, the Authorized Entities or Supporting Partners may acquire the additional lands with funds from the South Sacramento HCP or San Joaquin County MSHCP.
- Once the additional land is acquired outside of the overlap area, the BDCP land within the overlap area will be transferred in fee-title or conservation easement holder to the South Sacramento HCP or San Joaquin County MSHCP.
- The land acquired by the South Sacramento HCP or San Joaquin County MSHCP outside of the Plan Area with equivalent or greater conservation value to the BDCP will be transferred to an Authorized Entity or Supporting Partner.
- Once the transfers are complete, the credit assigned to each plan for the conserved land will also be transferred.

The BDCP will ultimately acquire no more than 1,500 acres in the overlap area with South Sacramento HCP. The BDCP will prioritize acquisitions in the South Sacramento HCP overlap area to lands within the Stone Lakes National Wildlife Refuge project boundary[11]. The BDCP will coordinate with the refuge to identify appropriate lands to acquire within the project boundary, and may transfer conservation lands within the project boundary to the refuge following acquisition.

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[11] The project boundary delineates the area surrounding the existing refuge for which the refuge has authority to acquire land or easements.

3.4.3.3.2 Siting and Reserve Design

Siting Criteria

The Implementation Office will apply, and revise when necessary, the following criteria for evaluating and prioritizing acquisition of lands to achieve natural community conservation target acreages (Table 3.3-2) established for the Plan Area. Two sets of criteria are presented, each for different groups of natural communities. These criteria apply to all of the natural communities within each group. Additional site selection and reserve design criteria unique to each natural community, conservation zone, and in some cases covered species, are also presented below.

Criteria for evaluating the suitability of lands supporting grasslands and associated vernal pool and alkali seasonal wetland complex are as follows.

- Effectiveness in contributing towards achieving multiple biological goals and objectives.
- Adherence to the principles described in Section 3.2.4.2.1, *Reserve System Assembly Principles*.
- Level of benefits the acquisition will provide for covered species.
- Presence and abundance of covered species.
- Presence of uncommon site-specific attributes (e.g., soil types, hydrology) required by covered species with narrow range of habitat requirements.
- Likely effects of adjacent land uses on the ability to maintain or improve desired ecological functions into the future.
- Natural community patch size relative to the habitat patch size of the covered species intended to benefit from the habitat.
- Opportunities for effectively implementing management actions to enhance ecological functions.
- Level of contribution for maintaining local and regional ecological processes.
- Level of connectivity provided between and among existing conservation lands.
- Level of contribution to preserve natural environmental gradients consistent with Objective L1.4.
- Level of contribution towards establishment of large areas of conserved lands.
- Likely effects of climate change on future ecological functions, and expected resiliency of site to those effects.
- Role in maintaining and complementing the habitat functions of adjoining natural communities for covered and other native species.
- Level of contribution toward protection of a heterogeneous mix of natural communities and native species, including native grasses and forbs. Iodine bush scrub will be prioritized for protection of alkali seasonal wetland in Conservation Zone 8, because it is a rare subset of the natural community.
- Likely contribution toward achieving biological objectives for approved and planned HCPs and NCCPs overlapping or adjacent to the Plan Area.

Criteria for acquiring land for restoring tidal natural communities, riparian natural community, nontidal marsh, and seasonally inundated floodplain are as follows.

- Potential for restoration on the site to achieve multiple biological goals and objectives.
- Suitability and cost-effectiveness for restoring target habitats.
- Suitability for supporting the restored habitat over time.
- Adherence to the principles described in Section 3.2.4.2.1, *Reserve System Assembly Principles*.
- Expected level of management necessary to maintain desired ecological functions into the future.
- Compatibility with adjacent land uses.
- Likely effects of climate change on future ecological functions, and expected resiliency of site to those effects.

The Implementation Office is committed to securing a sufficient acreage of land to achieve the seasonally inundated floodplain restoration, channel margin enhancement, and riparian natural community restoration targets described in *CM5 Seasonally Inundated Floodplain Restoration, CM6 Channel Margin Enhancement,* and *CM7 Riparian Natural Community Restoration.* These commitments cannot be tied to specific conservation zones, but rather to the geographies identified in the conservation measures. Therefore they are not described in the conservation zone acquisition requirements.

Landscape Linkages

Section 3.2.5, *Landscape Linkages*, describes landscape linkages that have been identified to provide natural community and habitat connectivity within the Plan Area and with areas outside the Plan Area. The linkages that have been identified at a regional level are described in Table 3.2-3 and shown on Figure 3.2-16. The site selection process for establishing the reserve system will involve prioritizing areas that would facilitate connectivity for those linkages in Table 3.2-3 for which CM3 is identified as an applicable conservation measure. In addition to these regional linkages, site selection will prioritize areas that will meet smaller-scale connectivity needs (identified during Plan implementation as the reserve system is assembled) such as connecting sites that are protected during implementation, connecting aquatic and upland habitat for covered amphibians, and connecting riparian and emergent wetland natural communities with adjacent uplands for covered mammals (i.e., riparian brush rabbit, salt marsh harvest mouse, Suisun shrew). These smaller scale connectivity needs are further described in Section 3.2.5.1.3, *Other Connectivity*.

Reserve Design Criteria by Natural Community Group

In addition to the general site selection criteria described above and in Section 3.2.4.2.1, *Reserve System Assembly Principles*, requirements for siting and reserve design specific to the natural communities and covered species habitat to be protected and restored are provided in Table 3.4.3-1. For the purpose of minimizing redundancy and addressing landscape-scale conservation needs, the siting and reserve design requirements in Table 3.4.3-1 are presented six groups: tidal natural communities, grasslands and associated vernal pool and alkali seasonal wetland complexes, nontidal marsh, managed wetland, seasonally inundated floodplain and riparian natural community, and cultivated lands.

1 **Table 3.4.3-1. Natural Community Siting and Reserve Design Requirements**

ID	Type	Protection		Restoration	
		Amount (Acres)	Location and Other Requirements	Amount (Acres)	Location and Other Requirements
Tidal Natural Communities					
#1	Tidal natural communities (CM4)	0	N/A	#1 restoration and #2 protection collectively total 65,000	• At least 7,000 acres in Suisun Marsh ROA. • At least 1,500 acres in Cosumnes/Mokelumne ROA. • At least 2,100 acres in West Delta ROA. • At least 5,000 acres in South Delta ROA. • Also see #3, # 4, #5, #29, #30.
#2	Transitional uplands to accommodate sea level rise (CM4)	#1 restoration and #2 protection collectively total 65,000	• Adjacent to restored tidal natural communities. • Sufficient acreage to meet the 65,000-acre requirement for tidal restoration plus sea level rise accommodation.	As needed	• Cultivated lands within a 200-foot-wide band adjacent to restored emergent wetland, within the transitional uplands will be restored to natural uplands such as grassland or riparian. • The restored grassland will not count toward the 2,000-acre grassland restoration objective (GNC1.2), but restored riparian will count toward the 5,000-acre riparian restoration objective (VFRNC1.1).
#3	Tidal brackish emergent wetland	0	N/A	At least 6,000	• Subset of #1. • In Conservation Zone 11 among the Western Suisun/Hill Slough Marsh Complex, the Suisun Slough/Cutoff Slough Marsh Complex, and the Nurse Slough/Denverton Marsh Complex. • Also see #6.
#4	Tidal freshwater emergent wetland (CM4)	0	N/A	At least 24,000	• Subset of #1. • See also #37 and #40.
#5	Tidal perennial aquatic (CM4)	0	N/A	As needed to achieve #1	• Subset of #1. • Creation of this natural community is expected to be a byproduct of the tidal restoration and not the primary restoration goal. Therefore, restoration will be designed to maximize tidal emergent wetlands and minimize deep subtidal areas.
#6	Salt marsh	0	N/A	1,500	• Subset of #3.

ID	Type	Protection		Restoration	
		Amount (Acres)	Location and Other Requirements	Amount (Acres)	Location and Other Requirements
	harvest mouse habitat				• At least 1,500 acres high and middle brackish marsh distributed among the Western Suisun/Hill Slough Marsh Complex, the Suisun Slough/Cutoff Slough Marsh Complex, and the Nurse Slough/Denverton Marsh Complex.
#7	Suisun thistle and soft bird's-beak habitat	0	N/A	As needed to meet requirement	• Restore tidal inundation to wetlands in the Hill Slough Ecological Reserve and the ponded area at Rush Ranch. Implementation of this action depends on cooperation with CDFW and the Solano Land Trust, the entities that own and manage the Hill Slough Ecological Reserve and Rush Ranch, respectively.
Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complexes					
#8	Grasslands (CM8)	8,000	• At least 2,000 acres in Conservation Zone 1; 1,000 acres in Conservation Zone 8; and 2,000 acres in Conservation Zone 11, and the remainder distributed among Conservation Zones 1, 2, 4, 7, 8, and 11. • See also #11, #12, #13, #14, #16, and #17.	2,000	• See also #11, #12, and #14.
#9	Vernal Pool Complex (CM9)	600	• Conservation Zones 1, 8, and/or 11, primarily in core vernal pool recovery areas identified in the *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (U.S. Fish and Wildlife Service 2005). • See also #15, #16, #17, #18, and #19.	As needed to meet requirement (Approx. 67)	• Sufficient vernal pool complex will be restored in Conservation Zones 1, 8, or 11 to achieve no net loss of vernal pool wetted acres, for up to 10 wetted acres.
#10	Alkali Seasonal Wetland Complex (CM9)	150	• Conservation Zones 1, 8, and/or 11 among a mosaic of protected grasslands and vernal pool complex. • See also #16, #17, #19, and #20.	As needed to meet requirement. (Approx. 72)	• Sufficient alkali seasonal wetland complex will be restored to achieve no net loss of alkali seasonal wetland wetted acres.
#11	Riparian brush rabbit habitat, grasslands	As needed to provide upland refugia	• Subset of #8. • Grassland protection or restoration on landward side of levees adjacent to protected or restored riparian brush rabbit	As needed to meet requirement	• See "Protection" column. • Subset of #8. Grassland conservation for brush rabbit may be met through protection, restoration, or a combination of both.

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
			habitat as needed to provide flood refugia for riparian brush rabbit. • Based on site-specific conditions and the need for upland habitat areas on the landward side of levees. For example, grassland restoration or protection will not be necessary if the protected riparian habitat is already adjacent to protected upland areas that provide sufficient refugia for the rabbit.		• Based on site-specific conditions and the need for upland habitat areas on the landward side of levees. For example, grassland restoration will not be necessary if the restored riparian habitat is already adjacent to protected upland areas that provide sufficient refugia for the rabbit.
#12	Tidal brackish marsh wildlife habitat, adjacent upland habitat	As needed to meet requirement	• Subset of #8. • Grassland protection or restoration within 200 feet of transitional uplands (beyond sea level rise accommodation).	As needed	• See "Protection" column. • Subset of #8. Upland habitat may be met through grassland protection, restoration, or a combination of both. • Also see #26 and #27.
#13	Swainson's hawk foraging habitat	8,750	• Consists of acreage from #8, #9, and #10 (grasslands, vernal pool complex, and alkali seasonal wetland complex). • Provide suitable Swainson's hawk foraging habitat. • See also #32.	0	• N/A
#14	Giant garter snake habitat, uplands	See "Restoration" column.	• See "Restoration" column.	At least 400	• Subset of #8 (unless 2,000 acres of grassland restoration is not sufficient to meet biological objectives for all species, in which case grassland restoration for giant garter snake may include acreage above and beyond the restoration required under Objective GNC1.2). • At least 200 acres of grasslands will be protected and/or restored adjacent to aquatic habitat at each of the 600-acre nontidal restoration locations (Goal GGS1 and Goal GGS2). • Additionally, up to one-third of the habitat protected or restored to achieve Objectives GGS1.4 and GGS3.1 will consist of restored or protected grasslands adjacent to protected or restored giant

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
					garter snake aquatic habitat. • The grasslands will have ample exposure to sunlight for facilitating giant garter snake thermoregulation and will be characterized by low vegetation, bankside burrows, holes, and crevices providing critical shelter for snakes throughout the day. All giant garter snake preserves will be established at least 2,500 feet from urban areas or areas zoned for urban development.
#15	Conservancy fairy shrimp occurrence	As needed to meet occurrence requirement	• Within the 600 acres of vernal pool complex to be protected, one currently unprotected conservancy fairy shrimp occurrence will be protected. Subset of #9.	0	N/A
#16	Heartscale habitat	75	• Subset of #8, #9, and #10 (grassland, vernal pool complex, and alkali seasonal wetland complex. • Protect heartscale modeled habitat.	0	N/A
#17	Brittlescale habitat	75	• Subset of #8, #9, and #10 (grassland, vernal pool complex, and alkali seasonal wetland complex. • Protect brittlescale modeled habitat.	0	N/A
#18	Heckard's peppergrass occurrences	As needed to meet occurrence requirement	• Subset of #9. • Establish occurrences as needed to maintain no net loss of Heckard's peppergrass in Conservation Zones 1, 8, or 11.	0	N/A
#19	San Joaquin spearscale occurrences	As needed to meet occurrence requirement	• Subset of #9 and #10. • Protect two currently unprotected occurrences of San Joaquin spearscale in Conservation Zones 1, 8, or 11.	0	N/A
#20	Carquinez goldenbush occurrences	As needed to meet occurrence requirement	• Subset of #10. • Protect three unprotected occurrences of Carquinez goldenbush in Conservation Zones 1 and/or 11.	0	N/A

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
Nontidal Marsh					
#21	Giant garter snake aquatic habitat (CM10)	0	N/A	1,200	• At least 600 acres in Conservation Zone 2 outside Yolo Bypass, and at least 600 acres in Conservation Zones 4 and/or 5. • All giant garter snake preserves will be established at least 2,500 feet from urban areas or areas zoned for urban development. • See also #37 and #38. • Additional nontidal marsh may be restored to meet the restoration and protection requirements under Goal GGS3.
#22	Tricolored blackbird nesting habitat	50	• Within 5 miles of occupied or recently occupied (within the last 15 years) nesting tricolored blackbird habitat, with preference given to previously occupied sites. • Protection of nesting habitat can be accomplished on existing conservation lands, provided these lands are not currently being managed specifically to encourage the young, lush stands of bulrush/cattail emergent vegetation favored by nesting tricolored blackbirds.	0	N/A
Managed Wetland					
#23	Managed wetland	8,100	• Suisun Marsh • At least 1,500 acres to be managed for salt marsh harvest mouse and the remaining 6,600 acres to be managed for managed wetland biodiversity, including waterfowl and shorebirds overwintering and	500	• 320 acres in Conservation Zones 3, 4, or 6, to provide roosting habitat for greater sandhill crane (CM10 Nontidal Marsh Restoration). Minimum patch sizes of 40 acres within the Greater Sandhill Crane Winter Use Area[12] in Conservation Zones 3, 4, 5, or 6, with consideration of sea level rise and

[12] Important geographically defined greater sandhill crane wintering areas in the Central Valley (Pogson and Lindstedt 1988; Littlefield and Ivey 2000; Ivey pers. comm.) (Figure 2.A.19-2, *Greater Sandhill Crane Habitat Model and Recorded Occurrences*, in Appendix 2.A).

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
			breeding. • 6,600 acres will comprise existing seasonal, semipermanent, and permanent wetlands. • Protection of semipermanent and permanent wetlands will target areas adjacent to suitable upland nesting habitat, preferably those upland sites known to already support waterfowl and shorebird breeding. • For waterfowl, semipermanent and permanent wetlands will have the greatest benefit when located in proximity to upland areas within the Grizzly Island Wildlife Area.		local seasonal flood events. The wetlands will be located within 2 miles of existing permanent roost sites and protected in association with other protected natural community types (excluding nonhabitat cultivated lands) at a ratio of 2:1 upland to wetland to provide buffers around the wetlands. • 180 acres consisting of two wetland complexes within the Stone Lakes National Wildlife Refuge project boundary[13], no more than 2 miles apart to help provide connectivity between the Stone Lakes and Cosumnes greater sandhill crane populations. Each complex will consist of at least three wetlands totaling 90 acres of greater sandhill crane roosting habitat, and will be protected in association with other protected natural community types (excluding nonhabitat cultivated lands) at a ratio of at least 2:1 uplands to wetlands (i.e., two sites with at least 90 acres of wetlands each). One of the 90-acre wetland complexes may be replaced by 180 acres of cultivated lands (e.g., cornfields) that are flooded following harvest to support roosting cranes and provide highest-value foraging habitat, provided such substitution is consistent with the long-term conservation goals of Stone Lakes National Wildlife Refuge for greater sandhill crane.
Seasonally Inundated Floodplain and Riparian Natural Community					
#24	Seasonally inundated floodplain	10,000	• In areas that provide the greatest opportunities for 10,000 acres of floodplain restoration (majority expected to be in Conservation Zone 7)	0	N/A
#25	Riparian (CM7)	750	• Conservation Zone 7, to be protected during near-term implementation period.	5,000	• At least 3,000 acres will be within the areas

[13] The project boundary delineates the area surrounding the existing refuge for which the refuge has authority to acquire land or easements.

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
			May be fully or partially within the areas identified in #24. • When siting, consider need to maintain at least 500 acres of mature riparian forest in Conservation Zones 4 or 7 (Objective VFRNC2.3). • When siting, consider need to maintain the 500 acres of mature riparian forest (VFRNC2.3) intermixed with a portion of the early- to midsuccessional riparian vegetation (VFRNC2.2) in large blocks with a minimum patch size of 50 acres and minimum width of 330 feet (Objective VFRNC2.4).		identified in #24. • When siting, consider need to maintain at least 500 acres of mature riparian forest in Conservation Zones 4 or 7 (Objective VFRNC2.3). • When siting, consider need to maintain the 500 acres of mature riparian forest (VFRNC2.3) intermixed with a portion of the early- to midsuccessional riparian vegetation (VFRNC2.2) in large blocks with a minimum patch size of 50 acres and minimum width of 330 feet (Objective VFRNC2.4).
#26	Riparian brush rabbit habitat, riparian (CM7)	200	• Subset of #25. • Occupied riparian brush rabbit habitat in Conservation Zone 7. • Occupied habitat will consist of riparian areas that are contiguous with riparian brush rabbit sightings or capture events within the last 5 years.	800, of which 300 meet more detail requirements	• Subset of #25. • At least 800 acres of early- to midsuccessional riparian within the range of the riparian brush rabbit (Conservation Zone 7), in areas that are adjacent to or that facilitate connectivity with occupied or potentially occupied habitat. • Of the 800 acres of early- to midsuccessional riparian, 300 acres that meet specific ecological requirements for the species (Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat*) and that are within or adjacent to or that facilitate connectivity with existing occupied or potentially occupied habitat.
#27	Riparian woodrat habitat, riparian (CM7)	0	N/A	300	• Subset of #25. • Riparian woodrat habitat that meets the ecological requirements for the species (Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat*) and that is within or adjacent to or that facilitates connectivity with existing occupied or potentially occupied habitat, and that facilitates expansion of the distribution

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
					and increase in the abundance of the species.
#28	Valley elderberry longhorn beetle	0	N/A	As needed to meet requirement	• Sufficient lands in drainages immediately adjacent to or within dispersal distance of known populations of the beetle to restore or create habitat to mitigate for impacts resulting from covered activities consistent with the USFWS valley elderberry longhorn beetle mitigation guidelines (Appendix 3.F). • Because valley elderberry longhorn beetle dispersal distance is currently unknown (U.S. Fish and Wildlife Service 2005), sites immediately adjacent to occupied habitat will be prioritized. • The best available information will be used to assess whether sites that are not immediately adjacent to occupied habitat are within dispersal distance and likely to become occupied by the species.
#29	Delta button celery occurrences	0	N/A	As needed to meet occurrence requirement	• Subset of #24. • Establish two occurrences of delta button celery within suitable habitat in the restored floodplain on the mainstem of the San Joaquin River in Conservation Zone 7 between Mossdale and Vernalis.
#30	Slough thistle occurrences	0	N/A	As needed to meet occurrence requirement	• Subset of #24. • Establish two occurrences of slough thistle within suitable habitat in the restored floodplain on the mainstem of the San Joaquin River in Conservation Zone 7 between Mossdale and Vernalis.
Cultivated Lands					
#31	Cultivated lands	48,625	• See species-specific requirements, below. • See also #37–#39.	0	N/A
#32	Swainson's hawk foraging habitat	At least 43,325	• Subset of #31. • May overlap with species-specific cultivated land requirements for other	0	N/A

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
			species. • Moderate, high, or very high value foraging habitat for Swainson's hawk, 50% of which is of very high value foraging habitat. See Table 3.4.3-3 for habitat values by crop type. • Up to 1,500 acres may be located in Conservation Zone 5 and 6, but must be at a land surface elevation at or greater than -1 foot (NAVD88).		
#33	Greater Sandhill Crane foraging habitat and cultivated lands roosting habitat	7,300 foraging habitat. 95 cultivated lands roosting habitat.	• Subset of #31. Foraging habitat: • May overlap with species-specific cultivated land requirements for other species. • High and very high value foraging habitat within 2 miles of a known roost site, 80% of which must be of very high value and 10% of which must be converted from a land cover type that is currently incompatible with greater sandhill crane foraging. • Reserve siting will consider the location of habitat loss and, if appropriate and feasible, be sited in proximity to that loss. • Reserve lands will be sited to minimize the potential effects of sea level rise by considering the land surface elevation of the site, the potential threat of catastrophic levee failure, and the resulting flooding of the reserve. They will also be sited to minimize the potential threat of seasonal flooding that is incompatible with management goals for the species. • See Table 3.4.3-3 for habitat values by crop	0	N/A

ID	Type	Protection		Restoration	
		Amount (Acres)	Location and Other Requirements	Amount (Acres)	Location and Other Requirements
			type. Cultivated lands roosting habitat: • Located within 2 miles of existing permanent roost sites. • Consist of active corn fields that are sequentially flooded following harvest to support roosting cranes and provide highest-value foraging habitat. • Individual fields will be at least 40 acres and can move throughout the Greater Sandhill Crane Winter Use Area. • Roosting habitat will be in place prior to removal of roosting habitat from construction of water conveyance facilities.		
#34	Tricolored blackbird, breeding season foraging habitat	At least 11,050	• Subset of #31. • May overlap with species-specific cultivated land requirements for other species. • High to very high value foraging habitat for breeding tricolored blackbird, within 5 miles of occupied or recently occupied (within the last 15 years) nesting habitat. • See Table 3.4.3-3 for habitat values by crop type.	0	N/A
#35	Tricolored blackbird, nonbreeding season foraging habitat	At least 26,300	• Subset of #31. • May overlap with species-specific cultivated land requirements for other species. • Moderate or higher value foraging habitat for wintering tricolored blackbird, 50% of which is of high or very high value. • See Table 3.4.3-4 for habitat values by crop type.	0	N/A
#36	Western	At least 1,000	• Subset of #31.	0	N/A

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
	burrowing owl habitat		• May overlap with species-specific cultivated land requirements for other species. • Pasture within 0.5 mile of grasslands, or within 0.5 mile of other burrowing owl habitat that is occupied by western burrowing owl.		
Other Species-Specific Requirements					
#37	Giant garter snake aquatic habitat "rice or equivalent" (Objective GGS1.4)	See "Restoration" column.	• See "Restoration" column.	1,500	• 1,500 acres of rice land or equivalent-value habitat (e.g., perennial wetland) will be protected, restored, and/or created for the giant garter snake in Conservation Zones 4 and/or 5 to meet Objective GGS1.4. • The rice protection may be a subset of the 48,625 acres of cultivated lands protection (#31) as long as all the other protection requirements for cultivated lands for covered species can still be met. • All or a portion of the 1,500 acres may consist of tidal freshwater emergent wetland, which will be a subset of #4 (24,000 acres of tidal freshwater emergent wetland restoration) if it meets specific giant garter snake habitat criteria as described in CM4 *Tidal Natural Communities Restoration*. • If nontidal marsh is restored to meet this 1,500-acre requirement, it will not be a subset of the 1,200 acres of restoration (#21). • Up to one-third of this requirement may be met by protecting or restoring giant garter snake upland habitat adjacent to restored or protected aquatic habitat. • All giant garter snake preserves will be established at least 2,500 feet from urban areas or areas zoned for urban development.
#38	Giant garter snake aquatic	See "Restoration"	• See "Restoration" column.	2,740	• 2,740 acres of rice land or equivalent-value habitat (e.g., perennial wetland) will be protected, restored,

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
	habitat "rice or equivalent" (Objective GGS3.1)	column.			and/or created for the giant garter snake in Conservation Zones 1, 2, 4, or 5 to meet Objective GGS3.1. • The rice protection may be a subset of the 48,625 acres of cultivated lands protection (#31) as long as all the other protection requirements for cultivated lands for covered species can still be met. • Up to 1,700 acres of the 2,740 acres may consist of rice fields in the Yolo Bypass if this portion will not experience high flow rates; includes high-ground refugia; and is occupied or is adjacent to occupied habitat. The intent is to focus this conservation acreage on the west side of the Yolo Bypass. • Up to 500 of the 2,740 acres may consist of tidal freshwater emergent wetland in the Cache Slough ROA, which will be a subset of #4 (24,000 acres of tidal freshwater emergent wetland restoration), if it meets specific giant garter snake habitat criteria as described in *CM4 Tidal Natural Communities Restoration*. • If nontidal marsh is restored to meet this 2,740-acre requirement, it will not be a subset of the 1,200 acres of restoration (#21). • Up to one-third of this requirement may be met by protecting or restoring giant garter snake upland habitat adjacent to restored or protected aquatic habitat. • All giant garter snake preserves will be established at least 2,500 feet from urban areas or areas zoned for urban development.
#39	Giant garter snake buffers and habitat expansion area in Conservation	700 acres, and additional as needed to establish Minimum 200-	• Minimum 200-foot-wide buffers will be established and protected between all protected giant garter snake nontidal marsh and roads (other than those roads primarily used to support adjacent	0	N/A

ID	Type	Protection: Amount (Acres)	Protection: Location and Other Requirements	Restoration: Amount (Acres)	Restoration: Location and Other Requirements
	Zone 2 outside the Yolo Bypass	foot-wide buffers	cultivated lands and levees). • 700 acres of cultivated lands will be protected in Conservation Zone 2 to serve as habitat and a buffer around created nontidal marsh. At least 500 of the 700 acres will be rice lands, and the remaining will be cultivated lands with irrigation and drainage channels capable of supporting giant garter snakes. • The buffer lands can be a subset of cultivated lands protection (#31). • The 200-foot buffer in Conservation Zone 2 can be a subset of the 700 acres. That is, the 700-acre target can include the buffer.		
#40	California black rail habitat	N/A	• N/A	1,700	• At the ecotone that will be created between restored tidal freshwater emergent wetlands and transitional uplands (Objectives L1.3 and TFEWNC1.1), provide California black rail habitat consisting of shallowly inundated emergent vegetation at the upper edge of the marsh (within 50 meters of upland refugia habitat) with adjacent riparian or other shrubs that will provide upland refugia, and other moist soil perennial vegetation.
N/A = not applicable					

Additional siting and reserve design considerations for natural communities that are not included in Table 3.4.3-1 are provided below.

Tidal Natural Communities

Lands will be secured to restore 65,000 acres of tidal natural communities, which will include a restored gradient of natural communities ranging from shallow subtidal aquatic to mudflat, emergent marsh plain, riparian (in suitable locations), and transitional uplands. Transitional uplands will include sufficient land to accommodate future upslope establishment of marsh plain vegetation expected to result from sea level rise. Lands will be secured by the Implementation Office to achieve the requirements for tidal natural communities described in Table 3.4.3-1. Additional siting and design criteria for tidal marsh restoration is provided in *CM4 Tidal Natural Communities Restoration*.

Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complexes

This community group is comprised of the grassland, alkali seasonal wetland complex, and vernal pool complex natural communities. Most of the grasslands and associated vernal pools and alkali seasonal wetlands will be secured in Conservation Zones 1, 8, and 11, although additional grasslands may be conserved in Conservation Zones 2, 4, and 7 to provide upland habitat for covered species. Lands will be secured by the Implementation Office to achieve the requirements for these natural communities described in Table 3.4.3-1. Additionally, acquisition of lands for protection or restoration will be prioritized based on the following characteristics.

- In Conservation Zones 1, 8, and 11, large contiguous landscapes that consist of grasslands, vernal pool complex, and alkali seasonal wetland complex and encompass the range of vegetation, hydrologic, and soil conditions that characterize these communities.
- In Conservation Zone 1, lands that provide opportunities to maintain habitat connectivity with protected grassland and vernal pool landscapes immediately adjacent to the Plan Area (e.g., Jepson Prairie Preserve) and with transitional uplands associated with tidal natural communities restored in the Cache Slough ROA.
- In Conservation Zone 8, lands that provide opportunities to maintain connectivity with protected grassland, vernal pool complex, and alkali seasonal wetland complex landscapes in and immediately adjacent to the Plan Area, including connectivity with lands that have been protected or may be protected in the future under the East Contra Costa HCP/NCCP.
- In Conservation Zone 11, lands that provide opportunities to for protection along the upland fringe of Suisun Marsh to maintain connectivity with much larger protected (e.g., Jepson Prairie Preserve) and unprotected grassland landscapes that are immediately adjacent to the conservation zone.
- Grasslands containing stock ponds and other aquatic features that provide aquatic breeding habitat for native amphibians (particularly California red-legged frog and California tiger salamander) and aquatic reptiles.
- Grassland restoration sites in locations that connect fragmented patches of protected grassland and locations that provide upland areas adjacent to riparian, tidal, and nontidal natural communities for wildlife foraging and upland refugia.

- Lands providing opportunities to protect a gradient of natural communities that range from grassland upland communities downslope to existing and restored tidal wetland communities. Vernal pool complexes in core recovery areas as identified in the *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (Vernal Pool Recovery Plan) (U.S. Fish and Wildlife Service 2005).
- Vernal pool sites that provide opportunities to protect the range of inundation characteristics that are currently represented by vernal pools throughout the Plan Area.

The Implementation Office will secure lands for restoration based on siting criteria described in *CM8 Grassland Natural Community Restoration* and *CM9 Vernal Pool Complex and Alkali Seasonal Wetland Complex Restoration.*

Cultivated Lands

Cultivated lands will be secured by the Implementation Office to achieve the requirements described in Table 3.4.3-1. Additionally, acquisition of lands for protection of cultivated lands will be prioritized based on the following characteristics.

- Effectiveness in contributing towards achieving multiple species-specific biological goals and objectives.
- Proximity to active Swainson's hawk nesting territories.
- Proximity to greater sandhill crane roost sites.
- Location of lands within the Greater Sandhill Crane Winter Use Area[14].
- Proximity to habitat occupied by the Coldani Marsh/White Slough and Yolo Basin/Willow Slough giant garter snake populations.
- Opportunities to incorporate riparian corridors into cultivated land reserves. Opportunities to protect small patches of important wildlife habitats associated with BDCP conserved cultivated lands, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant oak groves, riparian corridors, water conveyance channels, grasslands, and wetlands.
- Opportunities to maintain a mosaic of crop types to allow for the periodic rotation of essential crop types (those crop types with very high, high, and moderate foraging habitat values) to nonessential crop types to ensure acreage commitments (Table 3.3-2) are met.
- Cultivated lands that expand upon or provide connectivity between existing conservation lands.

Reserve Design Requirements by Species

Although the conservation needs for most of the covered species will be met through the natural community siting and reserve design requirements, additional species-specific protection and

[14] The Greater Sandhill Crane Winter Use Area is a geographic extent created by Gary Ivey specifically for BDCP planning purposes (Pogson and Lindstedt 1988; Littlefield and Ivey 2000; Ivey pers. comm.) (Figure 2A.19-2). This area is based on known, current distribution of greater sandhill cranes in the Plan Area. If future research informs an expanded winter use area, this will result in additional opportunity for preservation. If the winter use area contracts, the Implementation Office will confer with wildlife agency staff to determine what changes to future acquisitions are needed to meet the biological goals and objectives for this species, consistent with the adaptive management and monitoring program described in Section 3.6.

restoration requirements are necessary to ensure that conservation needs and regulatory standards are met for these key species. These requirements were designed to provide as much flexibility as possible while meeting the conservation needs of the species. Additional siting and reserve design considerations not included in Table 3.4.3-1 are provided below.

Riparian Brush Rabbit

Existing populations within the Plan Area occur in railroad rights-of-way that support suitable shrubs (e.g., the corridor north of the intersection of Interstates 5 and 205). These vegetated railroad rights-of-way can provide linear corridors to connect to river systems and large networks of suitable habitat through otherwise unsuitable agricultural zones. Reserve system connectivity may be facilitated through strategic protection and restoration of riparian brush rabbit habitat in proximity to such corridors.

Greater Sandhill Crane

The Implementation Office will secure and protect lands (per the location requirements described in Table 3.4.3-1) to be restored, enhanced, and/or managed as greater sandhill crane roosting and foraging habitat.

Greater sandhill crane foraging habitat values are described in Table 3.4.3-2.

Table 3.4.3-2. Greater Sandhill Crane Habitat Values

Foraging Habitat Value Class	Assigned Agricultural Crops/Habitats
Very high	Corn, rice
High	Alfalfa, irrigated pasture, wheat, managed wetland
Moderate	Other grain crops (barley, oats, sorghum), grasslands
Low	Other irrigated field crops, natural seasonal wetland, idle cropland

For a discussion of the enhancement and management requirements and considerations for greater sandhill crane roosting and foraging habitat see *CM11 Natural Communities Enhancement and Management.*

Swainson's Hawk

The Implementation Office will protect Swainson's hawk foraging habitat to meet the location requirements described in Table 3.4.3-1. Foraging habitat values for Swainson's hawk are described in Table 3.4.3-3.

Table 3.4.3-3. Swainson's Hawk Habitat Values

Foraging Habitat Value Class	Assigned Agricultural Crops/Habitats
Very high	Alfalfa
High	Native pasture, undifferentiated pasture, mixed pasture, clover, miscellaneous grasses (grown for seed), sugar beets, tomatoes, grain and hay, annual grasslands, vernal pool grasslands, alkali grasslands
Low	Broccoli, sudan, dry beans, undifferentiated field crops, asparagus, green beans, cole crops, carrots, melons/squash/cucumbers, onions/garlic, peppers, cabbage, undifferentiated truck and berry crops, artichokes, lettuce (all types), spinach, mixed truck and berry
Marginal	Safflower, corn, grain sorghum, sunflower

Tricolored Blackbird

The Implementation Office will protect lands to be restored, enhanced, or managed as nesting, foraging and winter roosting habitat for tricolored blackbird to meet the location requirements described in Table 3.4.3-1. Foraging habitat values for tricolored blackbird are described in Table 3.4.3-4.

Table 3.4.3-4. Tricolored Blackbird Foraging Habitat Value Classes

Foraging Habitat Value Class	Agricultural Crop Type/Habitat	
	Breeding Season[a] Foraging Habitat	Nonbreeding Season Foraging Habitat
Very high	Native pasture, nonirrigated native pasture, annual grasslands, vernal pool grasslands, alkali grasslands	Livestock feed lots
High	Sunflower, alfalfa and mixed alfalfa, mixed pasture, induced high water table native pasture, nonirrigated mixed pasture, dairies	Corn, sunflower, millet, alfalfa and mixed alfalfa, mixed pasture, native pasture, induced high water table native pasture, nonirrigated native pasture, rice, dairies, annual grasslands, vernal pool grasslands, alkali grasslands
Moderate	Miscellaneous grass pasture, fallow lands cropped within 3 years, new lands prepped for crop production, livestock feed lots	Miscellaneous grass pasture, nonirrigated mixed pasture, fallow lands cropped within 3 years, new lands prepped for crop production
Low	Wheat, mixed grain and hay, farmsteads	Wheat, oats, mixed grain and hay, farmsteads
Marginal	Rice	None
None	All remaining crop types	All remaining crop types

[a] Generally March through August; occasional breeding in fall (September through November).

Giant Garter Snake

In addition to the siting requirements described in Table 3.4.3-1, giant garter snake habitat needs will be considered when establishing a reserve system along the eastern edge of the Plan Area (Conservation Zones 4 and 5) to create connections north from the White Slough population to other areas in the giant garter snake's historical range. The 600 acres of nontidal marsh and 1,500 acres of rice land or equivalent to be protected, restored, and/or created in this area (Objectives GGS1.1 and GGS1.4) will be integrated into a large, interconnected reserve system, including cultivated lands, to provide habitat buffers and irrigation and drainage channels[15] to accommodate giant garter snake movement. Existing water bodies may be integrated into the reserve system to provide "stepping stones" of aquatic giant garter snake habitat from the White Slough population northward. In this way, the 2,100 acres of habitat to be conserved for the giant garter snake in Conservation Zones 4 and 5 can be configured both to serve as a large core habitat area and to provide connectivity along the eastern edge of the Plan Area.

Preacquisition Surveys and Assessments

The Implementation Office will develop and implement protocols for assessing lands being considered for acquisition. Preacquisition surveys will be conducted by qualified biologists and other qualified scientists or technical experts as appropriate under agreements with the landowners. Surveys will assess the physical and biological attributes of the lands and the extent to which acquisition would meet the BDCP biological goals and objectives and the siting and design criteria and considerations described above. Surveys will also identify natural communities and covered species present or potentially present on the lands, for which measures provided in Appendix 3.C, *Avoidance and Minimization Measures*, would apply.

3.4.3.4 Natural Communities Restoration Implementation

This section describes actions related to the development of site-specific plans for restoration projects, and describes restoration projects that have been implemented in and around the Plan Area in the past. Additional restoration requirements for each natural community type are provided in CM4 through CM10.

Restoration projects will be developed consistent with the relevant conservation measures for each natural community (CM4 through CM10). Restoration design will consider historical conditions in the Delta, based on information provided in *Sacramento-San Joaquin Delta Historic Ecology Investigation: Exploring Pattern and Process* (Whipple et al. 2012).

3.4.3.4.1 Past Restoration Implementation

The feasibility of implementing natural communities restoration is evidenced by similar restoration projects that have been successfully implemented in the past. Table 3.4.3-5 describes some of natural community restoration projects that have been successfully implemented in and around the Plan Area over the last 30 years.

Table 3.4.3-5 lists 43 restoration projects across the following seven natural community types found in the Plan Area: riparian, grassland, vernal pool complex, floodplain, tidal brackish emergent wetland, tidal freshwater emergent wetland, and nontidal marsh. The restoration efforts range in size from a small 1-acre project to a large multiphase project consisting of 46,000 acres of riparian and floodplain restoration. The 43 projects comprise over 80,000 total acres of restoration. Many of the projects are relatively young with implementation occurring within the past 10 years; however, monitoring programs to date indicated that the majority of the projects have been successful based on success criteria specific to each restoration project.

[15] The irrigation ditches are often owned by a water district and their water levels can vary greatly. Drainage ditches are more often privately owned and water levels are more consistent, therefore they are generally better for providing giant garter snake habitat. Drainage ditches are also easier to manage for giant garter snake habitat than irrigation ditches.

1 **Table 3.4.3-5. Examples of Restoration Projects Implemented in and around the Plan Area, Sorted by Primary Natural Community**

Project Name	Location	In Plan Area	Restoration Initiation Date	Natural Community Type(s)	Amount Restored	Project Sponsors	Monitoring Program	Results
Riparian Restoration								
San Joaquin River Restoration	San Joaquin River, confluence with Merced River		2009	Riparian Corridor/River Channel	153 miles of river corridor and channel improvements	San Joaquin River Restoration Fund (Public Law 111-11)	As part of the San Joaquin River Restoration Program, the physical and biological effects of flows are monitored along the San Joaquin River from Friant Dam to the confluence of the Merced River.	Reintroduction of Chinook salmon is scheduled for late 2012–early 2013.
San Joaquin National Wildlife Refuge	Grayson		2002	Riparian	2,350 acres	River Partners	Monitoring is conducted by multiple federal, state, and local agencies, as well as local universities, schools, and environmental groups.	In 2005, a pair of least Bell's vireos successfully bred twice in a 3-year-old riparian restoration site at the San Joaquin River National Wildlife Refuge, the first confirmed record of this species breeding in the Central Valley in over 50 years.
Cosumnes River Project	Galt	✓	1987	Riparian/ Floodplain	46,000 acres	The Nature Conservancy	Monitoring is conducted by multiple federal, state, and local agencies, as well as local universities, schools, and environmental groups.	In restored habitat, population trends for the 22 species covered by the project were generally positive. The river supports Chinook salmon. The rare giant garter snake makes its home in marshes and uplands as well as several nesting pairs of threatened Swainson's hawk. There have been rare sightings of the least Bell's vireo.
Sacramento River Restoration	Sacramento County		1988	Riparian	6,000 acres	The Nature Conservancy	Monitoring is conducted by multiple federal, state, and local agencies, as well as local universities, schools, and environmental groups.	Collectively, riparian restoration along the Sacramento River has been successful in restoring a broad suite of faunal species. Restoration projects have been successful in providing habitat for special-status species (e.g., valley elderberry longhorn beetle, yellow-billed cuckoo, western red bat).
San Joaquin County Habitat Conservation Plan Implementation	San Joaquin County	✓	2000	Riparian	105 acres	San Joaquin County and all cities in County; USFWS, CDFW	San Joaquin Council of Governments is responsible for the implementation of the HCP, which includes compliance, performance, and biological monitoring.	The plan covers 97 species, including several species that use riparian habitat. Over 6,000 riparian plant species were planted in 2011–2012 to support species that are dependent on or use riparian habitat including the valley elderberry longhorn beetle, Swainson's hawk, and white-tailed kite.
Parkway at Blue Raven Phase I	Sacramento County		1994	Riparian	42 acres		Not available	Not available
Coyote Creek 1	Santa Clara County		1994	Riparian	8 acres		Multiple agencies and groups have monitored the restoration at Coyote Creek. The Avian Research Program operates 12 nets in each habitat once a week for a standard 5-hour period. These bird data have been used in conjunction with vegetation data to assess the success of the restoration sites, make management recommendations, and study the general use of an urban riparian site. The ultimate goal is to monitor the site for at least the next 40 years to document changes in the avian populations over time as the site matures.	By April 1998, the Avian Research Program banded almost 84,000 birds (and recaptured approximately 54,000) of almost 170 species.
Sacramento Urban Area Levee Reconstruction Project, Mitigation Planting and Maintenance	Sacramento County		1995	Riparian	49.7 acres	Sacramento Area Flood Control Agency	Not available	Not available
Coyote Creek 2	Santa Clara		1995	Riparian	22 acres	Not available	Not available	Not available
Willow Creek	Sacramento County		1996	Riparian/ upland	42 acres	Not available	Not available	Not available
Guadalupe Creek	Santa Clara County	✓	2001	Riparian/ upland	20.4 acres	Santa Clara Valley Water District	Not available	Not available

Project Name	Location	In Plan Area	Restoration Initiation Date	Natural Community Type(s)	Amount Restored	Project Sponsors	Monitoring Program	Results
Jensen River Ranch	Fresno County		2001	Riparian/ upland/ wetland	160 acres	San Joaquin River Conservancy, the City of Fresno, and the California Department of Water Resources	Not available	Not available
West Sacramento Levee Project—Sacramento River	Yolo County		2001	Riparian/ upland	78 acres	City of West Sacramento	Not available	Not available
Del Paso Park	Sacramento, County		2004	Riparian/ wetland/ upland	13.6 acres	City of Sacramento, Parks and Recreation	Not available	Not available
Miners Ravine	Placer County		2005	Riparian/ wetland/ upland	20.5 acres	State Water Resources Control Board; Placer County	Several monitoring programs have been established since completion of the Miners Ravine Restoration Project, including water quality, data collection, fish populations, and stream health.	Thirty avian species and ten mammalian species were identified in riparian habitat. Birds included scrub jay, mourning dove, Anna's hummingbird, bushtit, Bewick's wren, American robin, golden-crowned sparrow, house finch, great horned owl, red-shouldered hawk, northern flicker, yellow-bellied magpie, and ring-necked pheasant. Mammals included western harvest mouse, California vole, house mouse, deer mouse, black rat, river otter, raccoon, and western gray squirrel, and blacktail jackrabbit.
TOTAL[a]					**54,911.2 acres + 153 miles**			
Grassland Restoration								
Mori Point Restoration Project	Pacifica		2006	Grassland/ coastal scrub/ wetlands	1,110 acres	U.S. National Park Service	Monitoring is conducted by multiple federal, state, and local agencies, as well as local universities, schools, and environmental groups.	California red-legged frog and giant garter snake have been observed at Mori Point after intensive restoration efforts.
Edgewood Park and Nature Preserve	Redwood City		1993	Grassland/ woodland	467 acres	County of San Mateo Division of Parks	Monitoring is conducted by multiple federal, state, and local agencies, as well as local universities, schools, and environmental groups.	The Bay checkerspot butterfly, once an inhabitant of the entire Bay Area and now listed as an endangered species, is found only in this park, in Kirby Canyon in southern Santa Clara County, Coyote Ridge in San Jose, and San Bruno Mountain State and County Park in northern San Mateo County.
Yolo County Grassland Regional Park	Yolo County	✓	1972	Grasslands/ vernal pool	184 acres	Yolo County Parks	Monitoring is conducted by multiple federal, state, and local agencies, as well as local universities, schools, and environmental groups.	The park provides ongoing inventory and management of endangered species. The site contains vernal pools, seasonal wetlands, and grasslands that provide vital habitat for a variety of plants and wildlife, including state and federally protected species such as vernal pool fairy shrimp, Swainson's hawk, and one of the last known populations of Solano grass.
Stone Lakes National Wildlife Refuge	Elk Grove	✓	1994	Grassland/ wetland/ riparian	6,000 acres	USFWS	A variety of surveys and studies have been conducted by USFWS staff, volunteers, and students on the refuge since its establishment. These studies are primarily intended to evaluate the effectiveness of the management activities and monitor the status of biological resources.	Nearly 6,000 acres have been restored within the refuge and now provide habitat for such wildlife as sandhill crane, burrowing owl, and giant garter snake. As part of refuge management, USFWS has initiated a grazing program using cattle to reduce fire danger and encourage native grasses. These restored grasslands now support foraging habitat for migratory birds such as sandhill crane, Swainson's hawk, and geese and waterfowl on the North Stone Lake property. Grazed grasslands have also opened habitat for raptors and snakes in search of small rodents and created potential burrowing owl sites.
TOTAL[b]					**7,761 acres**			

Project Name	Location	In Plan Area	Restoration Initiation Date	Natural Community Type(s)	Amount Restored	Project Sponsors	Monitoring Program	Results
Vernal Pools								
Del Sol Open Space and Vernal Pool Reserve	Isla Vista		1997	Vernal pool	12 acres	Isla Vista Recreation and Park District	To help evaluate the construction and revegetation portions of the Del Sol Vernal Pools Enhancement Plan, a 2-year postconstruction monitoring program was implemented that included studies of the physical environment, flora, and vegetation. Postconstruction activities included developing a topographic map, recording the extent and duration of flooding patterns, taking inventory of the flora, recording plant cover, determining plant species abundance indices, and qualitatively assessing invertebrate and vertebrate animal use of the wetlands.	Results in 2007 concluded that a decade of preconstruction and postconstruction habitat monitoring data suggest that the enhanced, restored, recreated, and created-inoculated vernal pools are self-sustaining and provide a broad array of ecosystem functions similar to those of naturally occurring vernal pools. These functions include, for example, the establishment of wetland hydrology, habitat for native plants and animals, habitat for sensitive species, food chain support, and the roles of vernal pools in grassland ecosystems.
USFWS Vernal Pool Restorations in California	Placer, Sacramento, and Butte Counties	✓	1987	Vernal pool	1,500 total pools	USFWS	USFWS monitored intact natural vernal pools as reference pools. These reference pools were used to assess the overall success of construction techniques and maintenance practices and determine if the pools were recovering on their own.	Vernal pool ecosystems in Placer, Sacramento, and Butte Counties have shown significant recovery as a result of USFWS restoration efforts. USFWS learned about the fragility of vernal pool habitat and construction of these shallow, saucer-like, ephemeral ponds.
Yolo County Grassland Regional Park	Yolo County	✓	1972	Vernal pool/ grassland	184 acres	Yolo County Parks	Monitoring is conducted by multiple federal, state, and local agencies, as well as local universities, schools, and environmental groups.	The park provides ongoing inventory and management of endangered species. The site contains vernal pools, seasonal wetlands, and grasslands that provide vital habitat for a variety of plants and wildlife, including state and federally protected species such as vernal pool fairy shrimp, Swainson's hawk, and one of the last known populations of Solano grass.
Storke Ranch Vernal Pool Restoration	Goleta		2006	Vernal pool	12 acres	Storke Ranch Home Owners Association	Ongoing monitoring is conducted by homeowners association: annual monitoring of hydrology, bird use, and vernal pool vegetation for 5 years.	Excavated to restore two vernal pools, inoculated pools with material from established pools, removed weeds, planted native plants around the edges of the pools, and restored a portion of the buffer area with coastal scrub and oak woodland species.
Teichert's Aspen Complexes	Sacramento	✓	1998	Vernal pool complex	15 acres	A. Teichert & Son	A monitoring program was established to assess the establishment and continued maturation of restored vernal pools. Performance standards were used to measure restoration success during the monitoring period.	Not available
Placer County Vernal Pools and Seasonal Wetlands at Lincoln	Placer County		1998	Vernal pool complex/ seasonal wetland	25 acres	Placer County Community Resources	A monitoring program was established to assess the establishment and continued maturation of restored vernal pools. Performance standards were used to measure restoration success during the monitoring period.	Not available
Gridley Mitigation Bank	Sacramento County	✓	2005	Vernal pool complex	1 acres		Monitoring is conducted local agencies, as well as local universities, schools, and environmental groups.	Vernal pools dominated by vernal pool vegetation; difficult to establish pool boundary due to gradual transition of pool edge from upland grasses to wetland vegetation.
TOTAL[c]					**249 acres + 1,500 pools**			
Floodplain								
Lower Carmel River Floodplain Restoration Project	Monterey County		2004	Floodplain	128 acres	California Coastal Conservancy, California Department of Parks and Recreation	Monitoring and assessment of project success is conducted by the Big Sur Land Trust with partner agencies including Monterey County Water Resources Agency, Monterey Peninsula Water Management District, Monterey Peninsula Regional Park District, California State Parks, and Cal Trans.	Not available

Project Name	Location	In Plan Area	Restoration Initiation Date	Natural Community Type(s)	Amount Restored	Project Sponsors	Monitoring Program	Results
Lower Tuolumne River Floodplain Restoration	Stanislaus County	✓	2004	Floodplain		U.S. Fish and Wildlife Service's Anadromous Fish Restoration Program, CALFED	A river-wide and site-specific monitoring program was developed for the project. The river-wide component assesses large-scale processes, characteristics, and trends, providing information necessary to evaluate the overall effectiveness of flow and nonflow management measures. The site-specific component evaluates and measures the success of specific restoration projects.	In the most recent evaluation report, monitoring efforts detected 2,817 fall-run Chinook salmon during 2011, a substantial increase over the previous 2 years. Although there were no apparent relationships between migration timing and turbidity or dissolved oxygen, there appeared to be an increase in passage once temperature decreased below 60°F. These temperature decreases coincided with a small increase in flow due to managed pulse-flow releases for fall-run Chinook salmon migration attraction. There also appeared to be an increase in passage in relation to very small peaks (i.e., fluctuations) in flow. However, the total catch in 2011 was only half of that in 2006, despite the abbreviated sampling during that year. The variation in catch during 2006 is likely due to environmental conditions, specifically high flows that averaged approximately 5,300 cubic feet per second during the juvenile migration season (i.e., January–May/June) and the higher overall abundance.
Napa River Floodplain Restoration Project	Napa County		2002	Floodplain	1,000 acres	U.S. Army Corps of Engineers, Sacramento District; Napa County Flood Control District; Napa County Resource Conservation District	The Napa River Fisheries Monitoring Program was implemented along 11.1 kilometers (6.9 miles) of the Napa River to determine fish use on and near the enhanced wetland and floodplain habitats created as a result of the Napa River Floodplain Restoration Project.	The fisheries monitoring program has documented that restoration of the area is providing habitat for native and nonnative species. The sampling program to date (March 2001 to July 2002, January 2003 to July 2003, March 2004 to July 2004, March 2005 to July 2005) has documented use of the project area by 74,952 larval, juvenile, and adult fish of 37 species. The number of fish captured varied widely between sampling sites in the project area. In 2001, inland silversides dominated the catch in recently created/restored areas. In 2002, over 3,000 young-of-the-year Pacific herring were captured in created/restored habitats. In July 2003, an increase of striped bass and threadfin shad dominated the catch in created/restored and nonrestored sites. Comparatively, in June–July 2004 and May–June 2005, Sacramento splittail were the most abundant native fish captured in the same created/restored habitats. Results to date indicate that juvenile Sacramento splittail abundance is positively correlated with salinity in created/restored habitat; juvenile Sacramento splittail were more abundant in shallow created/restored habitat than surrounding deep nonrestored habitat; juvenile Sacramento splittail were found to have a greater abundance in created marsh plain habitat than in restored floodplain habitat; striped bass have a seasonal distribution, and their abundance is positively correlated with salinity; and interannual variability exists with inland silverside, threadfin shad, Pacific herring, and Sacramento splittail.
Merced River Corridor Floodplain Restoration	Merced County		2006	Floodplain	318 acres	CDFW, CALFED	The monitoring program addresses project implementation activities (i.e., does the implementation match the design?), effectiveness (i.e., did the project recover conditions suitable for salmonid rearing and spawning?), and validation of project actions (i.e., was productive habitat for salmonids and native riparian vegetation created by the project?). Monitoring activities include topography/bathymetry surveys, monitoring flow and flooding inundation, physical conditions (i.e., temperature, dissolved oxygen, turbidity), biological conditions (i.e., fish use, macroinvertebrate abundance and composition, fish diets and growth potential), among other evaluations.	Since project implementation, the channel has been rescaled to match current flows on the Merced River; periodic overtopping of banks and inundation of adjacent floodplain has occurred; the quantity and quality of spawning and rearing habitat for native salmon and trout have improved as a result of adding coarse sediment to the channel, balancing sediment supply with sediment transport capacity, creating new bars and riffles, and reducing riparian encroachment; and the area of high-value habitat for terrestrial wildlife has increased.
TOTAL[d]					**1,446 acres**			

Project Name	Location	In Plan Area	Restoration Initiation Date	Natural Community Type(s)	Amount Restored	Project Sponsors	Monitoring Program	Results
Tidal Brackish Emergent Wetland								
Blacklock Restoration Project	Suisun Marsh	✓	2005	Tidal brackish emergent wetland	70 acres	DWR in cooperation with CDFW, Reclamation, USFWS, and Suisun Resource Conservation District	The 10-year monitoring period consists of the following components: inundation regime, levee breach geometry, sedimentation, channel network evolution, native marsh vegetation development, wildlife surveys, fish surveys (pending additional secured funding), water quality, methylmercury, erosion of adjacent sloughs, and control of invasive plant species.	The levee has been breached, and a 10-year monitoring program has been initiated. Results are not yet available.
South Bay Salt Pond Restoration Project	South San Francisco Bay	✓	2003	Tidal brackish emergent wetland	15,100 (total)	USFWS, CDFW	Water quality monitoring occurs at the Alviso Pond Complex and Ravenswood Pond. Fisheries monitoring occurs at the Phase I project sites. Two-year bird monitoring at Alviso, Eden Landing, and Ravenswood complexes was completed in 2006. Waterbird nest monitoring was conducted from 2005 to 2010. Western snowy plover monitoring occurred at Eden Landing Ecological Reserve in 2011. Additional studies will begin in 2012.	Three ponds totaling 630 acres in the Eden Landing Ecological Reserve were breached to restore tidal connection. The first of eight tide gates at Alviso Pond was opened to allow tides into this 400-acre area. The Island Ponds, tidally restored in 2006, are developing habitat faster than expected. The native salt marsh plants will eventually provide habitat for endangered species such as California clapper rail and salt marsh harvest mouse. Shorebirds nested at newly constructed Ravenswood Pond nesting islands.
Marin Islands National Wildlife Refuge	San Pablo Bay		2002	Tidal brackish emergent wetland	339 acres (total)	USFWS	USFWS currently manages the onsite egret and heron rookery and will eventually remove artificial facilities from east Marin Island.	Onsite egret and heron rookery. Future restoration of the sites includes removal of invasive vegetation and restoration of marsh plants and nesting trees.
Santa Venetia Marsh	San Rafael		2006	Tidal brackish emergent wetland	33 acres (total)	Marin Open Space and Park District	Save the Bay monitors for plant survival.	The salt marsh reappeared following a levee breach and now pickleweed and saltgrass are present. The surrounding area is a patchwork of channels, marshland, and flood control lands that are inhabited by many bird species and other mammals.
Tolay Creek	Sonoma County		1997	Tidal brackish emergent wetland	435 acres	USFWS, CDFW	Five-year continuous water quality sampling and the following prebreach-postbreach surveys: channel morphology, slough length, levee erosion, sediment composition and content, vegetation establishment, invertebrate foodweb analysis, fish, bird and small mammal.	Monitoring and evaluation results suggest that this restoration project has been highly successful in reaching its goals.
TOTAL[e]					**15,977 acres**			
Tidal Freshwater Emergent Wetland								
Liberty Island Conservation Bank	Southern Yolo Bypass	✓	2010	Tidal freshwater emergent wetland	165.7 acres (34.22 acres of tidal emergent marsh)	Wildlands Inc.	Monitoring of emergent marsh vegetation is for scheduled for years 1, 3, and 5 and will include aerial photographic documentation and analysis as well as visual boat surveys of the emergent marsh vegetation.	The island already supports significant existing wildlife and has outstanding potential for restoration, floodplain management, and endangered species recovery. Future restoration plans for Liberty Island are envisioned to be passive restoration approaches that would allow wetland and riparian vegetation to establish naturally.
Decker Island Habitat Enhancement Project	Solano County	✓	2000 (Phase I), 2004 (Phase II)	Tidal freshwater emergent wetland	13.5 acres (Phase I), 12 acres (Phase II)	DWR, CDFW	Fish monitoring by CDFW and bird monitoring by DWR	This project recreated habitat that existed prior to dredging the Sacramento River and provided material necessary for levee reinforcement on several western Delta islands. Some hardy upland plant species are doing well, but many of the overstory tree plantings do not appear to be successful. The rest of the 470-acre island is fallow, and DWR has plans to acquire the land and continue restoration efforts at the site. The project site is relatively free of invasive species, presumably because of active maintenance.
Cosumnes River Floodplain Bank	Galt		2010	Tidal freshwater emergent wetland	493 acres (total bank)	Westervelt Ecological Services	The 5-year monitoring program beginning in 2012 will evaluate the progress of the habitat establishment and focus on functions that are normally associated with floodplain wetlands.	Project is currently in monitoring phase; results are not yet available.

Project Name	Location	In Plan Area	Restoration Initiation Date	Natural Community Type(s)	Amount Restored	Project Sponsors	Monitoring Program	Results
Camp 2 Wingo Unit Marsh Restoration	Napa and Sonoma County		2003	Tidal freshwater emergent wetland	608	North American Wetlands Conservation Act Grant	CDFW maintains the pond throughout the summer to provide waterfowl brood rearing habitat, and also to maintain mosquito fish as mosquito larvae predators.	Completed, but flooding of the Camp 2 Unit from Sonoma Creek will necessitate rehabilitation of the restoration sites.
TOTAL[f]					**1,160.72 acres**			
Nontidal Wetlands								
Natomas Basin Habitat Conservation Plan	Sacramento and Sutter County		1997	Nontidal wetlands/ managed wetlands	8,750 acres	City of Sacramento, Sacramento County and Sutter County	The Natomas Basin Conservancy, the nonprofit entity responsible for implementing this HCP, hired a team to conduct biological effectiveness monitoring, document the progress made toward meeting the biological goals and objectives of the HCP, and inform the adaptive management strategy.	In the 2010 annual report, 149 giant garter snake captures were recorded in the reserve system.
Coyote Hills Wetlands Enhancement and Drainage Improvement Project	Fremont		2003	Managed wetlands	500 acres	Alameda County Public Works Agency; East Bay Regional Park District	The monitoring program is designed to document habitat features and monitor changes at ecological reference sites that serve as models for habitat restoration. Tiered levels of monitoring focus the most statistically rigorous monitoring on the most sensitive species. College and high school students implement scientific monitoring programs.	The restoration goal is to create types of fresh-brackish perennial marsh with high potential suitability for native key species of concern including the California red-legged frog, western pond turtle, and California black rail. No results available.
Butte Sink Wildlife Management Area	Butte and Sutter County		1980	Seasonal and permanent nontidal wetlands	10,987 acres	USFWS	Major refuge objectives are to provide feeding and resting habitat for wintering waterfowl; provide habitat and management for endangered, threatened, or sensitive species of concern; protect and provide habitat for neotropical migratory land birds; preserve a natural diversity and abundance of flora and fauna; and alleviate crop depredation.	The Butte Sink typically supports wintering populations of over 300,000 ducks and 100,000 geese.
Bufferlands Upper Beach Lake Wildlife area	Sacramento County		1995	Managed wetlands	550 acres	Sacramento Regional Sanitary District	Monitoring is conducted by local agencies, local universities, schools, and environmental groups.	With a varied mix of upland and wetland habitats, the Bufferlands has become an important wildlife area, supporting over 200 species of birds, 20 species of native mammals and several native fish, amphibians, and reptiles. The Bufferlands is also home to more than 20 species of rare plants and animals, including several threatened and endangered species including Swainson's hawk, vernal pool fairy shrimp, and giant garter snake.
TOTAL[g]					**20,787 acres**			

CDFW = California Department of Fish and Wildlife
DWR = California Department of Water Resources
HCP = habitat conservation plan
Reclamation = Bureau of Reclamation
USFWS = U.S. Fish and Wildlife Service

[a] Total acreage includes some natural communities other than riparian.
[b] Total acreage includes some natural communities other than grassland.
[c] Total acreage includes some natural communities other than vernal pools.
[d] Total acreage includes some natural communities other than floodplain.
[e] Total acreage includes some natural communities other than tidal brackish emergent wetland.
[f] Total acreage includes some natural communities other than tidal freshwater emergent wetland.
[g] Total acreage includes some natural communities other than nontidal wetlands.

3.4.3.4.2 Site-Specific Restoration Plans

Restoration will be implemented consistent with site-specific plans for each project. Each site-specific plan will be prepared by a qualified restoration ecologist familiar with the natural communities in the Plan Area, and will include the following elements.

- A description of the hydrology, topography, soils/substrate, and vegetation for the existing condition of the site, and the anticipated condition of the restored site.
- Applicable biological goals and objectives to which the restoration would contribute.
- Success criteria for determining whether the desired condition for the restoration has been met.
- An implementation plan and schedule that describes site preparation, plantings and seeding (including planting palettes), and irrigation, as applicable.
- Applicable avoidance and minimization measures as described in Appendix 3.C, *Avoidance and Minimization Measures.*
- A description of maintenance activities and a maintenance schedule to be implemented until success criteria are met.
- A description of contingency measures to be implemented if success criteria are not met within the established monitoring timeframe.

These contingency measures will differ from adaptive management described in Section 3.6, *Adaptive Management and Monitoring Program*. These measures will be site-specific and will be targeted specifically toward meeting the success criteria indicated in the site-specific restoration plan.

3.4.3.5 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance monitoring as described in Section 3.6, *Adaptive Management and Monitoring Program*. Compliance monitoring will be conducted in association with natural communities protection and will consist of documenting in a GIS database the extent of natural communities, species habitats, and plant occurrences protected and restored. Natural communities will be considered successfully restored when they meet the success criteria specified in site-specific restoration plans (Section 3.4.3.4.2, *Site-Specific Restoration Plans*). Effectiveness monitoring of restoration is addressed in CM4 through CM10.

3.4.3.6 Consistency with the Biological Goals and Objectives

CM3 will advance the biological goals and objectives as identified in Table 3.4.3-6. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Table 3.4.3-6 also identifies the monitoring actions associated with each objective as it relates to CM3.

1 **Table 3.4.3-6. Biological Goals and Objectives Addressed by CM3 and Related Monitoring Actions**

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
Goal L1: A reserve system with representative natural and seminatural landscapes consisting of a mosaic of natural communities that is adaptable to changing conditions to sustain populations of covered species and maintain or increase native biodiversity.		
Objective L1.1: Protect or restore 142,200 acres of high-value natural communities and covered species habitats.	Natural communities will be protected to achieve protection acreage targets (Table 3.3-2). The siting criteria in Section 3.4.3.3.2, *Siting and Reserve Design*, and the natural community biological goals and objectives direct the Implementation Office to protect the highest quality natural communities and covered species habitats.	Compliance monitoring
Objective L1.2: Protect sufficient lands for the restoration of natural communities as described in Objective L1.1.	Lands will be secured for restoration to achieve restoration acreage targets for each natural community (Table 3.3-2). The siting criteria in Section 3.4.3.3.2, *Siting and Reserve Design*, and the natural community biological goals and objectives provide parameters and criteria for securing appropriate lands to meet the restoration-related biological objectives.	Compliance monitoring
Objective L1.3: Restore and protect 65,000 acres of tidal natural communities and transitional uplands to accommodate sea level rise. Minimum restoration targets for tidal natural communities in each ROA are 7,000 acres in Suisun Marsh ROA, 5,000 acres in Cache Slough ROA, 1,500 acres in Cosumnes/Mokelumne ROA, 2,100 acres in West Delta ROA, and 5,000 acres in South Delta ROA.	Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Tidal Natural Communities* provides the criteria for siting lands to secure for tidal restoration consistent with this objective. Section 3.4.3.4.2, *Site-Specific Restoration Plans,* describes the necessary components for site-specific restoration plans to meet this objective. Additional tidal restoration actions are described in *CM4 Tidal Natural Communities Restoration*.	Compliance monitoring
Objective L1.4: Include a variety of environmental gradients (e.g., hydrology, elevation, soils, slope, and aspect) within and across a diversity of protected and restored natural communities.	The reserve system will be distributed over a majority of the 11 conservation zones, capturing a variety of hydrologic, elevation, soil, slope, and aspect conditions across a diversity of natural communities. Sites will be selected for protection based partially on their potential to preserve natural environmental gradients (Section 3.4.3.3.2, *Siting and Reserve Design*). Restored tidal natural communities will include a gradient ranging from shallow subtidal aquatic, to mudflat, emergent marsh plain, riparian (in suitable locations), and transitional uplands (Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group*, *Tidal Natural Communities*, and *CM4 Tidal Natural Communities Restoration*). Grasslands and associated vernal pool and alkali seasonal wetland complex will be protected in large, contiguous landscapes encompassing the range of vegetation, hydrologic, and soil conditions that characterizes these communities (Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and*	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
	Associated Vernal Pool and Alkali Seasonal Wetland Complexes).	
Objective L1.5: In restored floodplains, provide a range of elevations that transition from frequently flooded (e.g., every 1 to 2 years) to infrequently flooded (e.g., every 10 years or more) areas to provide a range of habitat conditions, upland habitat values, and refugia from flooding during most flood events.	When securing lands for floodplain restoration, sufficient land will be protected to provide a range of elevations consistent with this objective. See also *CM5 Seasonally Inundated Floodplain Restoration.*	Compliance monitoring
Objective L1.6: Increase the size and connectivity of the reserve system by acquiring lands adjacent to and between existing conservation lands.	When securing lands for restoration or protection, priority will be given to lands adjacent to and between existing conservation lands, within and adjacent to each conservation zone (Section 3.4.3.3.2, *Siting and Reserve Design*).	Compliance monitoring
Objective L1.7: Within the 65,000 acres of tidal natural communities and transitional uplands (Objective L1.3), include sufficient transitional uplands along the fringes of restored brackish and freshwater tidal emergent wetlands to accommodate up to 3 feet of sea level rise where possible and allow for the future upslope establishment of tidal emergent wetland communities that might be needed after the permit term.	When securing lands for tidal restoration, sufficient lands will be included to accommodate 3 feet of sea level rise (included in the 65,000-acre total). A 200-foot-wide swath adjacent to tidally restored areas will be maintained as upland habitat, as described further in *CM4 Tidal Natural Communities Restoration*.	Compliance monitoring
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.		
Objective L2.1: Allow floods to promote fluvial processes, such that bare mineral soils are available for natural recolonization of vegetation, desirable natural community vegetation is regenerated, and structural diversity is promoted, or implement management actions that mimic those natural disturbances.	Sufficient lands will be acquired and protected to accomplish this objective, as described in Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Seasonally Inundated Floodplain and Riparian Natural Community*, and under *CM5 Seasonally Inundated Floodplain Restoration.* Sufficient lands will be acquired and protected to accomplish this objective, as described in Table 3.4.3-1 and *CM5 Seasonally Inundated Floodplain Restoration.* See also *CM5 Seasonally Inundated Floodplain Restoration.*	Compliance monitoring
Objective L2.2: Allow lateral river channel migration.	Sufficient lands will be acquired and protected to accomplish this objective, as described in Table 3.4.3-1 and *CM5 Seasonally Inundated Floodplain Restoration.* See also *CM5 Seasonally Inundated Floodplain Restoration.*	Compliance monitoring
Objective L2.3: Connect rivers and their floodplains to allow input of large woody debris, leaves, and other organic material to rivers.	Sufficient lands will be acquired and protected to accomplish this objective, as described in Table 3.4.3-1 and *CM5 Seasonally Inundated Floodplain Restoration.*	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
Goal L3: Capacity for movement of native organisms and genetic exchange among populations necessary to sustain native fish and wildlife species in the Plan Area.		
Objective L3.1: Protect and improve habitat linkages that allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area.	Sites will be selected based on their level of contribution to connectivity between existing conservation lands (Section 3.4.3.3.2, *Siting and Reserve Design*). Tidal natural communities restoration in Conservation Zone 4 may provide giant garter snake habitat connectivity between the Coldani Marsh/White Slough subpopulation and the Stone Lakes National Wildlife Refuge lands to the north (Table 3.4.3-1). Lands in Conservation Zones 1 and 11 will be protected to increase habitat linkages between Suisun Marsh, Jepson Prairie, and the Cache Slough ROA (Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complex*). Lands in Conservation Zone 8 will be protected to maintain habitat linkages with existing conservation lands to the south and east, within the East Contra Costa HCP/NCCP area (Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complex*).	Compliance monitoring
Goal TPANC1: Tidal perennial aquatic natural community that supports habitat elements for covered and other native species and that supports improved productivity of covered species by providing improved aquatic primary productivity.		
Objective TPANC1.1: Within the 65,000 acres of tidal natural communities and transitional uplands (Objective L1.3), restore or create tidal perennial aquatic natural community as necessary when creating tidal emergent wetland natural communities with an emphasis on shallow intertidal areas that provide habitat and that support improved aquatic primary productivity for covered and other native species.	Sufficient lands will be acquired and protected to achieve this objective (Table 3.3-2 and Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Tidal Natural Communities*). See also *CM4 Tidal Natural Communities Restoration.*	Compliance monitoring
Goal TBEWNC1: Large expanses and interconnected patches of tidal brackish emergent wetland natural community.		
Objective TBEWNC1.1: Within the 65,000 acres of tidal natural communities and transitional uplands (Objective L1.3), restore or create at least 6,000 acres of tidal brackish emergent wetland in Conservation Zone 11 among the Western Suisun/Hill Slough Marsh Complex, the Suisun Slough/Cutoff Slough Marsh	This acreage is a subset of tidal marsh restoration target acreage. Sufficient lands will be acquired and protected to achieve this objective. See Table 3.3-2 and Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Tidal Natural Communities.* This objective is also advanced through implementation of *CM4 Tidal Natural Communities Restoration.* See also *CM4 Tidal*	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
Complex, and the Nurse Slough/Denverton Marsh Complex to be consistent with the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*.	*Natural Communities Restoration.*	
Goal TFEWNC1: Large, interconnected patches of tidal freshwater emergent wetland natural community.		
Objective TFEWNC1.1: Within the 65,000 acres of tidal natural communities and transitional uplands to accommodate sea level rise (Objective L1.3), restore or create at least 24,000 acres of tidal freshwater emergent wetland in Conservation Zones 1, 2, 4, 5, 6, and/or 7.	This acreage is a subset of tidal marsh restoration target acreage. Sufficient lands will be acquired and protected to achieve this objective. See Table 3.3-2 and Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Tidal Natural Communities.* This objective is also advanced through implementation of *CM4 Tidal Natural Communities Restoration.*	Compliance monitoring
Objective TFEWNC1.2: Restore tidal freshwater emergent wetlands in areas that increase connectivity among conservation lands.	When selecting lands to be protected for tidal freshwater emergent wetland restoration, those lands that increase connectivity among conservation lands will be prioritized. See also *CM4 Tidal Natural Communities Restoration.*	Compliance monitoring
Goal VFRNC1: Extensive wide bands or large patches of interconnected valley/foothill riparian natural community, with locations informed by both existing and historical distribution.		
Objective VFRNC1.1: Restore or create 5,000 acres of valley/foothill riparian natural community, with at least 3,000 acres occurring on restored seasonally inundated floodplain.	Sufficient lands will be protected to restore or create 5,000 acres of riparian natural community. At least 3,000 acres of this will be in restored seasonally inundated floodplain. See Table 3.4.3-1. Also see *CM7 Riparian Natural Community Restoration.*	Compliance monitoring
Objective VFRNC1.2: Protect 750 acres of existing valley/foothill riparian natural community in Conservation Zone 7 by year 10.	Sufficient lands will be acquired and protected to achieve this objective. See Table 3.3-2 and Table 3.4.3-1.	Compliance monitoring
Goal VFRNC2: Increased structural diversity including a mosaic of seral stages, age classes, plant zonation, and plant heights and layers characteristic of valley/foothill riparian natural community.		
Objective VFRNC2.3: Maintain at least 500 acres of mature riparian forest in Conservation Zones 4 or 7.	The need to achieve this objective will be considered when siting lands for riparian protection and restoration. See Table 3.4.3-1.	See CM11
Objective VFRNC2.4: Maintain the at least 500 acres of mature riparian forest (VFRNC2.3) intermixed with a portion of the early- to midsuccessional riparian vegetation (VFRNC2.2) in large blocks with a minimum patch size of 50 acres and minimum width of 330 feet.	The need to achieve this objective will be considered when siting lands for riparian protection and restoration. See Table 3.4.3-1.	See CM11
Goal NFEW/NPANC1: Nontidal marsh consisting of a mosaic of nontidal freshwater emergent perennial wetland and nontidal perennial aquatic natural communities, and providing habitat for covered and other native species.		
Objective NFEW/NPANC1.1: Create 1,200 acres of nontidal marsh consisting of a mosaic of nontidal perennial aquatic and nontidal freshwater emergent	Sufficient lands will be acquired and protected to achieve this objective. See Table 3.3-2 and Table 3.4.3-1. See also *CM10 Nontidal Marsh Restoration.*	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
wetland natural communities, with suitable habitat characteristics for giant garter snake and western pond turtle.		
Goal ASWNC1: A reserve system including alkali seasonal wetland complex within a mosaic of grasslands and vernal pool complex.		
Objective ASWNC1.1: Protect 150 acres of alkali seasonal wetland in Conservation Zones 1, 8, and/or 11 among a mosaic of protected grasslands and vernal pool complex.	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complexes.*	Compliance monitoring
Objective ASWNC1.2: Restore or create alkali seasonal wetlands in Conservation Zones 1, 8, and/or 11 to achieve no net loss of wetted acres (up to 72 acres of alkali seasonal wetland complex restoration, assuming all anticipated impacts occur).	Sufficient lands will be protected to achieve alkali seasonal wetland restoration for the purpose of achieving no net loss of wetted acres. Alkali seasonal wetlands will be restored as described in Table 3.4.3-1. See also *CM9 Vernal Pool and Alkali Seasonal Wetland Complex Restoration*.	Compliance
Goal ASWNC2: Alkali seasonal wetlands that are managed and enhanced to sustain populations of native alkali seasonal wetland species.		
Objective ASWNC2.1: Provide appropriate seasonal flooding characteristics for supporting and sustaining alkali seasonal wetland species.	When selecting sites for alkali seasonal wetland protection, priority will be given to sites that include the intact local surrounding watershed to sustain natural drainage patterns and sites that are not threatened by potential artificial flows (e.g., urban or agricultural runoff) from adjacent areas.	Compliance monitoring
Goal VPNC1: Vernal pool complexes composed of large, interconnected, or contiguous expanses that represent a range of environmental conditions**.**		
Objective VPNC1.1: Protect 600 acres of existing vernal pool complex in Conservation Zones 1, 8, and 11, primarily in core vernal pool recovery areas identified in the *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (U.S. Fish and Wildlife Service 2005).	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complexes.*	Compliance monitoring
Objective VPNC1.2: Restore vernal pool complex in Conservation Zones 1, 8, and/or 11 to achieve no net loss of vernal pool acreage (up to 67 acres of vernal pool complex restoration, assuming that all anticipated impacts [10 wetted acres] occur and that the restored vernal pool complex has 15% density of vernal pools).	Sufficient lands will be acquired and protected to achieve this objective. See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complexes*. Also see *CM9 Vernal Pool and Alkali Seasonal Wetland Complex Restoration.*	Compliance monitoring
Objective VPNC1.3: Increase the size and connectivity of protected vernal pool complex in the Plan Area and increase connectivity with protected vernal pool complex adjacent to the Plan Area.	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complexes.*	Compliance monitoring
Objective VPNC1.4: Protect the range of	See Section 3.4.3.3.2, *Siting and Reserve Design,*	Compliance

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
inundation characteristics that are currently represented by vernal pools throughout the Plan Area.	*Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complexes.*	monitoring
Goal MWNC1: Managed wetland that is managed and enhanced to provide suitable habitat conditions for covered species and native biodiversity.		
Objective MWNC1.1: Protect and enhance 8,100 acres of managed wetland, at least 1,500 acres of which are in the Grizzly Island Marsh Complex.	Managed wetlands will be protected in the appropriate quantity and location to achieve this objective.	Compliance
Goal GNC1: Extensive grasslands composed of large, interconnected patches or contiguous expanses.		
Objective GNC1.1: Protect 8,000 acres of grassland with at least 2,000 acres protected in Conservation Zone 1, at least 1,000 acres protected in Conservation Zone 8, at least 2,000 acres protected in Conservation Zone 11, and the remainder distributed among Conservation Zones 1, 2, 4, 5, 7, 8, and 11.	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complex.*	Compliance monitoring
Objective GNC1.2: Restore 2,000 acres of grasslands to connect fragmented patches of protected grassland and to provide upland habitat adjacent to riparian, tidal, and nontidal natural communities for wildlife foraging and upland refugia.	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complex*. Also see *CM8 Grassland Natural Community Restoration.*	Compliance monitoring
Objective GNC1.3: Protect stock ponds and other aquatic features within protected grasslands to provide aquatic breeding habitat for native amphibians and aquatic reptiles.	When selecting sites for grassland protection, priority will be given to sites that include aquatic features suitable for supporting native amphibians and aquatic reptiles.	Compliance monitoring
Objective GNC1.4: Of the 8,000 acres of grassland protected under Objective GNC1.1 and 2,000 acres of grassland restored under Objective GNC1.2, protect or restore grasslands adjacent to restored tidal brackish emergent wetlands to provide at least 200 feet of adjacent grasslands beyond the sea level rise accommodation.	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complex*. Also see *CM8 Grassland Natural Community Restoration.*	Compliance monitoring
Goal CLNC1: Cultivated lands that provide habitat connectivity and support habitat for covered and other native wildlife species.		
Objective CLNC1.1: Protect 48,625 acres of cultivated lands that provide suitable habitat for covered and other native wildlife species.	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Cultivated Lands.*	Compliance monitoring
Objective CLNC1.2: Target cultivated land conservation to provide connectivity between other conservation lands.	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Cultivated Lands.*	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
Objective CLNC1.3: Maintain and protect the small patches of important wildlife habitats associated with cultivated lands that occur in cultivated lands within the reserve system, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant groves, riparian corridors, water conveyance channels, grasslands, ponds, and wetlands.	Cultivated lands with patches of important wildlife habitat will be prioritized for protection. See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Cultivated Lands.*	Compliance monitoring
Goal RBR1: Suitable habitat available for the future growth and expansion of riparian brush rabbit populations.		
Objective RBR1.1: Of the 750 acres of protected valley/foothill riparian natural community protected under Objective VFRNC1.2, protect 200 acres of suitable riparian brush rabbit habitat (defined in *CM7 Riparian Natural Community Restoration*) that is occupied by the species or contiguous with occupied habitat.	See Table 3.4.3-1 and Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Requirements by Species, Riparian Brush Rabbit.*	Compliance monitoring
Objective RBR1.2: Of the at least 1,000 acres of early- to midsuccessional riparian habitat maintained under VFRNC2.2, maintain at least 800 acres within the range of the riparian brush rabbit (Conservation Zone 7), in areas that are adjacent to or that facilitate connectivity with existing occupied or potentially occupied habitat.	See Table 3.4.3-1 and Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Requirements by Species, Riparian Brush Rabbit.*	Compliance monitoring
Objective RBR1.3: Of the 5,000 acres of valley/foothill riparian natural community restored under Objective VFRNC1.1, restore/create and maintain 300 acres of early- to midsuccessional riparian habitat that meets the ecological requirements of the riparian brush rabbit and that is within or adjacent to or that facilitates connectivity with existing occupied or potentially occupied habitat.	See Table 3.4.3-1 and Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Requirements by Species, Riparian Brush Rabbit.* See also *CM7 Riparian Natural Community Restoration.*	Compliance monitoring
Objective RBR1.6: Of the 8,000 acres of grasslands protected under Objective GNC1.1 and the 2,000 acres of grasslands restored under Objective GNC1.2, protect or restore grasslands on the landward side of levees adjacent to restored floodplain to provide flood refugia and foraging habitat for riparian brush rabbit.	See Table 3.4.3-1 and Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Requirements by Species, Riparian Brush Rabbit.*	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
Goal RW1: A reserve system that includes suitable habitat available for the future growth and expansion of riparian woodrat populations.		
Objective RW1.1: Of the 5,000 acres of valley/foothill riparian natural community restored under Objective VFRNC1.1, restore/create and maintain 300 acres riparian habitat in Conservation Zone 7 that meets the ecological requirements of the riparian woodrat (e.g., dense willow understory and oak overstory) and that is adjacent to or facilitates connectivity with existing occupied or potentially occupied habitat.	See Table 3.4.3-1 and *CM7 Riparian Natural Community Restoration.*	Compliance monitoring
Goal CBR1: A reserve system that includes suitable habitat for the future growth and expansion of California black rail populations.		
Objective CBR1.1: At the ecotone that will be created between restored tidal freshwater emergent wetlands and transitional uplands (Objectives L1.3 and TFEW1.1), provide for at least 1,700 acres of California black rail habitat consisting of shallowly inundated emergent vegetation at the upper edge of the marsh (within 50 meters of upland refugia habitat) with adjacent riparian or other shrubs that will provide upland refugia, and other moist soil perennial vegetation.	See Table 3.4.3-1 and *CM4 Tidal Natural Communities Restoration.*	Compliance monitoring
Goal GSHC1: Protection and expansion of greater sandhill crane winter range.		
Objective GSHC1.1: Within the 48,625 acres of cultivated lands protected under Objective CLNC1.1, protect 7,300 acres of high- to very high-value habitat for greater sandhill crane, with at least 80% maintained in very high-value types in any given year, as defined in *CM3 Natural Communities Protection and Restoration*. This protected habitat will be within 2 miles of known roosting sites in Conservation Zones 3, 4, 5, and/or 6 and will consider sea level rise and local seasonal flood events, greater sandhill crane population levels, and the location of foraging habitat loss. Patch size of protected cultivated lands will be at least 160 acres.	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Requirements by Species, Greater Sandhill Crane.*	Compliance monitoring
Objective GSHC1.2: To create additional high-value greater sandhill crane winter foraging habitat, at least 10% of the habitat protected under Objective GSHC1.1 will involve acquiring low-value	See Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Requirements by Species, Greater Sandhill Crane.*	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
habitat or nonhabitat areas and converting it to high- or very high-value habitat. Created habitat will be within 2 miles of known roosting sites in Conservation Zones 3, 4, 5, and/or 6 and will consider sea level rise and local seasonal flood events, greater sandhill crane population level, and the location of habitat loss.		
Objective GSHC1.3: Create 320 acres of managed wetlands consisting of greater sandhill crane roosting habitat in minimum patch sizes of 40 acres within the Greater Sandhill Crane Winter Use Area[16] in Conservation Zones 3, 4, 5, or 6, with consideration of sea level rise and local seasonal flood events. The wetlands will be located within 2 miles of existing permanent roost sites and protected in association with other protected natural community types (excluding nonhabitat cultivated lands) at a ratio of 2:1 upland to wetland to provide buffers around the wetlands.	Suitable lands for managed wetland creation will be protected in the appropriate quantity and location to achieve this objective, and managed wetland will be created as described in Table 3.4.3-1. See also *CM10 Nontidal Marsh Restoration.*	Compliance monitoring
Objective GSHC1.4: In addition to the at least 320 acres of created managed wetland greater sandhill crane roosting habitat (Objective GSHC1.3), create two wetland complexes within the Stone Lakes National Wildlife Refuge project boundary[17]. The complexes will be no more than 2 miles apart and will help provide connectivity between the Stone Lakes and Cosumnes greater sandhill crane populations. Each complex will consist of at least three wetlands totaling 90 acres of greater sandhill crane roosting habitat, and will be protected in association with other protected natural community types (excluding nonhabitat cultivated lands) at a ratio of at least 2:1 uplands to wetlands (i.e., two sites with 90 acres of wetlands each). One of the 90-acre wetland complexes may be replaced by 180 acres of cultivated lands (e.g.,	Suitable lands for managed wetland creation will be protected in the appropriate quantity and location to achieve this objective, and managed wetland will be created as described in Table 3.4.3-1.	Compliance monitoring

[16] Important geographically defined greater sandhill crane wintering areas in the Central Valley (Pogson and Lindstedt 1988; Littlefield and Ivey 2000; Ivey pers. comm.) (Figure 2A.19-2).

[17] The project boundary delineates the area surrounding the existing refuge for which the refuge has authority to acquire land or easements.

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
cornfields) that are flooded following harvest to support roosting cranes and provide highest-value foraging habitat, provided such substitution is consistent with the long-term conservation goals of Stone Lakes National Wildlife Refuge for greater sandhill crane.		
Objective GSHC1.5: Create an additional 95 acres of roosting habitat within 2 miles of existing permanent roost sites. The habitat will consist of active cornfields that are flooded following harvest to support roosting cranes and that provide highest-value foraging habitat. Individual fields will be at least 40 acres and can shift locations throughout the Greater Sandhill Crane Winter Use Area, but will be sited with consideration of the location of roosting habitat loss and will be in place prior to roosting habitat loss.	Suitable lands for flooded cornfields will be protected in the appropriate quantity and location to achieve this objective, as described in Table 3.4.3-1.	Compliance monitoring
Goal SH1: Large, interconnected patches or contiguous expanses of protected Swainson's hawk foraging habitat.		
Objective SH1.1: Conserve 1 acre of Swainson's hawk foraging habitat for each acre of lost[18] foraging habitat.	Cultivated lands will be protected in the appropriate quantity and location, and with the appropriate composition, to achieve this objective, as described in Section 3.4.3.3.2, *Siting and Reserve Design*, *Reserve Design Requirements by Species, Swainson's Hawk.*	Compliance monitoring
Objective SH1.2: Within the 48,625 acres of protected cultivated lands, protect at least 43,325 acres of Swainson's hawk foraging habitat with at least 50% in very high-value habitat production in Conservation Zones 1, 2, 3, 4, 7, 8, 9, and 11.	Cultivated lands will be protected in the appropriate quantity and location, and with the appropriate composition, to achieve this objective, as described in Section 3.4.3.3.2, *Siting and Reserve Design*, *Reserve Design Requirements by Species, Swainson's Hawk.*	Compliance monitoring
Objective SH1.3: Of the at least 43,325 acres of cultivated lands protected as Swainson's hawk foraging habitat under Objective SH1.2, up to 1,500 acres can occur in Conservation Zones 5 and 6, all of which must have land surface elevations greater than -1 foot NAVD88.	Cultivated lands will be protected in the appropriate quantity and location, and with the appropriate composition, to achieve this objective, as described in Section 3.4.3.3.2, *Siting and Reserve Design*, *Reserve Design Requirements by Species, Swainson's Hawk.*	Compliance monitoring
Objective SH1.4: Within the 138,789 acres of lands protected or restored under Objective L1.1, protect at least 10,750 acres of grassland, vernal pool, and alkali seasonal wetland as Swainson's hawk foraging habitat.	Cultivated lands will be protected in the appropriate quantity and location, and with the appropriate composition, to achieve this objective, as described in Section 3.4.3.3.2, *Siting and Reserve Design*, *Reserve Design Requirements by Species, Swainson's Hawk.*	Compliance monitoring

[18] "Lost" is the combination of permanent habitat loss and loss due to borrow and spoil sites that will eventually be restored.

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
Goal TRBL1: Improved nesting, nesting-adjacent foraging, and wintering habitat for tricolored blackbirds in the Plan Area.		
Objective TRBL1.1: Protect and manage 50 acres of occupied or recently occupied (within the last 15 years) tricolored blackbird nesting habitat located within 5 miles of high-value foraging habitat in Conservation Zones 1, 2, 8, or 11. Nesting habitat will be managed to provide young, lush stands of bulrush/cattail emergent vegetation and prevent vegetation senescence.	Sufficient lands will be acquired and protected to achieve this objective.	Compliance monitoring
Objective TRBL1.2: Within the 48,625 acres of cultivated lands protected under Objective CLNC1.1, protect at least 26,300 acres of moderate-, high-, or very high-value cultivated lands as nonbreeding foraging habitat, at least 50% of which is of high or very high value.	Cultivated lands will be protected in the appropriate quantity and location, and with the appropriate tricolored blackbird habitat characteristics, as described in Section 3.4.3.3.2, *Siting and Reserve Design*, *Reserve Design Requirements by Species, Tricolored Blackbird*.	Compliance monitoring
Objective TRBL1.3: Within the 48,625 acres of protected cultivated lands, protect at least 11,050 acres of high- to very high-value breeding-foraging habitat within 5 miles of occupied or recently occupied (within the last 15 years) tricolored blackbird nesting habitat in Conservation Zones 1, 2, 3, 4, 7, 8, or 11. At least 1,000 acres will be within 5 miles of the 50 acres of nesting habitat protected under Objective TRBL1.1.	Cultivated lands will be protected in the appropriate quantity and location, and with the appropriate tricolored blackbird habitat characteristics, as described in Section 3.4.3.3.2, *Siting and Reserve Design*, *Reserve Design Requirements by Species, Tricolored Blackbird*.	Compliance monitoring
Goal WBO1: Contribute to the sustainability of burrowing owl population by protecting cultivated lands suitable for burrowing owl foraging.		
Objective WBO1.1: Of the 48,625 acres of cultivated land protected under Objective CLNC1.1, protect at least 1,000 acres in Conservation Zones 1 and 11 that support high-value burrowing owl habitat and are within 0.5 mile of high-value grassland habitat or occupied low-value habitat.	Cultivated lands will be protected in the appropriate quantity and location, and with the appropriate western burrowing owl habitat characteristics, as described in Section 3.4.3.3.2, *Siting and Reserve Design*, *Reserve Design Requirements by Species, Tricolored Blackbird*.	Compliance monitoring
Goal GGS1: Well-connected high-value upland and aquatic giant garter snake habitat in Conservation Zones 4 and/or 5.		
Objective GGS1.1: Of the 1,200 acres of nontidal marsh created under Objective NFEW/NPANC1.1, create at least 600 acres of aquatic habitat for the giant garter snake that is connected to the 1,500 acres of rice land or equivalent-value habitat (Objective GGS1.4).	See Table 3.4.3-1. See also *CM10 Nontidal Marsh Restoration.*	Compliance monitoring
Objective GGS1.2: Of the 8,000 acres of grassland protected under Objective	See Table 3.4.3-1. See also *CM8 Grassland Natural Community Restoration*.	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
GNC1.1 and 2,000 acres restored under Objective GNC1.2, create or protect 200 acres of high-value upland giant garter snake habitat adjacent to the at least 600 acres of nontidal perennial aquatic habitat being restored and/or created in Conservation Zones 4 and/or 5 (Objective GGS1.1).		
Objective GGS1.3: Protect giant garter snakes on restored and protected nontidal marsh and adjacent uplands (Objectives GGS1.1 and GGS1.2) from incidental injury or mortality by establishing 200-foot buffers between protected giant garter snake habitat and roads (other than those roads primarily used to support adjacent cultivated lands and levees). Establish giant garter snake reserves at least 2,500 feet from urban areas or areas zoned for urban development.	See Table 3.4.3-1.	Compliance monitoring
Objective GGS1.4: Create connections from the White Slough population to other areas in the giant garter snake's historical range in the Stone Lakes vicinity by protecting, restoring, and/or creating 1,500 acres of rice land or equivalent-value habitat (e.g., perennial wetland) for the giant garter snake in Conservation Zones 4 and/or 5. Any portion of the 1,500 acres may consist of tidal freshwater emergent wetland and may overlap with the at least 24,000 acres of tidally restored freshwater emergent wetland if it meets specific giant garter snake habitat criteria described in *CM4 Tidal Natural Communities Restoration*. Up to 500 (33%) of the 1,500 acres may consist of suitable uplands adjacent to protected or restored aquatic habitat.	See Table 3.4.3-1. See also *CM4 Tidal Natural Communities Restoration* and *CM10 Nontidal Marsh Restoration.*	Compliance monitoring
Goal GGS2: Expansive high-value upland and aquatic giant garter snake habitat in Conservation Zone 2 located outside the Yolo Bypass**.**		
Objective GGS2.1: Of the 1,200 acres of nontidal marsh created under Objective NFEW/NPANC1.1, create at least 600 acres of connected aquatic giant garter snake habitat outside the Yolo Bypass in Conservation Zone 2.	See Table 3.4.3-1. See also *CM10 Nontidal Marsh Restoration.*	Compliance monitoring
Objective GGS2.2: Of the 8,000 acres of grasslands protected under Objective GNC1.1 and the 2,000 acres restored under Objective GNC1.2, create or protect	See Table 3.4.3-1. See also *CM8 Grassland Natural Community Restoration*.	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
at least 200 acres of high-value upland habitat adjacent to the at least 600 acres of nontidal marsh habitat created in Conservation Zone 2 outside of Yolo Bypass (Objective GGS2.1).		
Objective GGS2.3: To expand upon and buffer the newly restored/created nontidal perennial habitat in Conservation Zone 2, protect 700 acres of cultivated lands, with at least 500 acres consisting of rice land and the remainder consisting of compatible cultivated land that can support giant garter snakes. The cultivated lands may be a subset of lands protected for the cultivated lands natural community and other covered species.	See Table 3.4.3-1.	Compliance monitoring
Objective GGS2.4: Protect giant garter snakes on created nontidal marsh (Objectives GGS2.1) and created or protected adjacent uplands (Objective GGS2.2) from incidental injury or mortality by establishing 200-foot buffers between protected giant garter snake habitat and roads (other than those roads primarily used to support adjacent cultivated lands and levees). Establish giant garter snake reserves at least 2,500 feet from urban areas or areas zoned for urban development.	See Table 3.4.3-1.	Compliance monitoring
Goal GGS3: At least 1 acre of giant garter snake habitat conserved for each acre of loss.		
Objective GGS3.1: Protect, restore, and/or create 2,740 acres of rice land or equivalent-value habitat (e.g., perennial wetland) for the giant garter snake in Conservation Zones 1, 2, 4, or 5. Up to 500 acres may consist of tidal freshwater emergent wetland and may overlap with the at least 5,000 acres of tidally restored freshwater emergent wetland in the Cache Slough ROA if this portion meets giant garter snake habitat criteria specified in *CM4 Tidal Natural Communities Restoration*. Up to 1,700 acres may consist of rice in the Yolo Bypass, if this portion meets the criteria specified in *CM3 Natural Communities Projection and Restoration*, (Section 3.4.3.3.2, *Siting and Reserve Design*, *Reserve Design Requirements by Species*). Any remaining acreage will consist of rice land or equivalent-value habitat outside the Yolo	See Table 3.4.3-1.	

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
Bypass. Up to 915 (33%) of the 2,740 acres may consist of suitable uplands adjacent to protected or restored aquatic habitat.		
Goal VELB1: Promote dispersal and expansion of the valley elderberry longhorn beetle where there are known source populations within the American River and Sacramento River systems.		
Objective VELB1.1: Mitigate impacts on elderberry shrubs by creating valley elderberry longhorn beetle habitat consistent with the U.S. Fish and Wildlife Service valley elderberry longhorn beetle conservation guidelines (Appendix 3.F) and planting elderberry shrubs in high-density clusters.	See Table 3.4.3-1.	Compliance monitoring
Objective VELB1.2: Site valley elderberry longhorn beetle habitat restoration within drainages immediately adjacent to or in the vicinity of sites confirmed to be occupied by valley elderberry longhorn beetle.	See Table 3.4.3-1. See also *CM7 Riparian Natural Community Restoration.*	Compliance monitoring
Goal VPC1: Protected occurrences of the rarest covered vernal pool crustacean species.		
Objective VPC1.1: Protect one currently unprotected occurrence of conservancy fairy shrimp.	The 600 acres of protected vernal pool complex will include one conservancy fairy shrimp occurrence.	Compliance monitoring
Goal BRIT/HART/SJSC1: A reserve system that includes habitat for and occurrences of brittlescale, heartscale, and San Joaquin spearscale.		
Objective BRIT/HART/SJSC1.1: Of the 150 acres of alkali seasonal wetland complex protected under Objective ASWNC1.1, 600 acres of vernal pool complex protected under Objective VPNC1.1, and 8,000 acres of grassland natural community protected under Objective GNC1.1, protect at least 75 acres of suitable brittlescale habitat and 75 acres of suitable heartscale habitat in Conservation Zones 1, 8, or 11.	See Table 3.4.3-1 and Section 3.4.3.3.2, *Siting and Reserve Design, Reserve Design Criteria by Natural Community Group, Grasslands and Associated Vernal Pool and Alkali Seasonal Wetland Complex.*	Compliance monitoring
Objective BRIT/HART/SJSC 1.2: Protect two currently unprotected occurrences of San Joaquin spearscale in Conservation Zones 1, 8, or 11.	Lands with currently unprotected occurrences of this species in Conservation Zones 1, 8, or 11 will be prioritized for protection.	Compliance monitoring
Goal CGB1: A reserve system that includes Carquinez goldenbush occurrences and sustains suitable habitat for this species.		
Objective CGB1.1: Protect three unprotected occurrences of the Carquinez goldenbush in Conservation Zones 1 and/or 11.	See Table 3.4.3-1.	Compliance monitoring

Biological Goal or Objective	How CM3 Advances a Biological Objective	Monitoring Action
Goal DBC1: Expand the distribution and increase the abundance of delta button celery populations.		
Objective DBC1.1: Protect and enhance two occurrences of delta button celery. If occurrences are not found in the Plan Area, establish self-sustaining occurrences of delta button celery for a total of two occurrences[19] within the restored floodplain habitat on the mainstem of the San Joaquin River in Conservation Zone 7 between Mossdale and Vernalis.	See Table 3.4.3-1.	Compliance monitoring
Goal ST1: Expanded distribution and increased abundance of slough thistle populations.		
Objective ST1.1: Protect and enhance two occurrences of slough thistle. If occurrences are not found in the Plan Area, establish self-sustaining occurrences of slough thistle for a total of two occurrences[20] within the 10,000 acres of restored floodplain on the mainstem of the San Joaquin River in Conservation Zone 7 between Mossdale and Vernalis.	See Table 3.4.3-1.	Compliance monitoring
Goal VPP1: A reserve system that protects vernal pool plant populations.		
Objective VPP1.1: Protect two currently unprotected occurrences of alkali milk-vetch in the Altamont Hills or Jepson Prairie core recovery areas (Conservation Zones 1, 8, or 11).	See Table 3.4.3-1.	Compliance monitoring
Objective VPP1.2: Maintain no net loss of Heckard's peppergrass in Conservation Zones 1, 8, or 11 within restoration sites or within the area of affected tidal range of restoration projects.	See Table 3.4.3-1.	Compliance monitoring
[a] This objective allows protection of one occurrence and establishment of one occurrence in the reserve system, or establishment of two occurrences in the reserve system.		

3.4.4 Conservation Measure 4 Tidal Natural Communities Restoration

Under *CM4 Tidal Natural Communities Restoration*, the Implementation Office will provide for 65,000 acres of restored tidal natural communities and transitional uplands. Some or all of the transitional uplands may become tidal during the 50-year permit term and beyond. The tidal natural communities restoration will be focused within the ROAs (Figure 3.2-2). However, tidal restoration

[19] This objective allows protection of one occurrence and establishment of one occurrence in the reserve system, or establishment of two occurrences in the reserve system.

[20] This objective allows protection of one occurrence and establishment of one occurrence in the reserve system, or establishment of two occurrences in the reserve system.

projects may be implemented outside of the ROAs, as needed, to meet the biological goals and objectives, provided that take limits resulting from such restoration do not exceed those established for the Plan (Table 5.6-1, *Maximum Allowable Habitat Loss for Covered Wildlife Species*, and Table 5.6-2, *Maximum Allowable Habitat Loss for Covered Plant Species*, in Chapter 5). The transitional upland areas, which are included in the 65,000-acre total, may accommodate sea level rise by evolving into tidal marsh plain if sea level rises as expected in the future.

The restoration of all gradients of the tidal natural communities and protection of transitional uplands will be phased to develop[21] 19,150 acres by year 10, 29,800 acres (cumulative) by year 15, and 65,000 acres (cumulative) by year 40.

Refer to Chapter 6, *Plan Implementation,* for details on the timing and phasing of CM4. The process for identifying specific lands and planning individual restoration projects is described in *CM3 Natural Communities Protection and Restoration*. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM4 on covered species will be avoided or minimized. Refer to Section 5.4, *Natural Communities*, and Section 5.6, *Wildlife and Plants*, for descriptions of the effects of CM4 on natural communities and covered species.

3.4.4.1 Purpose

It is expected that by implementing CM4 the BDCP will restore tidal influence and tidal natural communities in the Plan Area and thereby increase and improve rearing habitat for covered fish species by providing the following functions.

- Increased local production of organic materials and organisms that support the aquatic foodweb.
- Transport of food resources through tidal action via tidal channels to habitat occupied by covered fish
- Improved marsh and tidal aquatic connectivity.
- Improved water quality

CM4 is also expected to increase and improve habitat for terrestrial species that depend on tidal natural communities.

Implementation of CM4 will meet or contribute to the biological goals and objectives as identified in Section 3.4.4.5, *Consistency with the Biological Goals and Objectives*.

CM4 will primarily be implemented within the Suisun Marsh, Cache Slough, Cosumnes/Mokelumne, West Delta, and South Delta ROAs. The overall intent of CM4 is to develop a broadly distributed mosaic of restored tidal natural communities that address the foraging needs of covered fish species by increasing habitat suitability, primarily by supporting a more productive aquatic foodweb. Large-scale restoration of tidal natural communities is expected to generate emergent benefits (i.e., benefits that are more than the sum of their individual parts) as the area of restored tidal natural

[21] In achieving these targets the term "developed" for tidal restoration means the complete reintroduction of tidal inundation to areas expected to develop as tidal natural communities. These target values represent the current plan identified timeline. Development of fully functioning restored natural communities may take years subsequent to initial tidal inundation through the effects of natural processes on the constructed surface.

communities increases as a result of implementation of individual BDCP restoration projects. Additionally, tidal wetland restoration implemented as part of BDCP will provide a broad range of habitat features, such as tidal channels within wetlands. Brown (2003) noted that many Delta tidal wetland areas do not have sufficient area or appropriate geomorphic conditions to develop extensive channel networks, and that much of the existing tidal wetland habitat in the Delta is restricted to a narrow band between steep levees and deep water within channels or flooded islands.

Enright et al. (2013) compared tidal sloughs, one with natural tidal marsh morphology and another with modified morphology for water control, and found that the natural tidal marsh is tuned to lunar phase and produces tidal and fortnight water temperature variability through interacting tide, meteorology, and geomorphic linkages. In contrast, temperature variability is dampened in the modified slough where the overbank marsh plain is disconnected by levees. Despite geomorphic differences, a key finding of Enright et al. (2013) is that both sloughs are heat sinks in summer by latent heat flux–driven residual upstream water advection and sensible and long-wave heat transfer. It should be noted, however, that the precession of a 335-year tidal harmonic assures that these dynamics will continue to shift at a timescale of years. For example, Suisun Marsh currently experiences high spring tides near midnight in the summer, and near noon in winter. Over the next 167 years, this pattern will reverse, with high spring tides near noon in summer and near midnight in winter. For now, mudflats are dewatered during summer days with implications for biochemical process rates, soil community metabolism, and availability of organisms to shorebirds. Three to five decades hence, daytime high tides will occur in late winter and early spring when nekton access and utilization may be improved (Enright et al. 2013). Enright et al. (2013) speculate that primary productivity is enhanced where a slough network includes fortnightly overbank tides as part of its underlying hydraulic character and see evidence of chlorophyll *a* subsidy from this water as it drains back to the tidal slough network on the subsequent spring sequence. Thus, restoring tidal natural communities that provide tidal sloughs and overbank inundation could contribute to an increase in primary productivity. The benefits of increased primary productivity could be enhanced for many juvenile life stages of covered fish species in the next three to five decades, when high tides will occur during the day in late winter and early spring, coinciding with feeding times of these juveniles.

In addition to the aquatic system benefits emergent at the scale of the Plan Area, additional local or site-specific benefits are expected to accrue within each ROA. The expected biological benefits associated with the restoration actions will vary among the ROAs based on geomorphic setting (e.g., expected changes in tidal amplitude and flux, salinity, and freshwater outflow will vary between ROAs), and the use of the site by specific life stages of covered fish species. For example, restoration actions implemented in the Suisun Marsh ROA are anticipated to increase the extent of suitable habitat for covered fish such as delta smelt and longfin smelt as well as increase food production in areas where these fish currently occur. Restoration in the West Delta ROA is intended to provide similar functions and benefits in the future with the predicted eastward movement of the low-salinity zone that would result from climate change. Restoration in the Cache Slough ROA is intended to provide increased rearing habitat for Chinook salmon, splittail, and sturgeon; increase the local production of food for covered fish species rearing in Cache Slough; and increase the export of food downstream of Rio Vista that would be available to covered fish species occurring in the Delta and Suisun Marsh.

Each of the covered fish species has different habitat needs that are expected to be addressed by tidal natural communities restoration implemented under CM4. A discussion of expected benefits to each of the covered fish species follows.

Delta smelt. Delta smelt spawning has not been observed in the Bay-Delta; however, it is generally thought to occur in shallow, low-salinity upstream areas with sand or gravel substrate on which adhesive egg sacs are deposited (Bennet 2005; Nobriga and Herbold 2009). CM4 is expected to increase the amount of suitable spawning habitat available to delta smelt, based on what is assumed to constitute suitable spawning habitat, because of the extent of tidal natural communities restoration that would occur adjacent to areas most frequently occupied by delta smelt, particularly in the Cache Slough and Suisun Marsh ROAs. However, the importance of freshwater tidal wetlands to delta smelt is largely speculative (Brown 2003). Recently hatched larval delta smelt are generally captured in shallow, nearshore habitats and in channels associated with freshwater tidal wetlands, but they have never been captured from within a tidal wetland or from areas of emergent wetland vegetation (Brown 2003). Juvenile and adult delta smelt are pelagic, and any benefits of restored freshwater tidal wetlands would be indirect in the form of export of primary or secondary production to the open-water habitats occupied by these life stages. The uncertainty associated with delta smelt use of tidal natural communities will be addressed through effectiveness monitoring actions (Table 3.4.4-1).

Longfin smelt. Juvenile, subadult, and sexually mature adult longfin smelt tend to aggregate in deep-water, high-velocity environments; however, it is possible that longfin smelt aggregate in these environments before making brief (perhaps nocturnal) migrations to spawning habitats, a behavior seen among other osmerids (Rosenfield 2010). It is not known whether sexually mature fish caught in brackish waters or marsh environments were preparing to migrate to fresh water or whether either group spawned near where they were captured (Rosenfield 2010). Longfin smelt larvae are distributed near the surface of the water column in fresh and brackish waters, with the center of larval distribution closely associated with the location of the low salinity zone, regardless of outflow conditions (Dege and Brown 2004 in Rosenfeld 2010). Moyle (2008), when considering potential catastrophic failure of levees in the Delta, noted that permanently flooded islands in the western Delta could ultimately become important rearing habitat for larval and juvenile longfin smelt, depending on whether large zooplankton populations develop. Thus, it is likely that large-scale restoration of tidal natural communities in the western Delta could similarly provide important rearing habitat and biological benefits for longfin smelt.

Chinook salmon. Recent evidence from the Pacific Northwest indicates that estuarine and tidal wetland habitats are important for rearing of juvenile anadromous salmonids (Shreffler et al. 1990; Healey 1991; Simenstad et al. 1993 in Brown 2003; Tanner et al. 2002). Small (1st or 2nd order), dendritic tidal channels (channels that end in the upper marsh) are important rearing habitats for Chinook salmon fry (Fresh 2006). Freshwater tidal wetland creation under CM4 may provide increased rearing and refuge habitat for fry. Such tidal wetland creation would be expected to result in greater survival and hence greater production of adult fish (Brown 2003). Estuaries may contain such habitats as tidally influenced freshwater sloughs with rich production of such insects as chrionomid (midge) larvae, preyed upon by ocean-type Chinook salmon, among other salmonids; brackish marshes with emergent vegetation providing insect larvae, mysids, and epibenthic amphipods for Chinook fry, as well as other salmonids; and open-water habitats with drifting insects, zooplankton such as crab larvae, pelagic copepods, and larval fish for Chinook and other salmonids to feed upon, among other benefits (Quinn 2005). Thus, restoration of tidal natural communities under CM4 is expected to provide suitable rearing habitat as well as suitable food for juvenile Chinook salmon and thereby contribute to achieving the biological goals and objectives (Table 3.4.4-3).

Steelhead. For steelhead, the importance of estuaries as juvenile rearing habitat varies inversely with the size at which the fish enter the estuaries (Williams 2010). Because juvenile steelhead spend from 1 to 2 years in fresh water before migrating through the Delta, they are relatively large and pass relatively quickly through the Delta (Quinn 2005; Williams 2010). Therefore, habitat restoration within the Delta seems unlikely to provide significant benefits for juvenile steelhead (Williams 2010). This is not to say that benefits will not occur. The benefits for steelhead are expected to be similar to those for juvenile Chinook salmon, but of substantially lesser significance.

Sacramento splittail. Observations on small-scale floodplain wetlands indicate that at a length of 20 millimeters splittail are strongly associated with shallow edge habitat, but gradually begin to use a variety of offshore habitats by the time they achieve a length of 29 millimeters (Sommer et al. 2002 in Moyle et al. 2004). Young splittail may become entirely benthic at night; thus the inundation of large areas of shallow-water habitat (creating more benthic resting areas) may contribute to high splittail production (Sommer et al. 2007a). Shallow, tidal, brackish water channels along Suisun Bay may provide important rearing habitat for splittail, and the characteristics of such habitat should be incorporated into marsh restoration projects (Kratville 2008). Splittail migration through portions of the Delta and improved tidal wetland habitat could facilitate increased survival during such movements (Brown 2003). However, this should be tempered with the understanding that studies have shown that greater than 90% of the fish observed in tidal wetlands have been nonnative species. As mentioned previously, much of the tidal wetland habitat within the Delta is restricted to a narrow band between steep levees and deep water within channels or flooded islands (Brown 2003). The creation of large areas of tidal wetlands with dendritic tidal channels under CM4 may provide habitat more suitable and beneficial to splittail.

Green and white sturgeon. Our understanding of juvenile green sturgeon habitat is poorly understood, although juvenile green sturgeon do inhabit the Bay-Delta. Very little is known about the growth and swimming capacity of green sturgeon in estuarine environments. Once green sturgeon juveniles have the capacity to live in saltwater, they are believed to spend 1 to 3 years in estuaries before making their initial ocean migration. Juvenile green sturgeon are believed to grow as large as 90 centimeters during their time in the estuary. While in the estuary, they feed on large benthic food items such as mysid shrimp and amphipods; however, available benthic food items have changed in the recent past, and the invasive overbite clam (*Potamocorbula amurensis*), commonly referring to as *Potamocorbula*, has replaced native mollusks and shrimps as the primary food item. This shift in food items may be leading to reduced growth and increased bioaccumulation of contaminants, with unknown consequences for green sturgeon. Channelization of the estuary has likely had a negative effect on the amount of subtidal and intertidal habitat available for green sturgeon foraging. These estuarine habitats are likely important for growth during the juvenile, coastal migrant, and adult life stages (Israel and Klimley 2008).

Similar to green sturgeon, very little is known on the specific distribution of juvenile white sturgeon in the Sacramento–San Joaquin River system and their use of tidal natural communities. Tidal marshes, particularly brackish marshes, presumably provide foraging resources for white sturgeon. While no studies have documented the relationship of tidal marsh foodwebs and white sturgeon, loss of these habitats presumably reduces nursery and foraging habitats for young-of-the-year (YOY) through spawning adult life stages. It is unlikely that these changes influence individual white sturgeon, but cumulatively affect the population by possibly lowering the ecosystem's carrying capacity (Israel et al. 2009).

Restoration of tidal natural communities under CM4 is expected to provide foodweb benefits and potentially suitable rearing habitat for juvenile green and white sturgeon.

Pacific and river lamprey. Very little is known of Pacific or river lamprey use of tidal natural communities and the potential biological benefit that may result from restoration of tidal natural communities under CM4. While it is expected that lamprey will use those portions of tidal natural communities that remain inundated during low tide, it is unknown whether the lack of these habitats is a limiting factor for lamprey. Electrofishing surveys conducted in the Delta indicate that lamprey (likely ammocoetes) were dominant in bare mud bank habitat (Chotkowski 1999 in Brown 2003).

Natural community changes anticipated to occur at the scale of individual ROAs are summarized below for each ROA.

Restoration actions implemented within the Suisun Marsh ROA are expected to provide opportunities for tidal natural communities restoration to contribute the following functions and biological benefits.

- Increase rearing habitat area for delta smelt, longfin smelt, Chinook salmon, splittail, and possibly steelhead (Healey 1991; Meng et al. 1994; Meng and Matern 2001; Matern et al. 2002; Siegel 2007; Moyle 2008).
- Increase the local production of food for rearing delta smelt, longfin smelt, salmonids, sturgeon, and splittail (Kjelson et al. 1982; Mueller-Solger et al. 2002; Feyrer et al. 2003, 2005; Hobbs et al. 2006).
- Provide an important linkage between current and future upstream restored habitat, such as Yolo Bypass with Suisun Marsh (Lehman et al. 2008, 2010).
- Increase the availability and production of food in Suisun Bay for juvenile and adult delta smelt and longfin smelt by exporting organic material via tidal flow from restored tidal marsh plains to stimulate the growth of phytoplankton, zooplankton, and other organisms produced in tidal channels into the bay (Mueller-Solger et al. 2002; Hobbs et al. 2006; Cohen and Bollens 2008).
- Reduce the frequency and duration of periodic low dissolved oxygen (DO) events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish tidal natural communities (Siegel 2007; Enright pers. comm.).
- Increase the extent of habitat available for colonization by Suisun Marsh aster and soft bird's-beak.
- Enhance and increase the extent, quality, and connectivity of habitat for salt marsh harvest mouse, Suisun shrew, California clapper rail, California black rail, and Suisun song sparrow.

Restoration actions implemented in the Cache Slough ROA are expected to provide opportunities for tidal natural communities to contribute the following functions and biological benefits.

- In conjunction with floodplain enhancement in the Yolo Bypass, increase the frequency and duration of the ecological gradient from river floodplain to tidal estuary and provide tidal marsh adjacent to open-channel habitat that is characteristic of less altered estuaries (sensu Peterson 2003; Moyle 2008).
- Increase rearing habitat area for Chinook salmon (Sacramento River runs), splittail, and sturgeon (Healey 1991; Fresh 2006; Essex Partnership 2009).

- Increase the local production of food for rearing salmonids, splittail, delta smelt, longfin smelt, lamprey, and sturgeon (Tanner et al. 2002; Siegel 2007; Lehman et al. 2010).
- Increase the export of food in the Delta downstream of Rio Vista available to juvenile salmonids, splittail, delta smelt, and sturgeon by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in tidal channels into the Delta and Suisun Marsh (Siegel 2007; Lehman et al. 2008, 2010).
- Provide improved habitat suitability for resident delta smelt.
- Expand habitat available for colonization by Mason's lilaeopsis, Suisun Marsh aster, delta mudwort, and Delta tule pea.
- Expand habitat for tricolored blackbird (winter roosting), California black rail, and giant garter snake (in locations with a muted tidal range).

Restoration actions in the Cosumnes/Mokelumne ROA are expected to provide opportunities for tidal natural communities to contribute the following functions and biological benefits.

- Increase rearing habitat area for Cosumnes/Mokelumne fall-run Chinook salmon, steelhead, lamprey, and splittail (Healey 1991; Moyle et al. 2003).
- Increase the local production of food for Cosumnes/Mokelumne fall-run Chinook salmon, steelhead, sturgeon, and splittail adults migrating to and, as appropriate, juveniles emigrating from spawning areas in the Cosumnes and Mokelumne Rivers (Kjelson et al. 1982; Siegel 2007).
- Increase the availability and production of food in the east and central Delta available to juvenile salmonids, splittail, lamprey and sturgeon by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in tidal channels into the Delta (Cloern 2007; Siegel 2007; Grimaldo et al. 2009; Lucas and Thompson 2012).
- Increase the extent of habitat available for colonization by side-flowering skullcap, Mason's lilaeopsis, Suisun Marsh aster, and Delta tule pea.
- Expand habitat for tricolored blackbird (winter roosting), California black rail, and giant garter snake (in locations with a muted tidal range).

Restoration actions in the West Delta ROA are expected to provide opportunities for tidal natural communities restoration to contribute the following functions and biological benefits.

- Connect the reserve system by providing a continuous reach of tidal marsh and subtidal aquatic habitat for covered fish species associated with food productivity between current and future restored habitats in Yolo Bypass, the Cache Slough Complex and Suisun Marsh and Suisun Bay.
- Increase tidal marsh habitat for covered fish species within the predicted future eastward position of the low-salinity zone of the estuary. (Refer to Appendix 5.A.1, *Climate Change Implications for Natural Communities and Terrestrial Species*, and Appendix 5.A.2, *Climate Change Approach and Implications for Aquatic Species*, for evaluations of climate change implications.).
- Increase rearing habitat area for Chinook salmon (Sacramento, San Joaquin, and Cosumnes/Mokelumne River runs), splittail, and possibly steelhead (Healey 1991; Brown 2003).

- Improve habitat suitability for delta smelt and longfin smelt within the anticipated eastward movement of the low salinity zone. (Refer to Appendix 5.A.1 and Appendix 5.A.2 for evaluations of climate change implications.)
- Increase the local production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982; Siegel 2007).
- Increase the extent of habitat available for colonization by Mason's lilaeopsis, Suisun Marsh aster, delta mudwort, and Delta tule pea.
- Expand habitat for tricolored blackbird, California black rail, and giant garter snake (in locations with a muted tidal range).

Restoration actions in the South Delta ROA provide opportunities for tidal natural communities restoration to contribute the following functions and biological benefits.

- Increase rearing habitat area for splittail, Chinook salmon, steelhead, and sturgeon produced in the San Joaquin River and other eastside tributaries (Healey 1991; Brown 2003).
- Increase the local production of food for rearing or outmigrating splittail, Chinook salmon, steelhead and sturgeon and other covered species (Kjelson et al. 1982; Siegel 2007).
- Increase the extent of habitat available for colonization by Mason's lilaeopsis, delta mudwort, and Delta tule pea.
- Expand habitat for tricolored blackbird, California black rail, and giant garter snake (in locations with a muted tidal range).

Although tidal natural communities restoration under CM4 is expected to provide biological benefits for the covered fish species, these restoration actions may also benefit less desirable species, such as nonnative predators or invasive species. Nonnative predators of covered fish species, such as centrarchids, are likely to occupy restored habitats (Grimaldo et al. 2009, 2012; Nobriga and Feyrer 2007), especially if invasive aquatic vegetation becomes established (see CM13 *Invasive Aquatic Vegetation Control* for a discussion of methods that will be used to avoid its establishment in restored areas). It is also likely that a portion of any increase in foodweb productivity would be lost to invasive bivalves, because these bivalves currently consume a substantial fraction of pelagic productivity (Nobriga et al. 2005). Grimaldo et al. (2012) indicated that tidal natural communities restoration should be prioritized to include diked tracts at intertidal elevations, where open-water shoals and tidal sloughs can be restored, because these habitats are more likely to support native fishes than areas that are deeply subsided (e.g., 3 to 8 meters below sea level). As noted Section 3.4.4.3, *Implementation*, selection of restoration sites will prioritize sites that are currently at intertidal elevation, particularly at upper intertidal elevations, to more effectively accommodate projected sea level rise. However, some lower intertidal sites will have to be included to meet the acreage target for this conservation measure.

Restoring 65,000 acres of tidal natural communities and transitional uplands across five ROAs is expected to provide ecosystem-scale benefits across these ROAs in terms of primary productivity and emergent biological benefits in the Plan Area once sufficient restoration actions have been implemented. The threshold for the extent of habitat restoration necessary for this anticipated beneficial outcome to become widespread and measurable is unknown, but it is expected that the scale at which restoration actions will be implemented under the BDCP will trigger a positive and detectable emergent response over time.

3.4.4.2 Problem Statement

The loss and degradation of tidal natural communities in the Plan Area has resulted in habitat loss for native plant, wildlife, and fish species, and has adversely affected tidal circulation and nutrient flow.

Suisun Marsh is the largest brackish marsh complex in the western United States. The majority of historical tidal brackish marsh has been lost as a result of diking and other reclamation activities; only approximately 8,300 acres of natural (unmanaged) wetlands remain in Suisun Marsh. This loss of tidal brackish marsh has greatly reduced the availability and quality of rearing habitat for many native fish species by reducing the input of organic and inorganic material and food resources into adjoining deep-water habitats (sloughs and channels) and the downstream bay and estuary. This loss of tidal brackish marsh has also greatly reduced the extent and quality of habitat for native wildlife and plants adapted to the tidal marsh environment, including many of the covered species (e.g., salt marsh harvest mouse and Suisun thistle).

Prior to the 1860s, tidal freshwater emergent wetland comprised an estimated 87% of the Delta, with extensive marshes forming dense stands of vegetation bisected by meandering channels (The Bay Institute 1998; Grossinger et al. 2008; 2012). Today, tidal freshwater emergent wetland exists in remnant patches. In the Delta, the remnant tidal freshwater emergent wetland natural community is distributed in narrow, fragmented bands along island levees, in-channel islands, shorelines, sloughs, and shoals. The loss and degradation of tidal freshwater emergent wetland are results of its conversion to agriculture and of industrial and urban development; its loss has led to dramatic reductions in the amount of habitat available for associated fish and wildlife species (The Bay Institute 1998; CALFED Bay-Delta Program 2000). Channelization, levee building, removal of vegetation to stabilize levees, and upstream flood management have also reduced the extent of this community and altered its ecological function through changes to flooding frequency, inundation duration, and quantity of alluvial material deposition.

3.4.4.2.1 Feasibility of Tidal Restoration

Approximately 165,000 acres in the Plan Area meet the elevational criteria for tidal restoration. Of the 165,000 acres, some areas are less viable or more difficult to convert to tidal natural communities because of dampening of tidal energy and channel constrictions. The 65,000-acre tidal restoration target was developed by the BDCP Steering Committee, facilitated by the California Natural Resources Agency. The Steering Committee reviewed tidal natural communities restoration targets proposed by the CALFED (2000) Ecosystem Restoration Program and the *Delta Vision Strategic Plan* (Governor's Delta Vision Blue Ribbon Task Force 2008), as well as a study prepared by Black & Veatch Corporation (2012) that assessed tidal restoration potential, to help formulate and refine the tidal natural communities restoration target. In late 2008 and early 2009, several analyses were performed to evaluate tidal restoration opportunity and feasibility in the Plan Area. The first evaluation identified the total acreage of land with elevations suitable for restoring tidal natural communities in the Plan Area; this analysis identified approximately 165,000 acres of lands with suitable elevations to restore tidal marsh and shallow subtidal natural communities. The second analysis then weighted these acres based on 17 different restoration opportunity criteria such as location, number and size of parcels, and proximity to critical infrastructure. The output from this analysis identified a total number of acres that had very high to very low potential opportunity to support tidal restoration. Of the area evaluated, 54,790 acres were rated as having high to very high restoration potential, 29,110 acres were rated as having moderate restoration potential, and 40,800 acres were rated as having low to very low restoration potential. The restoration target was developed from these two analyses. In mid-2009, after discussions with wildlife agency staff, the final restoration target of 65,000 acres was agreed upon as biologically appropriate, practicable, and achievable within the permit term. The target includes restored subtidal and intertidal natural communities as well as transitional upland areas to accommodate the effects of sea level rise (i.e., upland areas that may be inundated by rising tides). More detail regarding the 65,000-acre target is provided in Appendix 3.A, *Background on the Process of Developing the BDCP Conservation Measures*.

3.4.4.3 Implementation

Actions to restore freshwater and brackish tidal natural communities, as appropriate to site-specific conditions, will include the following measures.

- Secure lands, in fee-title or through conservation easements, suitable for restoring tidal natural communities and protect sufficient adjacent uplands to accommodate the future upslope establishment of tidal emergent wetland natural community given sea level rise predictions, and to provide upland habitat and refugia for native wildlife (*CM3 Natural Communities Protection and Restoration*).
- Design and implement site-specific avoidance and minimization measures consistent with those described in Appendix 3.C, *Avoidance and Minimization Measures*, to minimize effects on covered species.
- Restore tidal emergent wetlands using techniques and methods described below (Section 3.4.4.3.3, *Methods and Techniques*) to accomplish the following goals.
    - Reestablish tidal connectivity to reclaimed lands and reintroduce tidal exchange to currently leveed former tidelands.
    - Restore and create sinuous and high-density dendritic channel networks within the restored marsh plains.
    - Restore tributary stream functions to establish more natural patterns of sediment transport, which may increase local turbidity and thus improve rearing conditions for delta smelt.
    - Create habitat for covered species dependent on tidal marsh natural communities.
    - At the ecotone that will be created between restored tidal freshwater emergent wetlands and transitional uplands, provide for 1,700 acres of California black rail habitat consisting of shallowly inundated emergent vegetation at the upper edge of the marsh (within 50 meters of upland refugia habitat) with adjacent riparian or other shrubs that will provide upland refugia, and other moist soil perennial vegetation.
    - Restore a 200-foot band of upland or riparian vegetation adjacent to tidally restored areas within the transitional uplands. This 200-foot band will be maintained in the transitional uplands with sea level rise. It can consist of riparian vegetation, grasslands, or other suitable natural communities to provide upland cover for marsh species. Riparian vegetation within this 200-foot band can count toward the 5,000 acres of restored riparian natural community, but restored grassland in this area will not count toward the 2,000 acres of grassland in CM8, *Grassland Natural Community Restoration*. If the 200-foot band consists of grasslands, it will not be grazed or mowed, so that suitable cover for marsh species will be provided.

- Design levee and dike breaches to maximize the development of tidal marsh plain and create fast-flowing areas that disfavor invasive aquatic vegetation and centrarchids.

Measures to minimize the potential for methylation of mercury in restored tidal natural communities are described in *CM12 Methylmercury Management.*

3.4.4.3.1 Minimum Restoration Targets

The 65,000 acres of restored tidal natural communities and protected transitional uplands must include at least 6,000 acres of tidal brackish emergent wetland and 24,000 acres of tidal freshwater emergent wetland. The remainder of the 65,000 acres will consist of a combination of any of the restored tidal natural communities (tidal brackish emergent wetland, tidal freshwater emergent wetland, and tidal perennial aquatic) and protected transitional uplands to accommodate sea level rise during and after the 50-year permit term. The intent of this conservation measure is to gain tidal wetlands and accommodate sea level rise, and while a portion of the 65,000 acres will consist of subtidal aquatic areas (tidal perennial aquatic natural community), these areas are expected to be a byproduct of the tidal restoration and not the primary restoration goal. Therefore, restoration will be designed to maximize tidal emergent wetlands and minimize deep subtidal areas.

Of the 65,000-acre target for restored tidal natural communities, 20,600 acres must occur in particular ROAs (Figure 3.2-2), consistent with the following minimum restoration targets.

- Restore 7,000 acres of brackish tidal natural communities, of which at least 6,000 acres are tidal brackish emergent wetland and the remainder can be any combination of tidal brackish emergent wetland, tidal perennial aquatic, and tidal mudflat, in Suisun Marsh ROA.
- Restore 5,000 acres of freshwater tidal natural communities (tidal freshwater emergent wetland, tidal perennial aquatic, tidal mudflat) in the Cache Slough ROA.
- Restore 1,500 acres of freshwater tidal natural communities (tidal freshwater emergent wetland, tidal perennial aquatic, and tidal mudflat) in the Cosumnes/Mokelumne ROA.
- Restore 2,100 acres of freshwater tidal natural communities (tidal freshwater emergent wetland, tidal perennial aquatic, and tidal mudflat) in the West Delta ROA.
- Restore 5,000 acres of freshwater tidal natural communities (tidal freshwater emergent wetland, tidal perennial aquatic, and tidal mudflat) in the South Delta ROA.

The remaining 44,400 acres of restored tidal natural communities and protected transitional uplands will be distributed among the ROAs, or may occur outside the ROAs in order to meet the biological goals and objectives provided the restoration does not result in effects on terrestrial covered species habitats that exceed the incidental take limits established for terrestrial covered species described in Chapter 5, *Effects Analysis*.

Restoration actions distributed among the ROAs will be implemented at the discretion of the Implementation Office based on land availability, practicability considerations, the siting and design considerations described below, and opportunities for meeting the biological goals and objectives. Priority will be given to restoration that meets multiple biological goals and objectives for multiple covered species.

3.4.4.3.2 Restoration Opportunities by Restoration Opportunity Area

Restoration will be targeted in areas that provide the best opportunities for successful implementation consistent with the biological goals and objectives. Restoration opportunities particular to each ROA are described below.

- **Suisun Marsh ROA** encompasses the Suisun Marsh and is located at the western end of the Plan Area, in Conservation Zone 11. Those areas suitable for tidal natural communities restoration in Suisun Marsh ROA consist of diked wetlands that are managed for waterfowl and experience little natural tidal action. These managed areas are separated from tidal sloughs by gated culverts and other gated structures that control water exchange and salinity. Waterfowl club managers control the timing and duration of flooding to promote growth of food plants for waterfowl. Some of these are managed as perennial wetlands, others are dry-managed during the summer and early fall months then prepared for waterfowl habitat and hunting with a series of flood-drain-flood cycles. The periodic flooding and discharge of managed wetlands can lead to periods of severely low DO events in adjoining water bodies, which cause acute mortality in at-risk fish species and impair valuable fish nursery habitat (Siegel 2007). Co-occurring with these low DO levels are elevated levels of methylmercury, a toxin prevalent in the Delta that bioaccumulates in the foodweb and adversely affects fish and wildlife.

- **Cache Slough ROA** includes the southern end of the Yolo Bypass in Conservation Zone 1 and lands to the west in Conservation Zone 2 supporting a complex of sloughs and channels. This ROA supports multiple covered fish species and may currently be the only area where delta smelt spawn and rear successfully. The Cache Slough ROA has been recognized as possibly containing the best functioning tidal natural communities in the Delta. The complex includes Liberty Island, which is likely the best existing model for freshwater tidal natural communities restoration in the Delta for native fishes. Additionally, this ROA encompasses a substantial area of land with elevations suitable for freshwater tidal natural communities restoration that would involve few impacts on existing infrastructure or permanent crops relative to other areas of the north Delta. The Cache Slough ROA provides an excellent opportunity to expand the natural communities supporting multiple aquatic and terrestrial covered species. Based on existing land elevations, approximately 21,000 acres of public and private lands in the area are potentially suitable for restoration of tidal natural communities. Areas suitable for restoration in this ROA include, but are not limited to, Haas Slough, Hastings Cut, Lindsey Slough, Barker Slough, Calhoun Cut, Little Holland, Yolo Ranch, Shag Slough, Little Egbert Tract, and Prospect Island.

- **Cosumnes/Mokelumne ROA** is located in the eastern portion of the Plan Area, in Conservation Zone 4. This ROA consists primarily of cultivated lands and a complex of sloughs and channels at the confluence of the Cosumnes and Mokelumne Rivers, providing an opportunity to create extensive gradients of tidal and nontidal wetlands. Suitable restoration sites in this ROA include McCormack-Williamson, New Hope, Canal Ranch, Bract, and Terminous Tracts north of State Highway 12, and lands adjoining Snodgrass Slough, South Stone Lake, and Lost Slough.

- **West Delta ROA** consists of multiple small areas where tidal natural communities can be restored in the western Delta, in Conservation Zones 5 and 6. It primarily supports cultivated lands and grasslands in areas that were historically tidal wetlands but have been diked and hydrologically altered, isolating tidal natural communities in the Cache Slough ROA from Suisun Marsh. Areas suitable for restoration include Dutch Slough, Decker Island, portions of Sherman Island, Jersey Island, Bradford Island, Twitchell Island, Brannon Island, Grand Island, and along portions of the north bank of the Sacramento River where elevations and substrates are suitable.

- **South Delta ROA**, located in Conservation Zone 7, consists primarily of cultivated lands and a riverine system including the San Joaquin River and its tributaries. Potential sites for restoring freshwater tidal natural communities include Fabian Tract, Union Island, Middle Roberts Island, and Lower Roberts Island.

Many tidal restoration projects are being planned and implemented now to support the BDCP and other restoration programs in Suisun Marsh and the Delta. See Chapter 6, Section 6.2, *Interim Implementation Actions*, for a list and map of these restoration projects, most of which are expected to help meet the requirements of CM4.

3.4.4.3.3 Methods and Techniques

The following general methods and techniques may be used to implement CM4.

- Restore natural remnant meandering tidal channels.
- Excavate channels to encourage the development of sinuous, high-density dendritic channel networks within restored marsh plain.
- Modify ditches, cuts, and levees to encourage more natural tidal circulation and better flood conveyance based on local hydrology.
- Prior to levee breaching, recontour the ground surface to maximize the extent of surface elevation suitable for establishment of tidal marsh vegetation (marsh plain) by scalping higher-elevation land to provide fill for placement on subsided lands to raise surface elevations (taking into consideration that the surface sediment in higher elevation land that is seasonally inundated can be a significant source for zooplankton and aquatic invertebrates, and scalping may temporarily remove that resource).
- Prior to breaching, import dredge or fill and place it in shallowly subsided areas to raise ground surface elevations to a level suitable for establishment of tidal marsh vegetation (marsh plain).
- Prior to breaching, cultivate stands of tules through flood irrigation for sufficiently long periods to raise subsided ground surface to elevations suitable to support marsh plain; breach levees when target elevations are achieved.

Additional methods specific to freshwater and brackish tidal natural communities are discussed below.

Freshwater Tidal Natural Communities Restoration

Freshwater tidal natural communities will be restored by breaching or removing levees along Delta waterways. Restoration on deeply subsided Delta tracts and islands may require construction of cross levees or berms to isolate deeply subsided lands from inundation, avoiding the creation of large areas of subtidal aquatic natural communities that favor nonnative predator or competitor species and disfavor covered fish species (e.g., central Delta flooded islands discussed in Nobriga et al. 2005; Lopez et al. 2006; Grimaldo et al. 2012; Lucas and Thompson 2012). Where required, levees or berms will be constructed to prevent inundation of adjacent lands.

Where practicable and appropriate, portions of restoration sites will be raised to elevations that will support tidal marsh vegetation following breaching. Depending on the degree of subsidence and location, lands may be elevated by grading higher elevations to fill subsided areas, importing clean dredged or fill material from other locations, or planting tules or other appropriate vegetation to raise elevations in shallowly subsided areas over time through organic material accumulation (Ingebritsen et al. 2000). Surface grading will provide for a shallow elevation gradient from the marsh plain to the upland transition habitat. Based on assessments of local hydrodynamic conditions, sediment transport, and topography, restoration activities may be designed and implemented in a manner that accelerates the development of tidal channels within restored marsh plains. Following reintroduction of tidal exchange, tidal marsh vegetation is expected to establish and maintain itself naturally at suitable elevations relative to the tidal range. Depending on site-specific conditions and monitoring results, patches of native emergent vegetation may be planted to accelerate the establishment of native marsh vegetation on restored marsh plain surfaces. A conceptual illustration of restored tidal freshwater emergent wetland natural community is presented in Figure 3.4-17.

Brackish Tidal Natural Community Restoration

The brackish tidal natural communities will be restored by breaching or removing dikes along Montezuma Slough and other Suisun Marsh sloughs and channels and Suisun Bay. Disconnected remnant sloughs will be reconnected to Suisun Bay and remnant slough levees will be removed to reintroduce tidal connectivity to slough networks. Tidal natural communities restored adjacent to cultivated lands or lands managed as freshwater seasonal wetlands may require construction or maintenance of dikes to maintain those land uses. Where appropriate, portions of restoration sites will be raised to elevations that would support tidal marsh vegetation.

Depending on the degree of subsidence, location, and likelihood for natural accretion through sedimentation, lands may be elevated by grading higher elevations to fill subsided areas, importing dredged or fill material from other locations, or planting appropriate native vegetation to raise elevations in shallowly subsided areas over time through organic material accumulation prior to breaching dikes. Surface grading will be designed to result in a shallow elevation gradient from the marsh plain to the upland transition habitat. Remnant disconnected tidal channels will be restored, if present in restoration sites, to accelerate development of marsh functions. Existing tidal channels may also be deepened or widened, if necessary to increase tidal flow. Based on assessments of local hydrodynamic conditions, sediment transport, and topography, restoration sites may be graded to accelerate the development of tidal channels within restored marsh plains. Following reintroduction of tidal exchange, tidal marsh vegetation is expected to naturally establish at suitable elevations relative to the tidal range. Depending on site-specific conditions and monitoring results, patches of native emergent vegetation may be planted to accelerate the establishment of native marsh vegetation on restored marsh plain surfaces. A conceptual illustration of restored brackish tidal natural communities is presented in Figure 3.4-18.

Because land surface elevations in Suisun Marsh are relatively homogenous, opportunities to provide linkages to upland habitats are limited to restoration sites that are located along the fringe of Suisun Marsh. Dikes constructed to restore tidal natural communities in the interior of Suisun Marsh will be designed with low gradient slopes supporting high marsh and upland vegetation to provide flood refuge habitat. Where appropriate, higher-elevation islands of upland within restored tidal natural communities may also be created to provide flood refuge for marsh wildlife.

3.4.4.3.4 Siting and Design Considerations

Tidal natural communities restoration sites will be designed to support habitat mosaics and an ecological gradient of shallow subtidal aquatic, tidal mudflat, tidal marsh, and riparian areas, transitional uplands to accommodate sea level rise accommodation, and uplands (e.g., grasslands, cultivated lands to be restored to grasslands), as appropriate to specific restoration sites. Restoration sites will be chosen on the basis of their contribution to meeting the biological goals objectives, as described below and in Section 3.4.4.5, *Consistency with the Biological Goals and Objectives*. Design of tidal natural communities restoration sites may be informed through meta-analysis to maximize the expected biological benefit for covered species.

The Implementation Office will consider the following restoration variables in the design of restored freshwater tidal natural communities.

- Distribution, extent, location, and configuration of existing and proposed restored tidal natural communities.
- Potential for improving habitat linkages that allow covered and other native species to move among protected[22] habitats in and adjacent to the Plan Area.
- For tidal brackish restoration, distribution of restored tidal natural communities along salinity gradients to optimize the range and habitat conditions for covered species and food production.
- For tidal brackish restoration, elevation and location along the existing Suisun Marsh fringe to maximize opportunities for restoring middle and high marsh (as opposed to subtidal and low marsh), with a minimum of 1,500 acres but more as feasible.
- For tidal freshwater restoration, elevation and location in the Delta to maximize opportunities for restoring middle and high marsh (as opposed to subtidal and low marsh).
- Predicted tidal range at tidal natural communities restoration sites following reintroduction of tidal exchange.
- Size and location of levee breaches necessary to restore tidal action.
- Cross-sectional profile of tidal natural communities restoration sites (elevation of marsh plain, topographic diversity, depth, and slope).
- Density and size of restored tidal channels appropriate to each restoration site.
- Potential hydrodynamic and water quality effects on other areas of the Delta.
- Ability to accommodate sea level rise.
- Cost of the restoration project relative to benefits.

Restoration for tidal natural communities will include, but not be limited to, the following design considerations.

- **Marsh plain vegetation.** In the Suisun Marsh ROA, restored tidal marsh plains will be dominated by native brackish marsh vegetation (e.g., pickleweed, saltgrass) appropriate to marsh plain elevations, mimicking the composition and densities of historical Suisun Bay tidal brackish marshes. Restoration in Suisun Marsh ROA will be designed to provide at least 6,000

[22] Category 1 and 2 open space (see glossary for definitions).

acres of tidal brackish emergent wetland natural community, with at least 1,500 acres consisting of middle and high marsh. Other ROAs will be vegetated primarily with tules and other native freshwater emergent vegetation to reflect the historical composition and densities of Delta tidal marshes.

- **Hydrodynamic conditions.** Tidal natural communities restoration will be designed, within restoration site constraints, to produce sinuous, high-density, dendritic networks of tidal channels that promote effective tidal exchange throughout the marsh plain and provide foraging habitat for covered fish species.
- **Flow velocities.** Marsh channels and levee breaches will be designed to maintain flow velocities that minimize conditions favorable to the establishment of nonnative submerged aquatic vegetation (SAV) and floating aquatic vegetation (FAV) and habitat for nonnative predatory fish.
- **Tidal action.** Following breaching and reintroduction of tidal action to restoration sites, tidal action will begin the natural process of sediment movement and the restored bottom contours will evolve. A discussion of the types of changes expected is provided in Appendix 3.B, *BDCP Tidal Habitat Evolution Assessment*.
- **Environmental gradients.** As determined by site-specific constraints, tidal natural communities restoration projects will be designed to provide an ecological gradient among subtidal, tidal mudflat, tidal marsh plain, and riparian areas, and transitional uplands (within the sea level rise accommodation area) and uplands to accommodate the movement of fish and wildlife species and provide flood refuge habitat for marsh-associated wildlife species during high-water events. In addition, by protecting higher-elevation lands adjacent to restored marsh plains, transitional uplands will be available for future marsh establishment that may occur as a result of sea level rise.
- **Subtidal aquatic habitat.** Tidal restoration projects will be designed to maximize establishment of emergent wetland natural communities, and subtidal areas are expected to be established only as a byproduct of tidal restoration rather than the primary goal. Deep subtidal aquatic areas will be minimized when designing restoration projects.

  Restored shallow subtidal aquatic areas are expected to support—depending on the location as well as the frequency, extent, and duration of inundation—habitat for delta smelt, longfin smelt, juvenile salmonid rearing, sturgeon, and lamprey ammocoetes. Shallow subtidal areas in large portions of the Delta support extensive beds of nonnative SAV that adversely affect covered fish species (Nobriga et al. 2005; Brown and Michniuk 2007; Grimaldo et al. 2012). In other portions of the Delta, shallow subtidal areas provide suitable habitat for native species, such as delta smelt in the Liberty Island/Cache Slough area, and do not promote the growth of nonnative SAV (Nobriga et al. 2005; McLain and Castillo 2009). CM4 does not aim to restore large areas of shallow subtidal aquatic habitat, because it may generate habitat for nonnative predators; rather, shallow subtidal aquatic habitat will result in portions of restored tidal marsh plain that are subsided below elevations that support tidal marsh vegetation. Tidal restoration projects will be designed to minimize the establishment of nonnative SAV, which may serve as habitat for nonnative predators. As described in *CM13 Invasive Aquatic Vegetation Control,* the Implementation Office will actively remove SAV and FAV in subtidal portions of tidal restoration sites to reduce the levels of establishment of nonnative predators.

Restoration Opportunity Areas

The Implementation Office will restore tidal natural communities in the Suisun Marsh and South Delta ROAs (Figure 3.2-2) based on the following additional siting and design considerations.

Suisun Marsh Restoration Opportunity Area

Brackish tidal natural communities will be restored in Suisun Marsh ROA in coordination with the *Suisun Marsh Habitat Restoration and Management Plan* (Bureau of Reclamation, U.S. Fish and Wildlife Service, and California Department of Fish and Game 2011). The areas to be restored as brackish tidal natural communities currently consist of managed wetlands. Restoration projects will be designed to create ecological gradients that support a mosaic of tidal marsh, tide flat, shallow subtidal aquatic, transitional upland areas to accommodate sea level rise, and additional, adjacent upland areas to provide flood refugia for wildlife, as appropriate to specific restoration sites. The selection and design of restored tidal natural communities in Suisun Marsh ROA will consider potential hydrodynamic and water quality effects of the proposed restoration, including the effects on salinity intrusion, tidal mixing, and Delta salinity.

Hydrodynamic modeling conducted for the *Suisun Marsh Habitat Restoration and Management Plan* (DeGeorge pers. comm.) indicates that restoring tidal natural communities north of Montezuma Slough would shift the low-salinity zone westward and restoring tidal natural communities at sites adjacent to Suisun Bay would shift the low-salinity zone eastward, potentially adversely affecting delta smelt habitat and water quality in the west Delta. Consequently, implementation of tidal natural communities restoration projects in north and south Suisun Marsh will be sequenced to avoid or minimize these potential effects.

Additional siting and design considerations for Suisun Marsh ROA are provided under *Salt Marsh Harvest Mouse*, below.

South Delta Restoration Opportunity Area

Tidal natural communities restoration in the South Delta ROA will not be completed until the north Delta diversion facilities become operational. Planning and implementation may commence sooner, but access to these sites by fish will not be provided until the diversion facilities are operational. Phasing implementation in this way is intended to maximize benefits associated with restoration of tidal natural communities and minimize risk of entrainment or other adverse effects on covered fish.

Potential sites for restoring freshwater tidal natural communities include Fabian Tract, Union Island, Middle Roberts Island, and Lower Roberts Island. Sites selected for restoration would be dependent on the location and design of the selected conveyance pathway and operations for the through-Delta component of dual conveyance facility. Selected sites would be those that would provide substantial species and ecosystem benefits with the selected through-Delta conveyance configuration and most effectively avoid potential adverse effects of south Delta SWP/CVP operations. In conjunction with dual conveyance operations, tidal natural communities restoration in South Delta ROA will be designed to support the expansion of the current distribution of delta smelt into formerly occupied habitat areas.

Covered Species

The Implementation Office will restore tidal natural communities based on the following additional siting and design considerations specific to covered species.

Salt Marsh Harvest Mouse

The salt marsh harvest mouse occurs in the Plan Area only in Suisun Marsh. Because of its use of managed wetlands in this area, specific design, timing, and phasing considerations are needed for tidal restoration in Suisun Marsh to minimize temporary impacts from restoration activities, and to maximize long-term conservation value to this species. These additional criteria for Suisun Marsh are based on extensive coordination with USFWS and a review of key portions of the *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (Draft Tidal Marsh Recovery Plan) (U.S. Fish and Wildlife Service 2010), which is expected to be finalized in 2013.

The objectives of the Draft Tidal Marsh Recovery Plan (U.S. Fish and Wildlife Service 2010) include "Protection, management and restoration of suitable tidal marsh habitat in each marsh complex sufficient to support multiple viable habitat areas occupied by salt marsh harvest mice". Viable habitat areas are described in the Draft Tidal Marsh Recovery Plan as high and middle marsh areas of 150 acres or more providing vegetation important to this species. Restoration projects will build off of existing tidal brackish emergent wetland areas at elevations not likely to be affected by sea level rise, to achieve patch sizes of at least 150 acres. Twelve viable habitat areas have been identified for establishment in areas of Suisun Bay where the BDCP will restore tidal marsh habitat, and seven on Grizzly Island where existing managed wetland will be protected (i.e., placed in conservation easements that restrict land uses to those compatible with species conservation and allow for BDCP-related enhancement and management) and enhanced (as described in *CM11 Natural Communities Enhancement and Management*) for supporting salt marsh harvest mouse populations. The salt marsh harvest mouse conservation strategy requires that at least 6,000 acres of tidal brackish emergent wetland natural community be restored in Suisun Marsh, of which at least 1,500 acres will be high or middle marsh. This restored high and middle marsh will be the BDCP's contribution towards establishing or expanding tidal marsh viable habitat areas and will meet the definition of "Viable Habitat Area," per the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (Final Tidal Marsh Recovery Plan). The measurement of population recovery success will be based on capture efficiency target criteria from the Final Tidal Marsh Recovery Plan.

The salt marsh harvest mouse is the only covered wildlife or plant species for which managed wetlands support high population densities. Consequently, while restoration of tidal brackish emergent wetland natural community will benefit this species in the long term, population-level impacts will occur during the initial restoration actions. The salt marsh harvest mouse conservation strategy calls for the eventual development (historical plus restored) of at least 1,000 acres of tidal marsh within each of three marsh complexes (Nurse Slough/Denverton Marsh, West Suisun/Hill Slough, and Suisun Slough/Cutoff Slough). To minimize the initial impacts, restoration will be phased such that no more than a quarter (1,500 acres) of the at least 6,000 acres to be restored within the three marsh complexes will be restored at one time, and subsequent restoration will not occur until the previous restoration has met salt marsh harvest mouse habitat and population success criteria. Further, restoration sites will be selected that are adjacent to existing mouse populations, especially populations in tidal marsh habitats, that will provide a source for population recovery in the restored habitat. Additionally, tidal restoration activities will include the construction of habitat levees with benches or berms that will provide opportunities for the establishment of high marsh and upland areas. Habitat levees may be planted and seeded with native marsh species and/or allowed to colonize naturally with native and naturalized species. The habitat levees will provide habitat for the salt marsh harvest mouse as the remainder of the tidal wetland areas become established.

California Clapper Rail

Tidal brackish emergent wetland restoration will be prioritized at Goodyear Slough on Morrow Island to benefit California clapper rail This is identified as a high priority restoration area in the Draft Tidal Marsh Recovery Plan (U.S. Fish and Wildlife Service 2010). Restoration in this area could be accomplished on CDFW land and adjacent private lands. Restoration in this area will provide opportunities for protection of adjacent transitional uplands to accommodate sea level rise.

Giant Garter Snake

The giant garter snake conservation strategy requires restoration, protection, or creation of at least 1,500 acres of rice lands or equivalent-value habitat in Conservation Zones 4 and/or 5, to create connections from the White Slough population to other areas in the giant garter snake's historical range. Some or all of this 1,500-acre requirement may be met through tidal freshwater emergent wetland restoration in the Cosumnes/Mokelumne ROA or elsewhere in Conservation Zones 4 and/or 5, provided the restoration is consistent with Objective GGS1.1 and meets the following design criteria. Similarly, up to 500 acres of the giant garter snake conservation commitment may be met through tidal freshwater emergent wetland restoration in the Cache Slough ROA, provided it meets the following design criteria. These design criteria are necessary to ensure that the tidally restored areas contributing to the giant garter snake conservation strategy provide functional habitat for the species. Only those areas designed specifically to contribute to the 1,500-acre requirement will need to meet these criteria.

- The restored wetlands provide sufficient water during the active summer season (March–October) to supply constant, reliable cover and sources of food (e.g., small fish and amphibians) for giant garter snake.
- The restored wetlands are designed to mute or reduce flows; provide still or slow-flowing water over a substrate composed of soil, silt, or mud characteristic of those observed in marshes, sloughs, or irrigation canals; and avoid fast-flowing water over sand, gravel, or rock substrate of the type typically observed in flowing streams or rivers.
- The restored wetlands are designed (e.g., through grading) to facilitate extended hydroperiods in shallow basins that experience only small, gradual (i.e., slower than tidal flooding/draining) changes in inundation. Design features may include notched or lowered levees that prevent full draining during low tides, intertidal dendritic channels with variable bottom elevations, and other features that retain water such as potholes, ponds/pannes, and shallow isolated backwaters.
- The restored wetlands do not include large areas of deep, open water that would support nonnative predatory fish.
- The restored wetlands are characterized by a heterogeneous topography that provides the range of depths and vegetation profiles (i.e., emergent, herbaceous aquatic) required for suitable foraging habitat and refuge from predators at all tide levels.
- The restored wetlands are designed to provide adjacent terrestrial refuge—grasslands above the high water mark—for giant garter snake. For characteristics of these adjacent grasslands, see *CM3 Natural Communities Protection and Restoration* and *CM8 Grassland Natural Community Restoration.*
- Topography of the restored wetlands is designed to provide adjacent terrestrial refuge persisting above the high water mark. Terrestrial features are in close proximity to aquatic

foraging habitats at all tide levels, with slopes and grading designed to avoid exposing largely denuded intertidal mud flats during low tide.

Suisun Thistle

As part of the conservation strategy, wild seed from Suisun thistle will be collected and banked to protect the species against local extirpation or extinction. Wild seed will also be used to found a cultivated population that could be used as a seed source for experimental reintroduction through seed broadcast or the outplanting of nursery stock (U.S. Fish and Wildlife Service 2010). The Implementation Office will partner with private and public entities (e.g., Solano Land Trust, CDFW) interested in using collected or cultivated seed or nursery stock for Suisun thistle conservation. Protocols and guidelines for *ex situ* conservation associated with genetic material sourced as part of BDCP implementation will be developed in association with experts and agency staff and will adhere to guidelines, protocols, or policies put forth by the Center for Plant Conservation (e.g., Guerrant et al. 2004) and the California Native Plant Society (e.g., 1992), when and where applicable. Over time, these guidelines are likely to be modified in response to new information.

3.4.4.4 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting in a GIS database the extent and location of each tidal natural community type successfully restored, mapping habitat restored for each covered species life stage using as-built bathymetry, substrate (assessed before levee breaching), and water quality parameters. Benefits of restoring tidal natural communities for covered fish species will also be monitored (e.g., for use by covered fish species and productivity of food important to covered fish species within restored tidal natural communities). Such monitoring is expected to demonstrate contribution toward achievement of biological goals and objectives.

Effectiveness monitoring will be conducted to evaluate progress toward advancing the objectives listed in Section 3.4.5.5, *Consistency with the Biological Goals and Objectives*. Early restoration projects will be monitored to assess the response of native and nonnative species to restoration designs and local environmental conditions. This information will be used to modify restoration designs and implementation methods, if necessary, over time to further improve habitat conditions for covered fish species. Following reintroduction of tidal exchange, effectiveness monitoring will consist of assessing the establishment of native and invasive nonnative plants in restored natural communities. If indicated by monitoring results, invasive plant control measures will be implemented to help ensure the establishment of native marsh plain plant species.

Restored tidal natural communities will be monitored consistent with the restoration monitoring methods and schedule described in the site-specific restoration plan (Section 3.4.3.4.2, *Site-Specific Restoration Plans*), including relevant monitoring actions, metrics, success criteria, and schedules, to determine whether success criteria specified in the restoration plan have been met. If success criteria are not met within the specified schedule, contingency measures will be implemented as described in the restoration plan. Contingency measures to be implemented if tidal natural communities restoration is unsuccessful may include, but are not limited to, additional plantings or topographic re-contouring.

Table 3.4.4-1 provides potential monitoring actions, metrics, success criteria, and timing and duration for monitoring relevant to CM4. These monitoring elements may be modified, as necessary, to best assess the effectiveness of CM4, based on the best available information at the time of implementation.

Table 3.4.4-1. Effectiveness Monitoring Relevant to CM4

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM4-1	Site-level assessment	Tidal elevations and flooding frequency	Gradual transition in elevation and hydrology, from subtidal areas, to marsh plain, to ecotonal areas and adjacent uplands.	Annually for first 5 years after restoration
CM4-2	Site-level assessment	Water quality	Maintenance of high warm-weather dissolved oxygen concentrations and temperatures comparable to seasonal norms for the region.	Annually for first 5 years after restoration
CM4-3	Site-level assessment	Use of restoration sites by covered fish species	Detection of site use by Chinook salmon, splittail, and the following covered fish species: longfin smelt and Delta smelt in the Suisun Marsh, West Delta and Cache Slough ROAs; steelhead in the West Delta, Cache Slough and Cosumnes/ Mokelumne ROAs	Monthly seine/net surveys during one water year between the second and fifth year following restoration site construction. Existing studies/ monitoring efforts (i.e., FMWT, zooplankton study) will be used to track larger, emergent trends in abundance of covered fish and important foodweb species, such as zooplankton.
CM4-4	Site-level assessment	Tidal natural community geomorphology	Presence of sinuous, high-density, dendritic networks of tidal channels through tidal areas	As specified in site-specific restoration plans
CM4-5	Plankton and invertebrate sampling in restored tidal natural communities	Plankton and invertebrate abundance in restored floodplain	Presence within and transport from restored tidal natural communities to adjacent open-water habitat occupied by covered fish species	Every 5 years following tidal restoration until end of permit term
CM4-6	Vegetation sampling	Vegetation composition, diversity, and structural complexity	Reflective of historic conditions. Comparable to natural, undisturbed reference sites or based on historical ecology studies such as Beagle et al. 2012	As specified in site-specific restoration plans

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM4-7	Population Sampling	Livetrap capture efficiency	Criteria provided under Section 3.4.4.3.4, *Siting and Design Considerations, Covered Species, Salt Marsh Harvest Mouse*.	Every 5 years until capture efficiency targets have been met at least twice
CM4-8	Vegetation Sampling	Salt marsh harvest mouse viable habitat areas	Criteria to be provided in the Final Tidal Marsh Recovery Plan	Sampling prior to subsequent phasing to ensure initial or previous restoration is successful before initiating subsequent phases
CM4-9	Site-level assessment	Parameters described in Section 3.4.4.3.4, *Siting and Design Considerations, Covered Species, Giant Garter Snake*	Criteria provided under Section 3.4.4.3.4, *Siting and Design Considerations*, *Covered Species, Giant Garter Snake*	As specified in site-specific restoration plans
CM4-10	Site-level assessments	Extent and population size of all Suisun thistle occurrences and those soft bird's-beak occurrences in proximity to tidal restoration sites	Stable or increasing	Every three years after tidal restoration until success criteria are met

Table 3.4.4-2 lists key uncertainties and associated research actions relevant to CM4.

Table 3.4.4-2. Key Uncertainties and Potential Research Actions Relevant to CM4

Key Uncertainty	Potential Research Actions
How does tidal marsh restoration affect production of food suitable for covered fish species? Will restored tidal marsh natural communities produce sufficient food to support individuals that inhabit the restored tidal marsh? Are surplus food resources exported out of the restored tidal marsh into adjacent open-water habitats used by covered fish species?	• Quantify the primary and secondary production, including food suitable for covered species, both within restored tidal marsh natural communities and transported from restored areas to adjacent open-water habitat and its fate.
How have hydrodynamic changes associated with tidal restoration affected organic carbon transport and fate?	• Quantify the flux of organic carbon produced in restored tidal marsh plain into existing channels in the Plan Area.
How has tidal marsh restoration affected benthic invertebrate communities?	• Determine the extent and patterns of establishment of nonnative clams in restored subtidal aquatic habitats. • Document and evaluate water quality conditions in restored subtidal aquatic habitats.
How are invasive bivalves affecting zooplankton production in restored tidelands?	• Assess density and foraging effectiveness of Asian clams or other invasive species that colonize restoration sites. Periodically repeat surveys to determine if delayed colonization occurs.
How is temporal habitat loss resulting from tidal natural communities restoration affecting saltmarsh harvest mouse and Suisun shrew?	• On restored tidal brackish marsh, perform a capture and release tagging study to determine colonization rate, abundance, and distribution of salt marsh harvest mouse. • On lands adjacent to planned tidal restoration sites, perform capture and release tagging study to determine whether a sufficient population of salt marsh harvest mouse exists to serve as a source population for recolonizing newly restored areas. • Conduct similar studies on Suisun shrew.
How do nonnative species use restored tidal natural communities?	• Evaluate potential colonization of restored tidal natural communities by invasive flora and fauna. • Assess effects of nonnative species in restoration sites on covered species and natural communities. Identify ways to avoid and minimize those impacts.

3.4.4.5 Consistency with the Biological Goals and Objectives

CM4 will advance the biological goals and objectives as identified in Table 3.4.4-3. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.4-3. Biological Goals and Objectives Addressed by CM4 and Related Monitoring Actions

Biological Goal or Objective	How CM4 Advances a Biological Objective	Monitoring Action(s)
Goal L1: A reserve system with representative natural and seminatural landscapes consisting of a mosaic of natural communities that is adaptable to changing conditions to sustain populations of covered species and maintain or increase native biodiversity.		
Objective L1.3: Restore and protect 65,000 acres of tidal natural communities and transitional uplands to accommodate sea level rise. Minimum restoration targets for tidal natural communities in each ROA are 7,000 acres in Suisun Marsh ROA, 5,000 acres in Cache Slough ROA, 1,500 acres in Cosumnes/Mokelumne ROA, 2,100 acres in West Delta ROA, and 5,000 acres in South Delta ROA.	Tidal perennial aquatic, tidal mudflat, and tidal brackish and freshwater natural communities will be restored, and adjacent transitional uplands will be protected to accommodate sea level rise for a total of 65,000 acres restoration and protection.	Compliance monitoring
Objective L1.4: Include a variety of environmental gradients (e.g., hydrology, elevation, soils, slope, and aspect) within and across a diversity of protected and restored natural communities.	Tidal restoration projects will be designed to provide gradual transition in elevation and hydrology, from subtidal areas, to marsh plain, to ecotonal areas and adjacent uplands.	CM4-1
Objective L1.7: Within the 65,000 acres of tidal natural communities and transitional uplands (Objective L1.3), include sufficient transitional uplands along the fringes of restored brackish and freshwater tidal emergent wetlands to accommodate up to 3 feet of sea level rise where possible and allow for the future upslope establishment of tidal emergent wetland communities that might be needed after the permit term.	Transitional uplands will be protected adjacent to tidally restored areas to accommodate up to 3 feet of sea level rise, where possible, and to allow for future upslope establishment of tidal emergent wetland communities. Some or all of the transitional uplands may become tidal during the 50-year permit term and beyond.	Compliance monitoring
Objective L1.8: To accommodate sea level rise, provide potential tidal marsh plain within the anticipated future eastward position of the low-salinity zone of the estuary.	Restoration in West Delta ROA will provide tidal marsh plains within the anticipated future eastward position of the low-salinity zone of the estuary with sea level rise.	Compliance monitoring

Biological Goal or Objective	How CM4 Advances a Biological Objective	Monitoring Action(s)
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.		
Objective L2.5: Maintain or increase the diversity of spawning, rearing, and migration conditions for native fish species in support of life-history diversity.	Tidal restoration is expected to improve some rearing habitat elements for Chinook salmon, Sacramento splittail, longfin smelt, delta smelt, sturgeons, and possibly steelhead. Tidal natural communities restoration in West Delta ROA is also expected to improve future rearing habitat suitability for delta smelt within the anticipated eastward movement of the low-salinity zone with sea level rise.	CM4-3
Objective L2.7: Produce sinuous, high-density, dendritic networks of tidal channels through tidal areas to promote effective exchange throughout the marsh plain and provide foraging habitat for covered fish species.	Where feasible, tidal restoration projects will be designed to meet this objective. This habitat element will provide direct foraging opportunities for salmon and splittail and, with sufficient amounts of restoration, may provide prey for pelagic fishes.	CM4-4
Objective L2.9: Increase the abundance and productivity of plankton and invertebrate species that provide food for covered fish species in the Delta waterways.	Restoration of tidal natural communities is expected to improve some rearing habitat elements for Chinook salmon, Sacramento splittail, longfin smelt, delta smelt, sturgeons, and possibly steelhead.	CM4-5
Objective L2.10: Restore or create 20 linear miles of transitional intertidal areas including tidal mudflat natural community and patches of subtidal and lower marsh.	Where feasible, tidal restoration projects will be designed to provide a suitable elevation and hydrologic gradient for achieving this objective.	Compliance monitoring
Goal L3: Capacity for movement of native organisms and genetic exchange among populations necessary to sustain native fish and wildlife species in the Plan Area.		
Objective L3.1: Protect and improve habitat linkages that allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area.	Tidal brackish restoration in the Suisun Marsh and West Delta ROAs will improve connectivity and provide a continuous reach of tidal marsh and subtidal aquatic natural communities between Yolo Bypass, the Cache Slough Complex, and Suisun Marsh and Suisun Bay.	Compliance monitoring
Goal TPANC1: Tidal perennial aquatic natural community that supports habitat elements for covered and other native species and that supports improved productivity of covered species.		
Objective TPANC1.1: Within the 65,000 acres of tidal natural communities and transitional uplands (Objective L1.3), restore or create tidal perennial aquatic natural community as necessary when creating tidal emergent wetland natural communities with an emphasis on shallow intertidal areas that provide habitat for covered and other native species.	Tidal restoration projects will be sited and designed to achieve this objective.	Compliance monitoring

Biological Goal or Objective	How CM4 Advances a Biological Objective	Monitoring Action(s)
Goal TBEWNC1: Large expanses and interconnected patches of tidal brackish emergent wetland natural community.		
Objective TBEWNC1.1: Within the 65,000 acres of tidal natural communities and transitional uplands (Objective L1.3), restore or create at least 6,000 acres of tidal brackish emergent wetland in Conservation Zone 11 among the Western Suisun/Hill Slough Marsh Complex, the Suisun Slough/Cutoff Slough Marsh Complex, and the Nurse Slough/Denverton Marsh Complex to be consistent with the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*.	Tidal restoration projects in Suisun Marsh ROA (Conservation Zone 11) will be sited and designed to meet this objective.	Compliance monitoring
Objective TBEWNC1.2: Within the at least 6,000 acres of restored or created tidal brackish emergent wetland (Objective TBEWNC1.1), distribute at least 1,500 acres of middle and high marsh among the Western Suisun/Hill Slough Marsh Complex, the Suisun Slough/Cutoff Slough Marsh Complex, and the Nurse Slough/Denverton Marsh Complex to contribute to total (existing and restored) acreage targets for each complex as specified in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*. Restore the at least 1,500 acres of middle and high marsh by year 25.	Tidal brackish emergent wetland restoration projects in Suisun Marsh ROA (Conservation Zone 11) will be sited and designed to collectively meet this objective. This will likely entail siting some restoration at the higher-elevation fringe of Suisun Marsh and implementing active restoration measures (e.g., earth moving, tule farming) as described in Section 3.4.4.3.3, *Methods and Techniques*, to ensure that sufficient middle and high marsh develop at a rate that exceeds sea level rise, so that restoration in subsided managed wetlands does not convert primarily to subtidal aquatic and low marsh natural communities.	Compliance monitoring
Objective TBEWNC1.3: Restore connectivity to isolated patches of tidal brackish emergent marsh where isolation has reduced effective use of these marshes by the species that depend on them.	Tidal brackish emergent wetland restoration projects will be sited and designed in Suisun Marsh to connect isolated patches consistent with this objective.	Compliance monitoring
Objective TBEWNC1.4: Create topographic heterogeneity in restored tidal brackish emergent wetland to provide variation in inundation characteristics and vegetative composition.	Tidal restoration projects will be designed to provide topographic heterogeneity consistent with this objective.	Compliance monitoring
Goal TFEWNC1: Large, interconnected patches of tidal freshwater emergent wetland natural community.		
Objective TFEWNC1.1: Within the 65,000 acres of tidal natural communities and transitional uplands to accommodate sea level rise (Objective L1.3), restore or create at least 24,000 acres of tidal freshwater emergent wetland in Conservation Zones 1, 2, 4, 5, 6, and/or 7.	Tidal restoration projects will be sited and designed to restore tidal freshwater emergent wetland and fully meet this objective.	Compliance monitoring
Objective TFEWNC1.2: Restore tidal freshwater emergent wetlands in areas that increase connectivity among conservation lands.	Tidal freshwater emergent wetland restoration projects will be sited and designed in areas that build off of existing protected lands to meet this objective.	Compliance monitoring

Biological Goal or Objective	How CM4 Advances a Biological Objective	Monitoring Action(s)
Goal TFEWNC2: Biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes and functions.		
Objective TFEWNC2.1: Restore and sustain a diversity of marsh vegetation that reflects historical species compositions and high structural complexity.	Tidal freshwater emergent wetland restoration projects will be sited and designed to meet this objective.	CM4-6
Objective TFEWNC2.2: Create topographic heterogeneity in restored tidal freshwater emergent wetland to provide variation in inundation characteristics and vegetative composition.	Tidal restoration projects will be designed to provide topographic heterogeneity consistent with this objective.	Compliance monitoring
Goal DTSM1: Increased end of year fecundity and improved survival of adult and juvenile delta smelt to support increased abundance and long-term population viability.		
Objective DTSM1.1: Increase fecundity over baseline conditions.[a]	One intended outcome of CM4 is increased primary productivity. This anticipated increase in primary productivity may contribute to an increase in food resources available to various life-stages of delta smelt. Increasing the density of food resources available to delta smelt and that co-occur with delta smelt in suitable/occupied habitat is anticipated to contribute to an increase in growth of delta smelt and thus an increase in per capita fecundity.	CM4-5
Objective DTSM1.3: Achieve an improved Recovery Index.[a]	One intended outcome of CM4 is increased primary productivity. This anticipated increase in primary productivity may contribute to an increase in food resources available to various life stages of delta smelt. Increasing the density of food resources that are available to delta smelt and that co-occur with delta smelt in suitable/occupied habitat is anticipated to increase delta smelt abundance.	CM4-5
Goal LFSM1: Increase fecundity and improved survival of adult and juvenile longfin smelt to support increased abundance and long-term population viability.		
Objective LFSM1.1: Achieve longfin smelt population growth.[a]	CM4 is expected to contribute toward increasing food supply for longfin smelt, thereby contributing to longfin smelt population growth.	CM4-5
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.		
Objective WRCS1.1: Improve through-Delta survival.[a]	Habitat conditions during juvenile rearing, including access to low velocity, shallow water habitat with few predators and abundant food supplies, are important for juvenile growth and survival. CM4 will provide suitable rearing habitat and increase the heterogeneity of habitat along key migration corridors, which likely to contribute to achieving this objective.	CM4-3, CM4-5

Biological Goal or Objective	How CM4 Advances a Biological Objective	Monitoring Action(s)
Goal SRCS1: Increase spring-run Chinook salmon abundance.		
Objective SRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM4-3, CM4-5
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.		
Objective FRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM4-3, CM4-5
Goal STHD1: Increased steelhead abundance.		
Objective STHD1.1: Objective STHD1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM4-3, CM4-5
Goal SAST1: Improved habitat and restored linkages to enhance survival, reproduction, and distribution of Sacramento splittail in the Plan Area.		
Objective SAST1.1: Improve splittail abundance.[a]	Tidal habitats, such as wetlands, are critical for splittail rearing. CM4 will directly contribute to providing tidally influenced wetlands, which are expected to contribute to increasing splittail abundance in the Plan Area.	CM4-3
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.		
Objective GRST1.1: Improve juvenile and adult survival.[a]	Historical reclamation of wetlands and islands and the channelization and hardening of levees with riprap have reduced and degraded the availability of suitable in- and off-channel habitat for subadult sturgeon. CM4 is expected to contribute to an increase in suitable rearing habitat for juvenile/subadult sturgeon as well as an increase in primary and secondary productivity, which may contribute to an increase in food available for juvenile and adult sturgeon that occur within the Plan Area. Increases in suitable habitat and food availability for juvenile and adult sturgeon are expected to contribute toward achieving this objective.	CM4-3, CM4-5
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.		
Objective WTST1.1: Improve juvenile and adult survival.[a]	See Objective GRST1.1 above.	CM4-3, CM4-5
Goal SMHM1: Suitable habitat and conditions to sustain a population of salt marsh harvest mouse in the reserve system.		
Objective SMHM1.1: Within the at least 1,500 acres of middle and high marsh restored under Objective TBEWNC1.2, provide viable habitat areas for salt marsh harvest mouse, as defined in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*. Meet population capture efficiency targets described in that plan.	Tidal brackish emergent wetland restoration projects in Suisun Marsh will be designed to provide salt marsh harvest mouse habitat with the appropriate vegetation composition to constitute Viable Habitat Areas, as defined in the Draft Tidal Marsh Recovery Plan, and as described in Section 3.4.4.3.4, *Siting and Design Considerations, Covered Species, Salt Marsh Harvest Mouse*.	Compliance monitoring, CM4-7, CM4-8

Biological Goal or Objective	How CM4 Advances a Biological Objective	Monitoring Action(s)
Goal GGS1: Well-connected high-value upland and aquatic giant garter snake habitat in Conservation Zones 4 and/or 5.		
Objective GGS1.1: Of the 1,200 acres of nontidal marsh created under Objective NFEW/NPANC1.1, create at least 600 acres of aquatic habitat for the giant garter snake that is connected to the 1,500 acres of rice land or equivalent-value habitat (Objective GGS1.4).	Tidal freshwater emergent wetland restoration in Conservation Zones 4 and/or 5 may contribute toward the 1,500-acre target in Objective GGS1.1, if the restored natural community meets the criteria for giant garter snake habitat as described under Section 3.4.4.3.4, *Siting and Design Considerations, Covered Species, Giant Garter Snake*.	Compliance monitoring, CM4-9
Objective GGS1.4: Create connections from the White Slough population to other areas in the giant garter snake's historical range in the Stone Lakes vicinity by protecting, restoring, and/or creating 1,500 acres of rice land or equivalent-value habitat (e.g., perennial wetland) for the giant garter snake in Conservation Zones 4 and/or 5. Any portion of the 1,500 acres may consist of tidal freshwater emergent wetland and may overlap with the at least 24,000 acres of tidally restored freshwater emergent wetland if it meets specific giant garter snake habitat criteria described in *CM4 Tidal Natural Communities Restoration*. Up to 500 (33%) of the 1,500 acres may consist of suitable uplands adjacent to protected or restored aquatic habitat.	Tidal restoration in Conservation Zones 4 and/or 5 that meet the giant garter snake habitat criteria described in Section 3.4.4.3.4, *Siting and Design Considerations*, *Covered Species*, *Giant Garter Snake*, will contribute to meeting this objective.	CM4-9
Goal CBR1: A reserve system that includes suitable habitat for the future growth and expansion of California black rail populations.		
Objective CBR1.1: At the ecotone that will be created between restored tidal freshwater emergent wetlands and transitional uplands (Objectives L1.3 and TFEW1.1), provide for at least 1,700 acres of California black rail habitat consisting of shallowly inundated emergent vegetation at the upper edge of the marsh (within 50 meters of upland refugia habitat) with adjacent riparian or other shrubs that will provide upland refugia, and other moist soil perennial vegetation.	Tidal freshwater emergent wetland will be restored consistent with this objective.	Compliance monitoring
Goal DTP/SMA1: A reserve system that supports the Delta tule pea and Suisun Marsh aster.		
Objective DTP/SMA1.1: No net loss of Delta tule pea and Suisun Marsh aster occurrences within restoration sites.	If Delta tule pea or Suisun Marsh aster occurrences are lost as a result of covered activities, occurrences will be established in tidal restoration sites to meet this objective.	CM4-6
Goal SBB/SuT1: Protected and expanded Suisun thistle and soft bird's-beak populations.		
Objective SBB/SuT1.1: Restore tidal inundation to wetlands in the Hill Slough Ecological Reserve and to the ponded area at Rush Ranch.	Tidal restoration under CM4 will be designed specifically to meet this objective.	Compliance monitoring

ROA = restoration opportunity area

[a] Summarized objective statement; full text presented in Table 3.3-1.

3.4.5 Conservation Measure 5 Seasonally Inundated Floodplain Restoration

Under *CM5 Seasonally Inundated Floodplain Restoration*, the Implementation Office will modify flood conveyance levees and infrastructure to restore 10,000 acres of seasonally inundated floodplain along river channels throughout the Plan Area. The floodplain restoration is separate from fisheries enhancement in Yolo Bypass: *CM2 Yolo Bypass Fisheries Enhancement* augments existing flood flows in the Yolo Bypass, whereas CM5 restores floodplains that historically existed elsewhere in the Plan Area but have been lost as a result of flood management and channelization activities. These restored floodplains will intentionally be allowed to flood to provide the benefits described in Section 3.4.5.1, *Purpose*. Restored floodplains will support valley/foothill riparian, nontidal freshwater perennial emergent, and nontidal perennial aquatic natural communities. Restored floodplains can remain in agricultural production as long as such activities meet the requirements for agricultural use described in Section 3.4.5.3.2, *Siting and Design Considerations*. CM5 actions will be phased, with at least 1,000 acres restored by year 15 and 10,000 acres (cumulative) by year 40.

Although seasonally inundated floodplains may be restored along channels in the north, east, and south Delta, the most promising opportunities for large-scale floodplain restoration are in the south Delta.

CM6 Channel Margin Enhancement and *CM7 Riparian Natural Community Restoration* will be combined with floodplain restoration (CM5) to provide a broad mosaic of natural communities and ecological functions. Floodplain restoration, channel margin enhancement, and riparian restoration are interrelated as described in Section 3.4.5.3.3, *Relationship with Other Conservation Measures*. The implementation of *CM7 Riparian Natural Community Restoration* depends partly on CM5, because at least 3,000 acres of riparian natural community will be implemented in restored floodplains. Seasonally inundated floodplain restoration (CM5) differs from channel margin enhancement (CM6) in that seasonally inundated floodplain restoration involves actions such as substantial levee setbacks (on the order of hundreds or thousands of feet) to allow for lateral channel migration and natural fluvial disturbances. While channel margin enhancement may involve levee setbacks in some cases, these setbacks will be relatively minor (setbacks on the order of a hundred feet or less) to provide for restoration of natural vegetation on the banks. Generally, channel margin enhancement actions will do little to restore natural channel migration and the accompanying ecological benefits that accrue from eroding banks and altered channel morphology.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM5. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM5 on covered species will be avoided or minimized. Refer to Chapter 5, Section 5.4, *Effects on Natural Communities*, Section 5.5, *Effects on Covered Fish*, and Section 5.6, *Effects on Covered Wildlife and Plant Species*, for effects of CM5 on natural communities and covered species.

3.4.5.1 Purpose

The purpose of CM5 is to restore floodplains to allow natural flooding regimes to achieve the following benefits.

- Increase the amount of functional floodplain habitat to increase the quantity and quality of rearing habitat for juvenile salmonids and sturgeon and spawning habitat for splittail, and to generate seasonal food resources for pelagic species (Ribeiro et al. 2004; Grosholz and Gallo 2006; Moyle et al. 2007; Jeffres et al. 2008).

- Promote regeneration of desirable natural community vegetation and structural diversity.
- Promote fluvial processes, such that vegetation is disturbed thereby creating variation in successional stages in riparian plant assemblages, bare mineral soils are available for natural colonization of vegetation and fresh deposits of sediments (i.e., fine sands and silt) are sorted and stored on the floodplain.
- Allow lateral river channel migration.
- Improve connectivity between rivers and their floodplains.
- Provide floodplains supporting riparian vegetation adjacent to rivers to allow input of large woody debris, leaves, and insects to river reaches, thereby increasing aquatic habitat structure and the abundance and productivity of plankton and invertebrate species that provide food resources for covered fish species (Sommer et al. 2004).
- Create seasonal inundation of the floodplain—including secondary or seasonal channels and pools in the floodplains—to create complex salmonid and splittail rearing and splittail spawning habitat, thereby providing a broad range of habitat conditions that support life-history diversity for covered and other native fish species over time (Ribeiro et al. 2004; Sommer et al. 2005).
- Protect and improve habitat linkages within the restored floodplain that allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area.

For descriptions of the ecological values and current condition of floodplain habitat in the Plan Area, see Chapter 2, *Existing Ecological Conditions,* and Section 3.3, *Biological Goals and Objectives*. Section 3.3 also describes the need for floodplain habitat restoration as a component of the conservation strategies for terrestrial and aquatic natural communities and associated covered species, based on the existing conditions and ecological values of these habitats.

3.4.5.2 Problem Statement

The discussion below describes conditions that will be improved through implementation of CM5.

Channel straightening and levee construction have disconnected river channels from their historical floodplains over much of the Plan Area, resulting in the reduction, degradation, and fragmentation of seasonally inundated floodplain and its associated natural communities. The result has been a decrease in rearing and juvenile foraging habitat for salmonids, a decrease in primary productivity and thus food resources available to planktivorous fishes, and a decline in the abundance and distribution of floodplain-associated species, including splittail, Chinook salmon, and slough thistle. Loss of floodplain has also resulted in loss of fluvial disturbance events that formerly produced high riparian vegetation diversity (Swenson et al. 2003) with suitable habitat conditions for many terrestrial riparian species such as yellow-billed cuckoo, yellow breasted chat, least Bell’s vireo, and riparian brush rabbit.

Splittail spawning is known to take place from February to July in freshwater on inundated floodplains in the Yolo and Sutter Bypasses and along the Cosumnes River (Sommer et al. 1997, 2001b, 2002; Crain et al. 2004; Moyle et al. 2004). The isolation of Delta islands and wetlands behind levees has removed or degraded large areas of high-value juvenile rearing and adult splittail spawning habitat (Moyle et al. 2004). In the 1960s and 1970s, USACE constructed levees and channelized the rivers and sloughs to increase the conveyance of water through the system and decrease flooding in the lower Sacramento River. These actions further reduced or eliminated suitable rearing habitat for splittail downstream from the city of Sacramento by substantially reducing floodplain connectivity as well as shallow channel margin habitat.

Juvenile salmon use natural stream banks, floodplains, marshes, and shallow-water habitats as rearing habitat during outmigration (Feyrer et al. 2005). Juvenile Chinook salmon rearing habitat has also been reduced by channel modifications and lack of access to floodplain habitat (Conomos et al. 1985; National Marine Fisheries Service 1996, 2009b; Yoshiyama et al. 1996, 2001; McEwan 2001; Mesick 2001; Moyle 2002; Williams 2006; McLain and Castillo 2009). This loss of foraging and rearing habitat may have contributed to reduction in the abundance and distribution of all anadromous salmonids in the Plan Area.

Several species of plants have also experienced a reduction in abundance and distribution related to the loss of the historical floodplain. Slough thistle is generally found in the portions of channels that flood at high water and on the banks of floodwater conveyance canals and drains (Griggs pers. comm.; Hansen pers. comm.). The reduction in slough thistle occurrence in the Plan Area is likely related to the loss of frequently scoured areas found in and along floodplains. The loss of woody debris and stumps that are typically associated with well-connected floodplain habitat are likely partially to blame for the limited distribution and abundance of side-flowering skullcap, as this species grows on decaying wood along channel banks.

3.4.5.3 Implementation

Seasonally inundated floodplain restoration will be achieved by implementing site-specific projects. Preparatory actions for each project may include interagency coordination, feasibility evaluations, site or easement acquisition, modifications to agricultural practices, engineering design, development of site-specific plans, and environmental compliance, if necessary, as described in *CM3 Natural Communities Protection and Restoration.*

A conceptual illustration of restored seasonally inundated floodplain with associated channel margin enhancement and riparian restoration is presented in Figure 3.4-19. Because restoration may require modification of levees that serve flood management functions, floodplain habitats will be restored in a manner that maintains flood conveyance capacity.

3.4.5.3.1 Restoration Actions

Actions to restore seasonally inundated floodplain habitats may include but are not limited to the following.

- Set levees back along selected river corridors and remove or breach levees thereby rendered nonfunctional.
- Create and expand new floodway bypasses to expand floodplain habitat and redirect flood flows along distributary channel networks into the estuary.
- Remove existing riprap or other bank protection to allow for channel migration between the setback levees through the natural processes of erosion and sedimentation. This will reestablish floodplain processes and support creation and maintenance of spawning and rearing habitat.

- Modify channel geometry in unconfined channel reaches or along channels where levees are set back in order to create backwater salmonid (Kjelson et al. 1982; Sommer et al. 2005) and splittail (Feyrer et al. 2005) rearing habitat.
- Secure lands, in fee-title or through conservation easements, suitable for restoration of seasonally inundated floodplain.
- Selectively grade restored floodplain surfaces to provide for drainage of overbank flood waters such that the potential for fish stranding is minimized.
- Lower the elevation of restored floodplain surfaces or modify river channel morphology to increase inundation frequency and duration and to establish elevations suitable for the establishment of riparian vegetation by either active planting or allowing natural establishment.
- Continue to farm in the floodplain consistent with achieving biological objectives, engaging in farming practices and crop types that provide high benefits for covered fish species.
- In cases where farming is no longer feasible or compatible with floodplain habitat goals, discontinue farming within the setback levees and allow native riparian vegetation to naturally establish on the floodplain or actively plant native riparian vegetation.

3.4.5.3.2 Siting and Design Considerations

Concept-level planning has resulted in the identification of four south Delta corridors (Figure 3.4-20) for potential implementation of floodplain restoration. Restoration sites for seasonally inundated floodplains will be selected based on the following considerations.

- Potential to meet or contribute to the applicable biological goals and objectives.
- Relative importance of the adjacent channel for use by covered species, especially by rearing/migrating juvenile salmonids.
- Potential to provide ecologically relevant flood inundation (i.e., areas inundated with the timing, frequency, and duration required by native species such as splittail and salmonids) given the anticipated range of flow regimes and sea level conditions influenced by climate change and potential management changes (i.e., the San Joaquin River Restoration Program's Restoration Flow Regime).
- Flood conveyance and risk reduction benefits provided relative to other potential restoration sites.
- Compatibility with ongoing agricultural uses.

Restoration designs for seasonally inundated floodplains will consider the following elements.

- **Floodplain topography.** Where appropriate, the topography of restored floodplains will be modified to reduce the risk of fish stranding and to provide topographic variability to increase hydraulic complexity when flooded.
- **Geomorphology.** The morphology of the river channel and floodplain will change when levees are removed and subsequent flood flows work the bed and banks of the river. For example, in some locations the bed of the river, which may currently be scoured between levees, may aggrade and widen, allowing for greater frequency and magnitude of floodplain inundation under a given flood flow regime.

- **Connectivity.** Where suitable landform is present, restored floodplains will be located and designed such that flows exiting the floodplain pass through existing or restored tidal marsh to recreate historical landscape proximity and to provide for connectivity with adjacent uplands that result in transitional habitats that accommodate species movement.
- **Habitat restoration on restored floodplains.** Native riparian forest and scrub vegetation will be actively or passively established in restored floodplain areas consistent with floodplain land uses and flood management requirements. Restored floodplains will provide a large area suitable to meet the 5,000-acre target for restoration of woody riparian habitat under *CM7 Riparian Natural Community Restoration*; approximately 80% of the riparian natural community restoration will occur at these restored floodplain sites. Established woody riparian vegetation will support habitat for riparian-associated covered species and provide cover and hydraulic complexity for covered fish species during inundation periods. Riparian vegetation will also serve as a source of instream woody material for fish habitat, organic carbon in support of the aquatic foodweb, and macroinvertebrates (e.g., insects) that provide food for covered fish species (CM7).
- **Land use on restored floodplains.** Restored floodplains may maintain existing agricultural uses that are compatible with the primary goal of restoring habitat for covered fish and wildlife species. To be included in the reserve system, cultivated lands in restored floodplains must comply with the following performance standards.
  - The use is compatible with seasonal inundation.
  - The farmed lands provide benefit to covered species (e.g., areas for rearing, foraging, and spawning by covered fishes).
  - Practices are implemented that do not preclude achievement of BDCP biological goals and objectives.
  - The use of persistent herbicides and pesticides that are toxic to aquatic organisms is avoided.
  - Practices are implemented that minimize disturbance of emergent woody vegetation and subsequent forest development necessary to meet the riparian natural community requirements, summarized in Table 3.4.7-1.
  - In areas with low risk of methylmercury production, promote cover and hydraulic complexity for fish by providing structure and biomass from residual crop material.
  - Provide sources of organic carbon in support of aquatic foodweb processes during inundation periods by leaving crop waste onsite.

3.4.5.3.3 Relationship with Other Conservation Measures

CM5 Seasonally Inundated Floodplain Restoration, *CM3 Natural Communities Protection and Restoration*, *CM6 Channel Margin Enhancement*, *CM7 Riparian Natural Community Restoration*, and *CM11 Natural Communities Enhancement and Management* are interrelated. Table 3.4.5-1 summarizes the relationship between CM5 and these other conservation measures. CM3 and CM11 will spatially overlap with CM5. CM7 may also spatially overlap with CM5 and CM6. CM5 and CM6 will not spatially overlap but may substitute each other in some cases, as described below.

CM7 requires 5,000 acres of riparian natural community restoration and will spatially overlap with CM5 and CM6. At least 3,000 of the 5,000 acres of the riparian natural community restoration must occur on the restored floodplain, and riparian restoration on restored channel margins will also contribute toward the 5,000 acres of riparian natural community restoration. The remainder of the 5,000 acres may occur anywhere in the Plan Area as long as it meets the biological goals and objectives, but at least a portion is expected to occur in association with tidal restoration (CM4).

A restoration project may, in some cases, involve a combination of floodplain restoration and channel margin enhancement. For example, if the levee is set back on one side of the river to provide inundated floodplain habitat and to allow channel migration and fluvial processes to occur, but the levee cannot be set back on the other side of the river, then the channel margin may be enhanced on the constrained side as described in CM6.

Floodplain restoration beyond the 10,000-acre requirement may substitute for portions of the 20-mile channel margin requirement, if it advances the biological goals and objectives for channel margin enhancement as described in Section 3.4.6.5, *Consistency with the Biological Goals and Objectives*, and if it occurs in the Sacramento or Cosumnes-Mokelumne basins. The use of floodplain restoration in place of channel margin enhancement will be based on the length of restored floodplain along the river channel (i.e., the distance of channel margin along the length of restored floodplain).

Table 3.4.5-1. Relationship between CM5 and other Conservation Measures

Conservation Measure	Ecological Functions and Relationship with other Conservation Measures
CM3 Natural Communities Protection and Restoration	Natural communities that are protected in the restored floodplain and retain their ecological values (e.g., protected riparian natural community, or protected cultivated lands that retain covered species habitat values) will contribute to the protection target acreages for those natural communities, provided that they meet the objectives for the natural community.
CM5 Seasonally Inundated Floodplain Restoration	Floodplain restoration involves levee setbacks sufficient to allow lateral channel migration and other fluvial processes (i.e., sediment deposition, flood storage). CM5 may be combined with CM6 in restoration projects (but with no spatial overlap), or CM5 may substitute CM6, as described in Section 3.4.5.3.3, *Relationship with Other Conservation Measures*. At least 3,000 of the 5,000 acres required under CM7 will occur on restored floodplains in association with CM5.
CM6 Channel Margin Enhancement	Channel margin enhancement involves no levee setbacks, or small setbacks that do not allow for lateral channel migration, but provide a "floodplain bench" where shallow water, channel edge habitat with greater habitat complexity is provided. Such habitat will provide cover from large predators and foraging opportunities for outmigrating juvenile fish. CM6 may be combined with CM5 in restoration projects (but with no spatial overlap), or CM6 may substitute CM5, as described in Section 3.4.5.3.3, *Relationship with Other Conservation Measures*. Any riparian restoration associated with CM6 will contribute to the 5,000-acre riparian restoration requirement under CM7.
CM7 Riparian Natural Community Restoration	Riparian restoration involves restoration of the riparian natural community with native vegetation. At least 3,000 acres of riparian restoration will occur in large blocks on restored floodplains. Riparian restoration may occur on enhanced channel margins, although it will likely only consist of narrow, linear corridors.
CM11 Natural Communities Enhancement and Management	Natural communities that are protected or restored in the restored floodplain to meet the BDCP protection and restoration requirements will be managed and enhanced consistent with the objectives for the natural community.

3.4.5.4 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring for this conservation measure will consist of documenting in a GIS database the extent of floodplain successfully restored, and mapping restored habitat for each covered species expected to use these areas based on habitat models.

Effectiveness monitoring will be conducted to evaluate progress toward advancing the objectives listed in Section 3.4.5.5, *Consistency with the Biological Goals and Objectives.* If necessary, the implementation actions described above will be adjusted via adaptive management, as described in Section 3.6, to meet these objectives.

Effectiveness monitoring will consist of verifying that restoration sites are performing the expected ecological functions as prescribed by success criteria in the site-specific restoration plans. See Section 3.4.3.4.2, *Site-Specific Restoration Plans*, for a description of relevant monitoring actions, metrics, success criteria, and schedules. Table 3.4.5-2 provides potential monitoring actions, metrics, success criteria, and timing and duration relevant to CM5. These monitoring elements may be modified, as necessary, to best assess the effectiveness of CM5, based on the best available information at the time of implementation.

If success criteria are not met within the specified schedule, contingency measures will be implemented as described in the site-specific restoration plan. Contingency measures to be implemented if floodplain restoration is unsuccessful may include, but are not limited to, removal of breached levees or recontouring floodplain topography.

In addition, one key uncertainty is associated with seasonally inundated floodplain restoration: How is predation affecting covered fishes in the restored floodplain? The distribution and abundance of covered fish species and predators at restoration sites will be evaluated to resolve this uncertainty.

Table 3.4.5-2. Effectiveness Monitoring Relevant to CM5

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM5-1	Site-level assessment	Floodplain elevations and flooding frequency and duration	A range of elevations that transition from frequently flooded (e.g., every 1 to 2 years) to infrequently flooded (e.g., every 10 years or more)	Annually for first 5 years after floodplain restoration and every 5 years thereafter until the end of the permit term
CM5-2	Site-level assessment	Lateral channel migration	Occurrence of lateral channel migration in restored floodplains	Every 5 years following floodplain restoration until end of permit term
CM5-3	Site-level assessment	Hydrologic connectivity	As specified in site-specific restoration plan	As specified in site-specific management plan
CM5-4	Plankton and invertebrate sampling in restored floodplain	Plankton and invertebrate presence in restored floodplain (plankton and invertebrate abundance may fluctuate based on predation by juvenile fish, water temperature, and fluctuations in the duration, extent, and frequency of floodplain inundation)	Plankton and invertebrate presence, as well as presence of juvenile fishes that may feed upon them (presence of juvenile fishes may result in decreased plankton and invertebrate abundance [Grosholz and Gallo 2006])	Every 5 years following floodplain restoration until end of permit term
CM5-5	Landscape-level assessment of restored floodplains throughout reserve system	Habitat connectivity for covered species	Increased connectivity between primary channels and seasonal floodplains, as well as use by covered species while avoiding stranding of covered fish species	Every 5 years following floodplain restoration until end of permit term
CM5-6	Frequency, duration, and extent of inundation of restored floodplain habitat in the South Delta	On average, out of 10,000 acres of restored floodplain, 50 acres of floodplain will be inundated a minimum of every other year, 500 acres will be inundated a minimum of every 5 years, and all 1,000 acres will be inundated a minimum of once every 10 years, by year 15.	To be inundated for a period of 1 week between December and June	Annually, following floodplain restoration until end of permit term

3.4.5.5 Consistency with the Biological Goals and Objectives

CM5 will advance the biological goals and objectives as identified in Table 3.4.5-3. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Table 3.4.5-3 also identifies the monitoring actions associated with each objective as it relates to CM5.

1 **Table 3.4.5-3. Biological Goals and Objectives Addressed by CM5 and Related Monitoring Actions**

Biological Goal or Objective	How CM5 Advances Biological Objective	Monitoring Action(s)
Goal L1: A reserve system with representative natural and seminatural landscapes consisting of a mosaic of natural communities that is adaptable to changing conditions to sustain populations of covered species and maintain or increase native biodiversity.		
Objective L1.5: In restored floodplains, provide a range of elevations that transition from frequently flooded (e.g., every 1 to 2 years) to infrequently flooded (e.g., every 10 years or more) areas to provide a range of habitat conditions, upland habitat values, and refugia from flooding during most flood events.	Floodplains will be restored with sufficient width to provide a transition from areas adjacent the main channel that are frequently flooded, to more upland areas that seldom flood and typically provide upland habitat values and refugia from most flood events.	CM5-1
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.		
Objective L2.1: Allow floods to promote fluvial processes, such that bare mineral soils are available for natural recolonization of vegetation, desirable natural community vegetation is regenerated, and structural diversity is promoted, or implement management actions that mimic those natural disturbances.	Floodplain restoration projects will be designed to promote periodic vegetation disturbances from flooding, to result in structural habitat diversity by creating a patchwork of riparian vegetation at different ages.	CM7-1, CM7-2
Objective L2.2: Allow lateral river channel migration.	Floodplains will be restored with sufficient width to allow lateral channel movement through the processes of erosion, deposition, and avulsion.	CM5-2
Objective L2.3: Connect rivers and their floodplains to allow input of large woody debris, leaves, and other organic material to rivers.	Floodplain restoration will connect channels with the vegetated floodplain and will allow for channel migration, thus promoting the input of large woody debris, organic material and insects to rivers.	CM5-3
Objective L2.9: Increase the abundance and productivity of plankton and invertebrate species that provide food for covered fish species in the Delta waterways.	Floodwaters on the restored floodplain will benefit fish by cycling nutrients and producing abundant plankton and aquatic insects (Jeffres et al. 2008).	CM5-4
Objective L2.11: Restore 10,000 acres of seasonally inundated floodplain.	CM5 will be implemented to fully achieve this objective.	Compliance monitoring
Goal L3: Capacity for movement of native organisms and genetic exchange among populations necessary to sustain native fish and wildlife species in the Plan Area.		
Objective L3.1: Protect and improve habitat linkages that allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area.	The restored floodplain and its associated vegetation is expected to establish or enhance habitat linkages along rivers for terrestrial wildlife.	CM5-5

Biological Goal or Objective	How CM5 Advances Biological Objective	Monitoring Action(s)
Goal VFRNC2: Increased structural diversity including a mosaic of seral stages, age classes, plant zonation, and plant heights and layers characteristic of valley/foothill riparian natural community.		
Objective VFRNC2.1: Restore, maintain, and enhance structural heterogeneity with adequate vertical and horizontal overlap among vegetation components and over adjacent riverine channels, freshwater emergent wetlands, and grasslands.	Floodplain restoration projects will be designed to create fluvial conditions that encourage patterns of disturbance and regrowth to produce structural heterogeneity.	CM7-2
Objective VFRNC2.2: Maintain 1,000 acres of early- to midsuccessional vegetation with a well-developed understory of dense shrubs on restored seasonally inundated floodplain.	Floodplain restoration projects will be designed to create fluvial conditions that encourage patterns of disturbance and regrowth to generate early- to midsuccessional vegetation.	CM7-3, compliance monitoring
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.		
Objective WRCS1.1: Improve through-Delta survival.[a]	Habitat conditions during juvenile rearing, including access to low-velocity, shallow-water habitat with few predators and abundant food supplies, are important for juvenile growth and survival. CM5 is intended to contribute to an increase in suitable rearing habitat for juvenile salmonids in the Plan Area, and particularly along key migration routes, which is intended to increase through-Delta survival. Seasonally inundated floodplain is expected to provide suitable rearing conditions (i.e., suitable water depths, cover from predators, food), as well as improve migration corridors.	CM5-3, CM5-4, CM5-5
Goal SRCS1: Increased spring-run Chinook salmon abundance.		
Objective SRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM5-3, CM5-4, CM5-5, CM5-6
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.		
Objective FRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM5-3, CM5-4, CM5-5, CM5-6
Goal STHD1: Increased steelhead abundance.		
Objective STHD1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM5-3, CM5-4, CM5-5, CM5-6

Biological Goal or Objective	How CM5 Advances Biological Objective	Monitoring Action(s)
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.		
Objective GRST1.1: Improve juvenile and adult survival.[a]	Historical reclamation of wetlands and islands, as well as channelization and hardening of levees with riprap, has reduced and degraded the availability of suitable in- and off-channel habitat for subadult sturgeon. CM5 is expected to contribute to an increase in primary and secondary productivity, which may contribute to an increase in food available for juvenile and adult sturgeon that occur in the Plan Area. Increases in suitable habitat and food availability for juvenile and adult sturgeon are expected to contribute toward achieving this objective.	CM5-4
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.		
Objective WTST1.1: Improve juvenile and adult survival.[a]	See Objective GRST1.1 above.	CM5-4
[a] Summarized objective statement; full text presented in Table 3.3-1.		

3.4.6 Conservation Measure 6 Channel Margin Enhancement

Under *CM6 Channel Margin Enhancement*, the Implementation Office will restore 20 linear miles of channel margin by improving channel geometry and restoring riparian, marsh, and mudflat habitats on the water side of levees along channels that provide rearing and outmigration habitat for juvenile salmonids. Linear miles of enhancement will be measured along one side or the other of a given channel segment (e.g., if both sides of a channel are enhanced for a length of 1 mile, this would account for a total of 2 miles of channel margin enhancement). At least 10 linear miles will be enhanced by year 10, and enhancement will then be phased in 5-mile increments at years 20 and 30, for a total of 20 miles by year 30. At least 15 miles of the enhancement will be sited along the channels of one or more of the following water bodies: the Sacramento River, Steamboat Slough, and Sutter Slough.

This conservation measure provides an overview of and guidelines for implementing channel margin enhancement. Additional information on channel margin enhancement suitable to implementing projects in the field will appear in detailed design and permitting documents for the projects as they are proposed, developed, and permitted.

The relationship between this conservation measure, *CM5 Seasonally Inundated Floodplain Restoration* and *CM7 Riparian Natural Community Restoration* is described in Section 3.4.5.3.3, *Relationship with Other Conservation Measures*. Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM6. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM6 on covered species will be avoided or minimized. Refer to Chapter 5, Section 5.4, *Effects on Natural Communities*, Section 5.5, *Effects on Covered Fish*, and Section 5.6, *Effects on Covered Wildlife and Plant Species*, for effects of CM6 on natural communities and covered species.

3.4.6.1 Purpose

The primary purpose of CM6 is to improve habitat conditions along important juvenile salmonid migration routes. CM6 is expected to increase rearing habitat; improve conditions along migration corridors by providing increased habitat complexity, overhead and in-water cover, and prey resources for covered fish species; and improve connectivity between patches of existing, higher-value channel margin habitat. This conservation measure also has the potential to increase spawning habitat for covered fish that spawn in the Plan Area, possibly delta smelt and longfin smelt, as well as increase resting habitat in the Plan Area for migrating adult covered fish species.

Primary Delta channels serve as migration corridors for the covered fish species and provide salmonid, sturgeon, and splittail rearing habitat. Chinook salmon and sturgeon use channel margin habitat for rearing and protection from predators. Vegetation along channel margins contributes woody material, both instream and on channel banks, which increases instream cover for fish and enhances habitat for western pond turtle.

CM6 is expected to increase rearing habitat for Chinook salmon fry in particular, through enhancement and creation of additional shallow-water habitat that will provide foraging opportunities and refuge from unfavorable hydraulic conditions and predation. Benefits for larger Chinook salmon juveniles and steelhead may be somewhat less than for Chinook salmon fry, although enhanced channel margins may serve as holding areas during downstream migration. Rearing habitat for Sacramento splittail may also increase under CM6. Delta smelt and longfin smelt may experience small increases in rearing habitat, because monitoring suggests that these species tend to occupy areas away from shore and are largely found downstream of the main channels proposed for channel margin enhancement. There may be some rearing benefit for green and white sturgeon from channel margin enhancement. Although little is known about use of channel margin habitat by Pacific lamprey and river lamprey, these species may benefit from enhancement that increases the area of nonrevetted substrate into which ammocoetes can burrow; recent monitoring suggests that ammocoetes may be relatively abundant in substrates in the Plan Area.

The focus of CM6 is to provide enhanced channel margin habitat along important juvenile salmonid migration routes; consequently, the measure will improve connectivity between patches of higher-value enhanced channel margins and primary channels. This is particularly necessary for reaches that currently have low habitat value for covered fishes and are heavily used by migrating and rearing fish—for example, the Sacramento River between Freeport and Georgiana Slough. Enhanced channel margin in the vicinity of the proposed north Delta intakes (upstream, between the intakes, and downstream) would provide resting spots and refuge for fish moving through this reach.

Any channel margin enhancements that increase the area of low-slope, sandy substrate may provide increases in delta smelt and longfin smelt spawning habitat; however, at present the distribution of these species is mostly found downstream and west of the main channels where the emphasis of CM6 is likely to be placed (e.g., Sacramento River from Freeport to Georgiana Slough, Steamboat and Sutter Sloughs, the lower Mokelumne River, and the San Joaquin River from Vernalis to Mossdale). The remaining covered fish species spawn upstream of the Plan Area; therefore, no increase in spawning habitat is anticipated for these species under CM6.

3.4.6.2 Problem Statement

For descriptions of the ecological values and current condition of channel margins in the Plan Area, see Chapter 2, *Existing Ecological Conditions,* and Section 3.3, *Biological Goals and Objectives*. Section

3.3 also describes the need for channel margin enhancement as a component of the conservation strategies for terrestrial and aquatic natural communities and associated covered species, based on the existing conditions and ecological values of these resources.

Most channels in the Delta are flanked by levees. In these areas, channel margins lack the diversity and complexity of habitat conditions associated with unmodified channels. Because of the riprap armoring on many levees, adjacent channel margins are devoid of vegetation or have only low-quality vegetation that provides very limited benefits for covered species. Without vegetation along channel margins to provide shade and nutrient inputs, habitat value for covered fishes in these channels has declined. Both the quality and quantity of riparian, emergent wetland, and tidal mudflat habitat for covered terrestrial species have declined as a result of the construction of channel-margin levees.

3.4.6.3 Implementation

Channel margin enhancement will be achieved by implementing site-specific projects. Prior to channel margin enhancement construction (the on-the-ground activities that will put the channel margin enhancements in place) for each project, preparatory actions may include interagency coordination, feasibility evaluations, site acquisition, development of site-specific plans, and environmental compliance, as described further in *CM3 Natural Communities Protection and Restoration.* After construction, each project will be monitored and adaptively managed to ensure that the success criteria outlined in the site-specific restoration plan are met, as described below in Section 3.4.6.4, *Adaptive Management and Monitoring*. Channel margin enhancement actions will often be implemented in conjunction with *CM5 Seasonally Inundated Floodplain Restoration* and *CM7 Riparian Natural Community Restoration* actions, as described in Section 3.4.5.3.3, *Relationship with Other Conservation Measures*.

3.4.6.3.1 Enhancement Actions

Channel margin enhancement, as appropriate to site-specific conditions, includes the following actions (Figure 3.4-21).

- Modify the waterward side of levees or set back levees landward to create low floodplain benches. Construct the floodplain benches with variable surface elevations and water depths (laterally and longitudinally) to create hydrodynamic complexity, support emergent vegetation, and provide an ecological gradient of environmental conditions.
- Install large woody debris (e.g., tree trunks, logs, and stumps) into constructed benches to provide physical complexity. Use finely branched material to minimize refuge for aquatic predators. Large woody debris will be installed to replace debris lost during enhancement; woody debris also is expected to increase or be replaced over time through recruitment from adjacent riparian vegetation.
- Plant native riparian and/or emergent wetland vegetation on constructed benches; open mudflat habitat may be appropriate too, depending on elevation and location.

These actions will be implemented along channels protected by levees in the Plan Area. At least 15 miles of the enhancement will be sited along the channels of one or more of the following water bodies: the Sacramento River, Steamboat Slough, and Sutter Slough. Channel margin enhancements associated with federal project levees will not be implemented on the levee, but rather on benches to the waterward side of such levees, and flood conveyance will be maintained as designed.

3.4.6.3.2 Siting and Design Considerations

Channel margin enhancement will be performed only along channels that provide rearing and outmigration habitat for juvenile salmonids (Figure 3.4-22). These include channels that are protected by federal project levees—including the Sacramento River between Freeport and Walnut Grove, the San Joaquin River between Vernalis and Mossdale, and Steamboat and Sutter Sloughs—and channels in the interior Delta that are protected by nonfederal levees—including the North and South Fork Mokelumne River.

Because channel margin enhancement will modify channels and levees with flood management functions, enhancements will be implemented to maintain or improve these functions. The Implementation Office will coordinate channel margin enhancement with the planning efforts of flood management agencies, including USACE, DWR, the Central Valley Flood Protection Board.

The following factors will also be considered when evaluating sites for potential location and design of enhanced channel margins.

- Existing poor habitat quality and biological performance for covered fish species, combined with extensive occurrence of covered fish species.
- Locations where migrating salmon and steelhead are likely to require rest during high flows.
- The length of channel margin that can be practicably enhanced and the distance between enhanced areas (There may be a tradeoff between enhancing multiple shorter reaches that have less distance between them and enhancing relatively few longer reaches with greater distances between them).The potential for native riparian plantings to augment breeding and foraging habitat for riparian covered species, such as Swainson's hawk, western yellow-billed cuckoo, least Bell's vireo, tricolored blackbird, and riparian brush rabbit, in proximity to known occurrences.
- The potential to create mudflats near known occurrences of' Suisun Marsh aster, Mason's lilaeopsis, delta mudwort, Delta tule pea and side-flowering skullcap, thereby creating opportunities for natural colonization of new habitat for these species.
- The potential cross-sectional profile of enhanced channels (elevation of habitat, topographic diversity, width, variability in edge and bench surfaces, depth, and slope).
- The potential amount and distribution of installed woody debris along enhanced channel margins.
- The extent of shaded riverine aquatic overstory and understory vegetative cover needed to provide future input of large woody debris.

3.4.6.4 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring for this conservation measure will consist of documenting in a GIS database the extent of channel margin successfully enhanced, and mapping restored habitat for each covered species expected to use this natural community based on habitat models.

Effectiveness monitoring will be conducted to evaluate progress toward advancing the landscape-scale, natural community and species-specific (i.e., fish) objectives discussed below in Section 3.4.6.5, *Consistency with the Biological Goals and Objectives.* If necessary, the implementation actions described above will be adjusted via adaptive management, as described in Section 3.6, to meet these objectives. Effectiveness monitoring will consist of verifying that enhancement sites are performing the expected ecological functions as prescribed by success criteria in the site-specific restoration plans. See Section 3.4.3.4.2, *Site-Specific Restoration Plans*, for a description of relevant monitoring actions, metrics, success criteria, and schedules. Table 3.4.6-1 provides potential monitoring actions and success criteria relevant to CM6.

Table 3.4.6-1. Effectiveness Monitoring Relevant to CM6

ID #	Monitoring Actions	Success Criteria
CM6-1	Assess whether splittail spawn in enhanced channel margins	Occurrence of spawning splittail, particularly during dry years when seasonally inundated floodplain habitat may be functioning at capacity
CM6-2	Assess the extent to which juvenile salmon and splittail hold and forage in enhanced channel margins	Occurrence of juvenile salmonids and splittail during periods of rearing and outmigration in the Plan Area
CM6-3	Assess whether piscivorous predators use woody debris associated with enhanced channel margins as ambush cover	Negligible use of woody debris in channel margins by known predators such as striped and largemouth bass
CM6-4	Measure plankton and invertebrate abundance in aquatic habitat within and adjacent to enhanced channel margins	Increased plankton and invertebrate abundance
CM6-5	Evaluate the distribution and abundance of covered fish species and predators at enhancement sites	Increased distribution and abundance of covered fish species and decreased distribution and abundance of predators at enhancement sites

If success criteria are not met within the schedule identified in the site-specific restoration plan, contingency measures will be implemented as described in the restoration plan. Contingency measures to be implemented if channel margin enhancement is unsuccessful may include, but are not limited to, additional enhancement actions as described in Section 3.4.6.3.1, *Enhancement Actions*.

No key uncertainties or research needs have been identified in connection with this conservation measure.

3.4.6.5 Consistency with the Biological Goals and Objectives

CM6 will advance the biological goals and objectives as identified in Table 3.4.6-2. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Table 3.4.6-2 also identifies potential monitoring actions associated with each objective as it relates to CM6.

Table 3.4.6-2. Biological Goals and Objectives Addressed by CM6 and Related Monitoring Actions

Biological Goal or Objective	How CM6 Advances a Biological Objective	Monitoring Action(s)
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.		
Objective L2.5: Maintain or increase the diversity of spawning, rearing, and migration conditions for native fish species in support of life-history diversity.	Channel margin enhancement is expected to increase the quality and area of rearing habitat for Chinook salmon, sturgeon, and possibly steelhead, by providing expanded nearshore habitat with improved inputs of terrestrial organic matter, insects, and woody material; riparian shade; and underwater cover (Sommer et al. 2001a, 2001b, 2002, 2007a, 2008; Moyle 2002; Moyle et al. 2004; Nakano and Murakami 2001; Feyrer et al. 2006).	CM6-1
Objective L2.8: Provide refuge habitat for migrating and resident covered fish species.	Enhancement of channel margins along migration routes within the Plan Area used by covered fish species and creation of habitat that provides refuge from flows, overhead and instream cover for protection from predators, emergent and riparian vegetation that produce organic carbon in support of the foodweb, and macroinvertebrates (a food source for covered fish species). This is expected to work in tandem with *CM13 Invasive Aquatic Vegetation Control*.	CM6-2
Objective L2.9: Increase the abundance and productivity of plankton and invertebrate species that provide food for covered fish species in the Delta waterways.	Establishment of riparian vegetation on channel margins will provide inputs of organic material (e.g., leaf and twig drop) into channels, resulting in increased production of zooplankton and macroinvertebrates that serve as or support production food for covered fish species. It will also increase the production and export of terrestrial invertebrates into the aquatic ecosystem (Nakano and Murakami 2001) where riparian vegetation is restored adjacent to channels to provide food for covered fish and western pond turtle.	CM6-4
Objective L2.12: Enhance 20 miles of channel margin in the Sacramento River and San Joaquin River systems to provide habitat along important migratory routes for anadromous fish and improve wildlife movement.	Channel margin enhancement will be performed as described in Section 3.4.6.3, *Implementation*, only along channels that provide rearing and outmigration habitat for juvenile salmonids. These channels include the Sacramento River between Freeport and Walnut Grove, the San Joaquin River between Vernalis and Mossdale, North and South Fork Mokelumne River, and Steamboat and Sutter Sloughs.	Compliance monitoring

Biological Goal or Objective	How CM6 Advances a Biological Objective	Monitoring Action(s)
Goal L3: Capacity for movement of native organisms and genetic exchange among populations necessary to sustain native fish and wildlife species in the Plan Area.		
Objective L3.1: Protect and improve habitat linkages that allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area.	Although channel margins will only be enhanced along channels that provide rearing and outmigration habitat for juvenile salmonids, and the riparian vegetation along channel margins will only be established in narrow strips, the riparian vegetation may provide limited opportunities for movement of terrestrial species as an ancillary benefit of channel margin enhancement.	CM6-4
Goal L4: Increased habitat suitability for covered fish species in the Plan Area.		
Objective L4.1: Manage the distribution and abundance of nonnative predators in the Delta to reduce predation on covered fishes.	Replacement of riprap levee embankments with shallow-water, natural substrate nearshore habitat is expected to improve habitat suitability for covered fish species and thereby reduce the risk of predation on native fish. Placement of large woody debris during early enhancement actions will be limited to wood that includes finely branched material, because it is not expected to provide refuge for aquatic predators; over time the restored riparian natural community is expected to supply this finely branched material.	CM6-3
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.		
Objective WRCS1.1: Improve through-Delta survival.[a]	Habitat conditions during juvenile rearing, including access to low-velocity, shallow-water habitat with few predators and abundant food supplies, are important for juvenile growth and survival. CM6 is intended to contribute to an increase in suitable rearing habitat for juvenile salmonids in the Plan Area, particularly along key migration routes, which may contribute to increased through-Delta survival. Enhancement of channel margins is expected to provide suitable rearing conditions (i.e., suitable water depths, cover from predators, food), as well as improve migration corridors.	CM6-2, CM6-3, CM6-4, CM6-5
Goal SRCS1: Increase spring-run Chinook salmon abundance.		
Objective SRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM6-2, CM6-3, CM6-4, CM6-5
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.		
Objective FRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM6-2, CM6-3, CM6-4, CM6-5

Biological Goal or Objective	How CM6 Advances a Biological Objective	Monitoring Action(s)
Goal STHD1: Increased steelhead abundance.		
Objective STHD1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM6-2, CM6-3, CM6-4, CM6-5
Goal SAST1: Improved habitat and restored linkages to enhance survival, reproduction, and distribution of Sacramento splittail in the Plan Area.		
Objective SAST1.1: Improve splittail abundance.[a]	Channel margin habitat may be important for splittail rearing in years when floodplain inundation is low. Thus, enhancement of channel margins may contribute toward achievement of this objective by providing suitable rearing habitat.	CM6-1, CM6-2, CM6-3, CM6-4, CM6-5
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.		
Objective GRST1.1: Improve juvenile and adult survival.[a]	Historical reclamation of wetlands and islands, as well as channelization and hardening of levees with riprap, has reduced and degraded the availability of suitable in- and off-channel habitat for subadult sturgeon. CM6 may contribute to an increase in primary and secondary productivity, which may contribute to an increase in food available for juvenile and adult sturgeon that occur in the Plan Area. Increases in suitable habitat and food availability for juvenile and adult sturgeon are expected to contribute toward achieving this objective.	CM6-3, CM6-4, CM6-5
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.		
Objective WTST1.1: Improve juvenile and adult survival.[a]	See Objective GRST1.1 above.	CM6-3, CM6-4, CM6-5
[a] Summarized objective statement; full text presented in Table 3.3-1.		

3.4.7 Conservation Measure 7 Riparian Natural Community Restoration

Under *CM7 Riparian Natural Community Restoration*, the Implementation Office will restore 5,000 acres of native riparian forest and scrub in association with *CM4 Tidal Natural Communities Restoration*, *CM5 Seasonally Inundated Floodplain Restoration*, and *CM6 Channel Margin Enhancement*. Riparian forest and scrub will be restored to include the range of conditions necessary to support habitat for each of the riparian-associated covered species. CM7 actions will be phased, with 1,100 acres restored by year 15 and 5,000 (cumulative) acres restored by year 40.

The relationship between this conservation measure, *CM5 Seasonally Inundated Floodplain Restoration* and *CM6 Channel Margin Enhancement* is described in Section 3.4.5.3.3, *Relationship with Other Conservation Measures*. Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM7. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that potential adverse effects of CM7 on covered species will be avoided or minimized. Refer to Chapter 5, Section 5.4, *Effects on Natural Communities*, Section 5.5, *Effects on Covered Fish*, and Section 5.6, *Effects on Wildlife and Plants*, for effects of CM7 on natural communities and covered species.

3.4.7.1 Purpose

The valley/foothill riparian natural community provides essential or important habitat for over 20 of the covered species. Valley/foothill riparian natural community supports riparian woodrat and riparian brush rabbit, and provides nesting habitat for Swainson's hawk and white-tailed kite. Valley elderberry longhorn beetle depends on elderberry shrubs, and while the species can occur in nonriparian areas, populations thrive only in riparian habitat. Yellow-breasted chat, least Bell's vireo, and western yellow-billed cuckoo depend on this habitat type for all life-history requirements. Riparian restoration is needed to increase the extent and connectivity of habitat for these species in the Plan Area. It is also needed to increase habitat extent and quality for native riparian plants, including side-flowering skullcap, Delta tule pea, Mason's lilaeopsis, delta mudwort, slough thistle, and Suisun Marsh aster.

Covered fish species that occur in the Plan Area and that rely on ecological attributes provided by valley/foothill riparian habitat include Chinook salmon, Central Valley steelhead, and lamprey. Splittail use low-velocity backwater habitats for spawning. Salmonids rely on riparian vegetation, because it supports the formation of steep, undercut banks that provide cover. Salmonids also benefit from contributions of the valley/foothill riparian natural community to the aquatic foodweb, in the form of terrestrial insects and leaf litter that enter the water (Healey 1991; Williams 2006).

Restoration of valley/foothill riparian habitats will increase the abundance and distribution of associated covered and other native species, improve connectivity among habitat areas within and adjacent to the Plan Area, improve genetic interchange among native riparian-associated species' populations, and contribute to the long-term conservation of riparian-associated covered species listed above.

3.4.7.2 Problem Statement

For descriptions of the ecological values and current condition of the valley/foothill riparian natural community in the Plan Area, see Chapter 2, *Existing Ecological Conditions,* and Section 3.3, *Biological Goals and Objectives*. Section 3.3 also describes the need for riparian natural community restoration as a component of the conservation strategies for natural communities and associated covered species, based on the existing conditions and ecological values of these resources.

The discussion below describes conditions that will be improved through implementation of CM7.

The valley/foothill riparian natural community currently occurs in mostly discontinuous patches throughout the Plan Area and in narrow linear stands in all conservation zones (Figure 2-14, *Distribution of Natural Communities and Urban Land Cover in the Plan Area*, in Chapter 2). This community consists of riparian forest and scrub primarily along channel margins and unfarmed floodplains. The current extent of this community represents a small fraction of its historical extent in the Plan Area (Thompson 1961; The Bay Institute 1998). An estimated 85 to 95% of riparian vegetation throughout California has been lost to human activities such as river and stream channelization, levee building, removal of vegetation to stabilize levees, and extensive agricultural and urban development (Riparian Habitat Joint Venture 2004). Covered activities will result in a net increase in native riparian vegetation within riparian zones of the Plan Area.

The substantial reduction in the extent, distribution, and diversity of valley/foothill riparian natural communities that historically occurred along the upper elevational margins of the Delta and along natural levees along Delta and Suisun Marsh channels and Delta islands has greatly reduced the availability of this natural community as habitat for associated covered and other native species. Design features of flood control levees such as steep slopes and the use of riprap generally preclude natural establishment or survival of native, woody riparian vegetation. These steep, riprapped surfaces provide little cover for covered fish species and may contribute to increased predation losses. A lack of riparian habitat associated with existing and restored tidal aquatic and marsh habitats limits potential ecological benefits to fish and wildlife by limiting important ecological gradients and ecosystem functions that such ecotones would provide.

3.4.7.3 Implementation

The Implementation Office will restore 5,000 acres of valley/foothill riparian natural community by implementing site-specific restoration projects. The general location and attributes of riparian restoration will be directed by the biological goals and objectives. Specific site selection and design will be guided by this conservation measure (see below). Prior to construction of each restoration project, preparatory actions may include interagency coordination, feasibility evaluations, site acquisition, development of restoration plans (Section 3.4.3.4.2, *Site-Specific Restoration Plans*), and additional environmental compliance. Construction of each restoration project will then occur consistent with the site-specific restoration plan, and will be monitored and adaptively managed to ensure that the success criteria outlined in the restoration plan are met. This planning and preparation process is described further in *CM3 Natural Communities Protection and Restoration*.

The valley/foothill riparian natural community will be restored primarily in association with the tidal and floodplain restoration and channel margin enhancements. Consistent with the riparian biological goals and objectives, discussed in Section 3.4.7.5, *Consistency with the Biological Goals and Objectives*, the 5,000 acres of restored riparian natural community will be restored as follows.

3.4.7.3.1 Siting and Design Considerations

Riparian restoration will be sited and designed to meet the applicable biological goals and objectives (Table 3.4.7-4). When siting riparian restoration projects, potential changes in salinity due to sea level rise and other factors will be considered, and the riparian natural community will be restored in areas that are likely to sustain this community.

Connectivity

The 5,000 acres of restored riparian natural community must meet numerous requirements for mid- and late-successional stage vegetation structure, and for species habitat, as summarized in Table 3.4.7-1 and described below. The location of riparian restoration will be determined during implementation in order to meet these specific geographic and species requirements. Site selection will also be guided, in part, by the needs of three other conservation measures, which have overlapping goals with riparian restoration: *CM4 Tidal Natural Communities Restoration*, *CM5 Seasonally Inundated Floodplain Restoration*, and *CM6 Channel Margin Enhancement*. Some riparian restoration will be accomplished in locations that can meet these dual requirements. At least 3,000 acres of the riparian restoration will take place in restored floodplains; concept-level planning has resulted in the identification of four south Delta corridors (Figure 3.4-20) for potential implementation of floodplain restoration, and additional floodplain siting considerations are provided in CM5 (Section 3.4.5.3.2, *Siting and Design Considerations*).

Riparian restoration sites will also be guided by priorities developed by other programs whose conservation goals overlap the BDCP, for example:

- Central Valley Restoration Program (Bureau of Reclamation 2011)
- Central Valley Joint Venture (Riparian Habitat Joint Venture 2004; Central Valley Joint Venture 2006)
- Great Central Valley Ecoregional Assessment (The Nature Conservancy 1998, in process of revision)

Table 3.4.7-1. Habitat Requirements for Riparian Restoration

Amount	Species Requirements	Riparian Successional Stage Requirements
5,000 acres (at least 3,000 acres in restored floodplain)	**Riparian brush rabbit:** Of the 1,000 acres of riparian natural community to be maintained as early- to midsuccessional vegetation, maintain at least 800 acres within the range of the riparian brush rabbit (Conservation Zone 7) in areas that are adjacent to or that facilitate connectivity with occupied or potentially occupied habitat. Of this 800 acres, at least 300 acres of habitat will be restored or created to meet specific requirements[a] described in Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat*. The following requirements also apply to riparian brush rabbit: **Riparian woodrat:** Of the at least 500 acres of riparian natural community to be maintained as late-successional vegetation, restore or create 300 acres to meet specific requirements[a] described in Appendix 3.E. **Valley elderberry longhorn beetle:** Consistent with USFWS conservation guidelines (Appendix 3.F) Also see AMM18 for **Swainson's hawk** and **white-tailed kite** (Appendix 3.C, *Avoidance and Minimization Measures*), which includes near-term riparian restoration (a component of the 5,000 acres) to offset temporal loss of nesting sites.	1,000 acres early- to midsuccessional (can be met through portions of both the 5,000 acres of restored and 750 acres of protected riparian natural community)[b] At least 500 acres late-successional (can be met through portions of both the 5,000 acres of restored and 750 acres of protected riparian natural community)[2]

[a] Riparian brush rabbit and riparian woodrat habitat acreages may overlap as long as the restored riparian area contains at least 300 acres with suitable habitat components for each species, as specified in *Species-Specific Actions*, below, and Table 3.4.7-2.

[b] Areas meeting successional requirements may overlap with areas meeting species requirements if they include both the necessary successional requirements and the necessary components of suitable habitat for the species. Additionally, the areas that meet these successional requirements may shift spatially within the reserve system over time, provided the total acreage throughout the reserve system meets the minimum requirement.

Riparian restoration sites will be prioritized in areas where they will improve linkages to allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area. Some of this connectivity will be accomplished through planting native riparian vegetation along channel margins as described in *CM6 Channel Margin Enhancement*. However, channel margin enhancement will consist mostly of narrow riparian bands that will likely be flanked by agriculture and highways, with limited value for wildlife movement. Therefore, projects that involve restoration of large riparian areas will focus on connecting existing wildlife habitat along riparian corridors to meet the riparian habitat connectivity objective.

Vegetation Diversity and Structure

Species Diversity and Structural Heterogeneity

Restoration projects will incorporate a diversity of native riparian species into planting schemes. This will include the use of uncommon native shrubs characteristic of riparian communities, including but not limited to buttonwillow (*Cephalanthus occidentalis*) and elderberry (*Sambucus* sp.).

Restoration projects will be designed to provide structural heterogeneity with adequate vertical and horizontal overlap among vegetation components. This will be accomplished by selecting native plant species for restoration that include herbaceous groundcover, small trees, and shrubs to provide understory and midstory vegetation, and large trees to provide high-canopy overstory vegetation. Riparian restoration projects will also be designed to provide native riparian vegetation that overlaps with adjacent channels, freshwater emergent wetlands, and grasslands.

Early- to Midsuccessional Vegetation

The Implementation Office will restore native riparian vegetation with the long-term objective of maintaining 1,000 acres (of the 5,000 acre total) of early- to midsuccessional vegetation with a well-developed understory of dense shrubs. Because the riparian natural community is structurally dynamic, flooding and scouring events will remove vegetation, and the community will naturally regenerate through a process of succession. *CM5 Seasonally Inundated Floodplain Restoration* will provide the necessary conditions for this dynamic process to occur under the existing riverine flow regime. Because of this dynamic nature of the riparian natural community, the 1,000 acres of early- to midsuccessional vegetation are not expected to be maintained in a single location; rather, the Implementation Office will ensure that 1,000 acres of early- to midsuccessional riparian vegetation with a well-developed understory of shrubs are present throughout the reserve system starting in year 15. This will be accomplished through a combination of riparian restoration, riparian protection (*CM3 Natural Communities Protection and Restoration*), and, if necessary, riparian enhancement and management (*CM11 Natural Communities Enhancement and Management*). Of early- to midsuccessional riparian vegetation, 300 acres will be located in Conservation Zone 7 within or adjacent to occupied riparian brush rabbit habitat, as described under *Riparian Brush Rabbit*, below.

Late-Successional Vegetation

The Implementation Office will restore native riparian vegetation with the long-term objective of maintaining at least 500 acres of mature vegetation in Conservation Zones 4 or 7 (i.e., the entire requirement will be met in a single zone, not distributed among both zones). The mature riparian vegetation will include tall-growing trees, such as oaks, sycamores, and cottonwoods, with a sufficiently open canopy to provide light for understory growth and a high level of structural understory diversity. It will not be a senescent community with a 100% closed canopy, in which new growth is suppressed. For additional details on this late-successional riparian vegetation, see *Riparian Woodrat* and *Western Yellow-Billed Cuckoo* under *Species-Specific Actions* below.

Because of the dynamic nature of the riparian natural community (see *Early- to Midsuccessional Vegetation,* above), the 500 acres of late-successional vegetation are not expected to be maintained in a single location; rather, the Implementation Office will ensure that at least 500 acres of late-successional riparian vegetation are present throughout either Conservation Zone 4 or 7 at any given point in time. This will be accomplished through a combination of riparian restoration and riparian protection (*CM3 Natural Communities Protection and Restoration*). In siting locations for management of mature riparian vegetation within floodplains, sea level rise and locations of likely fluvial disturbance will be considered (i.e., mature riparian will be sited in areas that are rarely flooded such as above the 50-year floodplain).

Species-Specific Actions

Riparian Brush Rabbit

Of the 1,000 acres of riparian natural community to be maintained as early- to midsuccessional vegetation (see *Early- to Midsuccessional Vegetation*, above), at least 800 acres will be maintained within the range of the riparian brush rabbit (Conservation Zone 7), in areas that are adjacent to or that facilitate connectivity with occupied or potentially occupied habitat. Of this, 300 acres will meet the ecological requirements of the riparian brush rabbit, and be located within or adjacent to, or facilitate connectivity with, existing occupied riparian brush rabbit habitat. These 300 acres will have the following components (based on Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat*). The restored riparian natural community will be actively managed as described in *CM11 Natural Communities Enhancement and Management.*

- **Large patches of dense brush composed of riparian vegetation.** Shrub species, such as California blackberry (*Rubus ursinus*), California wild rose (*Rosa californica*), sandbar willow (*Salix exigua*), coyote brush (*Baccharis pilularis*), golden currant (*Ribes aureum*), and other shrubs are necessary to provide protection from predators. The riparian restoration will include shrub species that grow high enough that they are not completely inundated during most flood events, their foliage remains above the high-water mark, and they can survive most flood events.
- **Ecotonal edges of brushy species that transition to grasses and herbaceous forbs.** Herbaceous forbs that remain during both the wet and dry seasons, such as mugwort (*Artemisia californica*), stinging nettle (*Urtica dioica*), and gumplant (*Grindelia camporum*), growing at the edges of riparian shrubs provide dense cover and protection from predators. Open fields adjacent to dense brush provide foraging habitat for riparian brush rabbits. Creeping wild rye (*Leymus triticoides*) or other suitable grasses will be established in these adjacent fields as this species is flood-tolerant and allows for production of tunnel-like rabbit runways that provide good cover. Santa Barbara sedge (*Carex barbarae*) may also be used, although it does not spread as quickly and is not as dense as creeping wild rye.
- **"Scaffolding plants" (dead or alive) to support blackberry plants above flood levels.** Small trees and tall shrubs such as coyote brush can provide scaffolding for blackberry and other climbing plants to allow these plants to climb above flood levels.

- **A tree overstory, if present, that is not closed**. Trees are not an essential component of riparian brush rabbit habitat; however, if trees are present, an open tree canopy is necessary, because a closed canopy can inhibit growth of a dense understory.
- **Refugia from flooding.** High-ground refugia will be built or maintained to provide refuge during flood events (short- and long-term) and sea level rise (long-term).

Riparian Woodrat

Of the 500 acres of riparian natural community to be maintained as late-successional vegetation, 300 acres will meet the ecological requirements of the riparian woodrat, and be located within or adjacent to, or facilitate connectivity with, existing occupied or potentially occupied riparian woodrat habitat. These 300 acres will have structure appropriate for nesting and nest building and will include the following components (based on Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat*).

- **Tree canopy.** Trees will consist primarily of oak (*Quercus* sp.) but may also include cottonwood (*Populus fremontii*), sycamore (*Platanus racemosa*), large willows, and other large trees that provide opportunities for woodrats to forage in the tree canopy.
- **Large patches of dense shrub understory.** Shrubs may include blackberries, wild rose, small willows, or other native shrub species to provide cover and substrate for nest building.
- **Canopy and understory connected by a midstory composed of native species.** Midstory may include small trees, tall shrubs, and vines such as California wild grape, to provide additional cover and facilitate woodrat access to the tree canopy.
- **Refugia from flooding.** High-ground refugia will be built or retained to provide refuge during flood events (short- and long-term) and sea level rise (long-term).

Table 3.4.7-2 summarizes the qualitative differences in riparian brush rabbit and riparian woodrat habitat needs that will be addressed through riparian habitat restoration and management. Riparian brush rabbit and riparian woodrat habitat acreages may overlap as long as the restored riparian area contains 300 acres with suitable habitat components for each species.

Table 3.4.7-2. Differences in Habitat Needs for Riparian Brush Rabbits and Riparian Woodrats

Species	Herbaceous Edge	Dense Understory	Dense Midstory	Tree Canopy
Riparian brush rabbit	Essential	Essential	Not important	Not important
Riparian woodrat	Not important	Essential	Important	Important
Source: Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat.*				

Western Yellow-Billed Cuckoo

Habitat needs for western yellow-billed cuckoo will be considered when designing riparian restoration projects to maintain at least 500 acres of mature riparian forest in Conservation Zone 4 or 7, intermixed with early- to midsuccessional riparian vegetation in large blocks with a minimum patch size of at least 50 acres and minimum width of 100 meters (Objectives VFRNC2.3 and VFRNC2.4). To meet habitat needs for this species, restoration projects will be designed to include cottonwoods, willows, and other riparian plant species to provide greater than 40% canopy closure, with a mean canopy height of approximately 7 to 10 meters (Laymon et al. 1997).

Valley Elderberry Longhorn Beetle

The loss of any elderberry shrubs resulting from covered activities will be mitigated through creation of additional valley elderberry longhorn beetle habitat consistent with USFWS conservation guidelines (Appendix 3.F). Based on these guidelines, shrubs with beetle exit holes are mitigated at a higher ratio than shrubs without any evidence of exit holes. Elderberry shrubs will be planted in large, contiguous clusters with a mosaic of associated natives.

3.4.7.3.2 Restoration Approaches

The approach for each riparian restoration project will differ depending on whether it is associated with floodplain restoration, tidal restoration, or channel margin enhancement. For general restoration techniques and site selection guidelines that apply to all natural communities, see *CM3 Natural Communities Protection and Restoration*.

The best available scientific and technical information and guidance will be applied to riparian restoration projects. Riparian restoration handbooks and guidance used in developing and implementing riparian restoration plans may include the following as well include additional guidelines as they become available during the term of the BDCP:

- *California Riparian Restoration Handbook* (Riparian Habitat Joint Venture 2009)
- *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998)
- *California Salmonid Stream Habitat Restoration Manual*, Part XI, *Riparian Habitat Restoration* (Circuit Rider Productions 2004)
- *Federal Stream Corridor Restoration Principles and Practices* (Federal Interagency Stream Restoration Working Group 1999)

Riparian Restoration in Restored Floodplains

At least 3,000 acres of the 5,000-acre riparian restoration requirement will occur in restored floodplains consistent with *CM5 Seasonally Inundated Floodplain Restoration*. The valley/foothill riparian natural community will actively be restored in some floodplains, and in other floodplains it will be allowed to naturally establish and grow where soils and hydrology are appropriate. Large patches of native riparian vegetation are expected to be established in floodplains in contrast to the existing narrow stringers of riparian vegetation that typically occur along channels and agricultural water conveyance features in much of the Plan Area.

Active restoration involving site preparation and planting of native riparian vegetation (e.g., Fremont cottonwood, Goodings' willow [*Salix gooddingii*], box elder [*Acer negundo*]) will be implemented if site-specific restored floodplain conditions indicate that such plantings will substantially increase the establishment of native riparian forest and scrub, and will be necessary to achieve the biological goals and objectives and restoration targets for each phase. Restoration sites will be monitored to determine if nonnative vegetation control or supplemental plantings of native riparian vegetation are necessary (see *CM11 Natural Communities Enhancement and Management* for description of nonnative vegetation control actions). Site-specific restoration designs will be based on the frequency and magnitude of geomorphically significant flood events likely at the restoration site. Designs will ensure that the floodplain vegetation community (naturally recruited or planted) is subjected to vegetation disturbance events sufficient to satisfy the needs of species requiring early- to midsuccessional vegetation assemblages.

Riparian vegetation can impede flood flows or reduce flood capacity of constrained channels. However, restoring floodplains consistent with *CM5 Seasonally Inundated Floodplain Restoration* is expected to greatly increase flood protection capacity of the restored river reaches, and riparian restoration in restored floodplains is expected to be consistent with flood-control requirements (Figure 3.4-20).

Riparian Restoration in Restored Tidal Natural Communities

Native woody riparian vegetation will be allowed to naturally reestablish along the upper elevation margins of restored tidal natural communities in ROAs (Figure 3.2-2 and *CM4 Tidal Natural Communities Restoration*) where soils and hydrology are suitable, including segments of stream channels that drain into restored marshes. Suitable soils for restoration are expected to be most extensive in the Cosumnes/Mokelumne and South Delta ROAs. In these ROAs, native riparian vegetation is expected to generally form as a band of variable width depending on site-specific soil and hydrologic conditions between high-marsh vegetation and herbaceous uplands.

Soil salinity in the Suisun Marsh ROA and extensive clay soils in the Cache Slough ROA are expected to limit the extent of native riparian vegetation that will become established. In these ROAs, native riparian vegetation is expected to generally establish in narrow stringers (e.g., along dikes) and in small patches with suitable soil conditions. Where conditions are appropriate, woody native riparian vegetation will be planted on new upland areas (dikes, field checks, and, where appropriate, nonfederal levees) that are constructed by the Implementation Office in ROAs as necessary to restore tidal natural communities and meet the biological goals and objectives. As described in *Riparian Restoration in Restored Floodplains*, native riparian vegetation may be planted to initiate establishment of riparian forest and scrub, and restoration areas will be monitored to determine the need for vegetation control and supplemental plantings.

Riparian Restoration on Enhanced Channel Margins

Where compatible with site-specific objectives for channel margin enhancement, native woody riparian vegetation will be planted along channel margins on benches on the waterward side of existing levees to enhance covered fish and wildlife species habitat (Figure 3.4-21). Native riparian vegetation restored in these locations is expected to form narrow stringers of riparian forest and scrub along enhanced channel margins.

3.4.7.4 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring for CM7 will consist of documenting in a GIS database the extent of native riparian natural community successfully restored and mapping restored habitat for each covered species expected to use this natural community based on habitat models.

Effectiveness monitoring will be conducted to evaluate progress toward advancing the biological goals and objectives, as described in Section 3.4.7.5, *Consistency with the Biological Goals and Objectives*. If necessary, the implementation actions described above will be adjusted via adaptive management, as described in Section 3.6, to meet these objectives.

Effectiveness monitoring will consist of verifying that restoration sites are performing the expected ecological functions as prescribed by success criteria in the site-specific restoration plans. See Section 3.4.3.4.2, *Site-Specific Restoration Plans*, for a description of the elements to be incorporated into site-specific restoration plans. Table 3.4.7-3 lists monitoring actions, metrics, success criteria, and schedules relevant to CM7, for incorporation into site-specific riparian restoration plans, as appropriate. The actual monitoring actions, success criteria, metrics, and timing will be based on the best available information at the time of implementation and may be adjusted or augmented over time through adaptive management.

If success criteria are not met within the specified schedule, contingency measures will be implemented as described in the restoration plan. Contingency measures to be implemented if restoration is unsuccessful may include, but are not limited to, plantings or management changes (e.g., invasive species control, temporary irrigation, addition of disturbance or clearing). After the riparian natural community has been successfully restored, effectiveness monitoring and research actions will be implemented as described for the protected riparian natural community in *CM11 Natural Communities Management and Enhancement*.

One key uncertainty has been identified in connection with this conservation measure: What is the status and trend of riparian brush rabbit populations in the Plan Area? The research action to resolve this uncertainty will likely consist of performing live trapping of riparian brush rabbit biannually in suitable riparian brush rabbit habitat in Conservation Zone 7, using methods developed in coordination with the Endangered Species Recovery Program, to estimate status and trends of the riparian brush rabbit population in the Plan Area.

1 **Table 3.4.7-3. Effectiveness Monitoring Relevant to CM7**

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM7-1	Landscape-level assessment of restored riparian natural community throughout reserve system	Covered species habitat connectivity	Increased connectivity between existing patches of riparian natural community	Every 5 years until end of permit term
CM7-2	Vegetation sampling of herbaceous, shrub, and canopy layers for plant community structure	Structural heterogeneity	As specified in site-specific restoration plan	As specified in site-specific restoration plan
CM7-3	Vegetation sampling of herbaceous, shrub, and canopy layers in restored riparian vegetation for plant community structure in areas targeted for 1,000-acre minimum (locations may shift over time)	Amount of early- to midsuccessional riparian vegetation	1,000 acres throughout reserve system	Every 5 years until end of permit term
CM7-4	Vegetation sampling, mapping vegetation based on successional stage, in areas targeted for the 500-acre minimum (locations may shift over time)	Amount of mature riparian forest intermixed early- to midsuccessional riparian vegetation, patch size	500 acres of mature riparian intermixed with early- to midsuccessional, in minimum 50-acre blocks	Every 5 years until end of permit term
CM7-5	Vegetation sampling and mapping rare vegetation alliances in representative locations	Amount of rare and uncommon riparian vegetation alliances in the reserve system	Increase acreage	Every 5 years until end of permit term
CM7-6	Vegetation sampling	Vegetation composition and structure	300 acres of suitable riparian brush rabbit habitat as specified in site-specific restoration plan	As specified in site-specific restoration plan
CM7-7	Site-specific assessment	Presence and location of suitable riparian brush rabbit refugia	Suitable refugia not further apart than 20 meters in riparian brush rabbit habitat	Annually for 5 years following creation (thereafter monitored under CM11)
CM7-8	Vegetation sampling	Vegetation composition and structure	300 acres of suitable riparian woodrat habitat as specified in site-specific restoration plan	As specified in site-specific restoration plan
CM7-9	Site-specific assessment	Presence and location of suitable riparian woodrat refugia	Suitable refugia not further apart than 20 meters in riparian woodrat habitat	Annually for 5 years following creation (thereafter monitored under CM11)

2

3.4.7.5 Consistency with the Biological Goals and Objectives

CM7 will advance the biological goals and objectives as identified in Table 3.4.7-4. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Table 3.4.7-4 also identifies the monitoring actions associated with each objective as it relates to CM7.

Objective L2.3: Connect rivers and their floodplains to allow input of large woody debris, leaves, and other organic material to rivers.

Riparian vegetation in

Table 3.4.7-4. Biological Goals and Objectives Addressed by CM7 and Related Monitoring Actions

Biological Goal or Objective	How CM7 Advances Biological Objective	Monitoring Action(s)
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.		
Objective L2.3: Connect rivers and their floodplains to allow input of large woody debris, leaves, and other organic material to rivers.	Riparian community restoration along rivers will increase instream cover through contributions of woody material derived from the riparian forest (U.S. Fish and Wildlife Service 2004), which will provide habitat complexity important for resting and refuge sites used by covered salmonids, and will contribute to creation of thermal refugia. Riparian community restoration will also increase leaf and twig drop and associated terrestrial insects when floodplain inundation through such vegetated areas occurs.	CM6-2, CM6-4
Objective L2.9: Increase the abundance and productivity of plankton and invertebrate species that provide food for covered fish species in the Delta waterways.	Riparian restoration will provide inputs of organic material (e.g., leaf and twig drop; associated terrestrial insects) where riparian forest and scrub is restored adjacent to channels and when these areas are inundated by flooding, resulting in increased production of zooplankton and macroinvertebrates that serve as or support production of food for covered fish species. It will also increase the production and export of terrestrial invertebrates into the aquatic ecosystem (Nakano and Murakami 2001) to provide food for covered fish, western pond turtle, and California red-legged frog.	CM5-5, CM6-4, CM6-3
Goal L3: Capacity for movement of native organisms and genetic exchange among populations necessary to sustain native fish and wildlife species in the Plan Area.		
Objective L3.1: Protect and improve habitat linkages that allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area.	See Section 3.4.7.3.1, *Siting and Design Considerations*. Riparian restoration projects will be prioritized in areas where they will improve linkages to allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area.	CM7-1

Biological Goal or Objective	How CM7 Advances Biological Objective	Monitoring Action(s)
Goal VFRNC1: Extensive wide bands or large patches of interconnected valley/foothill riparian natural community, with locations informed by both existing and historical distribution.		
Objective VFRNC1.1: Restore or create 5,000 acres of valley/foothill riparian natural community, with at least 3,000 acres occurring on restored seasonally inundated floodplain.	See Section 3.4.7.3.1, *Siting and Design Considerations*. The 5,000 acres of riparian forest will be achieved through a combination of active and passive restoration.	Compliance monitoring
Goal VFRNC2: Increased structural diversity including a mosaic of seral stages, age classes, plant zonation, and plant heights and layers characteristic of valley/foothill riparian natural community.		
Objective VFRNC2.1: Restore, maintain, and enhance structural heterogeneity with adequate vertical and horizontal overlap among vegetation components and over adjacent riverine channels, freshwater emergent wetlands, and grasslands.	See Section 3.4.7.3.1, *Siting and Design Considerations, Vegetation Diversity and Structure,* above. Site-specific restoration plans will be designed to meet this objective.	CM7-2
Objective VFRNC2.2: Maintain 1,000 acres of early- to midsuccessional vegetation with a well-developed understory of dense shrubs on restored seasonally inundated floodplain.	See Section 3.4.7.3.1, *Siting and Design Considerations, Vegetation Diversity and Structure,* above. Site-specific restoration plans will be designed to meet this objective.	CM7-3, compliance monitoring
Objective VFRNC2.3: Maintain at least 500 acres of mature riparian forest in Conservation Zones 4 or 7.	See Section 3.4.7.3.1, *Siting and Design Considerations, Vegetation Diversity and Structure,* above. Site-specific restoration plans will be designed to meet this objective.	CM7-4, compliance monitoring
Objective VFRNC2.4: Maintain the at least 500 acres of mature riparian forest (VFRNC2.3) intermixed with a portion of the early- to midsuccessional riparian vegetation (VFRNC2.2) in large blocks with a minimum patch size of 50 acres and minimum width of 330 feet.	See Section 3.4.7.3.1, *Siting and Design Considerations, Vegetation Diversity and Structure,* above. Site-specific restoration plans will be designed to meet this objective.	CM7-4, compliance monitoring
Goal VFRNC3: Maintenance or increase of native biodiversity that is characteristic of the valley/foothill riparian natural community.		
Objective VFRNC3.1: Maintain or increase abundance and distribution of valley/foothill riparian natural community vegetation alliances that are rare or uncommon as recognized by California Department of Fish and Game (2010), such as *Cephalanthus occidentalis* (button willow thickets) alliance and *Sambucus nigra* (blue elderberry stands) alliance.	See Section 3.4.7.3.1, *Siting and Design Considerations, Vegetation Diversity and Structure,* above. Site-specific restoration plans will be designed to meet this objective.	CM7-5

Biological Goal or Objective	How CM7 Advances Biological Objective	Monitoring Action(s)
Goal RBR1: Suitable habitat available for the future growth and expansion of riparian brush rabbit populations.		
Objective RBR1.2: Of the 1,000 acres of early- to midsuccessional riparian habitat maintained under VFRNC2.2, maintain at least 800 acres within the range of the riparian brush rabbit (Conservation Zone 7), in areas that are adjacent to or that facilitate connectivity with occupied or potentially occupied habitat.	See Section 3.4.7.3.1, *Siting and Design Considerations, Species-Specific Actions, Riparian Brush Rabbit,* above. Site-specific restoration plans will be designed to meet this objective.	Compliance monitoring
Objective RBR1.3: Of the 5,000 acres of valley/foothill riparian natural community restored under Objective VFRNC1.1, restore/create and maintain 300 acres of early- to midsuccessional riparian habitat that meets the ecological requirements of the riparian brush rabbit and that is within or adjacent to or that facilitates connectivity with existing occupied or potentially occupied habitat.	See Section 3.4.7.3.1, *Siting and Design Considerations, Species-Specific Actions, Riparian Brush Rabbit,* above. Site-specific restoration plans will be designed to meet this objective.	CM7-6, compliance monitoring
Objective RBR1.4: Create and maintain high-water refugia in the 300 acres of restored riparian brush rabbit habitat and the 200 acres of protected riparian brush rabbit habitat, through the retention, construction and/or restoration of high-ground habitat on mounds, berms, or levees, so that refugia are no further apart than 20 meters.	See Section 3.4.7.3.1, *Siting and Design Considerations, Species-Specific Actions, Riparian Brush Rabbit,* above. Site-specific restoration plans will be designed to meet this objective.	CM7-7
Goal RW1: A reserve system that includes suitable habitat available for the future growth and expansion of riparian woodrat populations.		
Objective RW1.1: Of the 5,000 acres of valley/foothill riparian natural community restored under Objective VFRNC1.1, restore/create and maintain 300 acres riparian habitat in Conservation Zone 7 that meets the ecological requirements of the riparian woodrat (e.g., dense willow understory and oak overstory) and that is adjacent to or facilitates connectivity with existing occupied or potentially occupied habitat.	See Section 3.4.7.3.1, *Siting and Design Considerations, Species-Specific Actions, Riparian Woodrat,* above. Site-specific restoration plans will be designed to meet this objective.	CM7-8

Biological Goal or Objective	How CM7 Advances Biological Objective	Monitoring Action(s)
Objective RW1.2: Provide and maintain high-water refugia in the 300 acres of riparian woodrat habitat restored under Objective RW1.1 through the retention, construction, and/or restoration of high-ground habitat on mounds, berms, or levees, so that refugia are no further apart than 20 meters.	See Section 3.4.7.3.1, *Siting and Design Considerations, Species-Specific Actions, Riparian Woodrat,* above. Site-specific restoration plans will be designed to meet this objective.	CM7-9
Goal VELB1: Promote dispersal and expansion of the valley elderberry longhorn beetle where there are known source populations within the American River and Sacramento River systems.		
Objective VELB1.1: Mitigate impacts on elderberry shrubs by creating valley elderberry longhorn beetle habitat consistent with the U.S. Fish and Wildlife Service valley elderberry longhorn beetle conservation guidelines (Appendix 3.F) and planting elderberry shrubs in high-density clusters.	See Section 3.4.7.3.1, *Siting and Design Considerations, Species-Specific Actions, Valley Elderberry Longhorn Beetle,* above. Site-specific restoration plans will be designed to meet this objective.	USFWS valley elderberry longhorn beetle conservation guidelines (Appendix 3.F)
Objective VELB1.2: Site valley elderberry longhorn beetle habitat restoration within drainages immediately adjacent to or in the vicinity of sites confirmed to be occupied by valley elderberry longhorn beetle.	See Section 3.4.7.3.1, *Siting and Design Considerations, Species-Specific Actions, Valley Elderberry Longhorn Beetle,* above. Site-specific restoration plans will be designed to meet this objective.	Compliance monitoring

3.4.8 Conservation Measure 8 Grassland Natural Community Restoration

Under *CM8 Grassland Natural Community Restoration*, the Implementation Office will restore 2,000 acres of grassland natural community in Conservation Zones 1, 8, and/or 11, and other zones as needed to achieve the biological goals and objectives for covered species. Actions under CM8 will be phased, with 1,140 acres restored by year 10 and 2,000 acres (cumulative) restored by year 40.

Grassland restoration under CM8 is intended to contribute toward achieving biological goals and objectives for the grassland natural community, and several landscape-level objectives. The grassland goals and objectives are detailed in Section 3.3.6.11, *Grassland*, and CM8 consistency with relevant goals and objectives is further described in Section 3.4.8.4, *Consistency with the Biological Goals and Objectives.*

Grassland restoration is one component of the conservation strategy for the grassland natural community. The strategy for this natural community also includes protection and management of grasslands. Refer to *CM3 Natural Communities Protection and Restoration* and *CM11 Natural Communities Management and Enhancement* for these other components of the grassland conservation strategy.

The primary purpose of CM8 is to connect fragmented patches of protected grassland and to provide upland habitat adjacent to riparian and tidal natural communities for wildlife foraging and upland refugia. Most of the restored grasslands will be located in Conservation Zones 1, 8, and/or 11 to connect patches of existing protected grasslands. Grasslands will be restored in the following areas.

- Adjacent to tidal brackish marsh in Conservation Zone 11 to provide upland flood refugia for salt marsh harvest mouse and other native wildlife (beyond the transitional uplands protected to accommodate sea level rise).
- Along the upper margins of restored floodplains or adjacent to the outside of levees adjacent to restored floodplain in Conservation Zone 7 to provide upland refugia for riparian brush rabbit.
- Adjacent to restored nontidal marsh to provide upland habitat for giant garter snake.

Grasslands will be restored to sustain critical habitat functions such as foraging, dispersal, and shelter for covered and other native species. Grassland restoration will increase the extent, connectivity, and quality of grassland habitat available for use by covered and other native species and thus contribute to their conservation. Covered species expected to benefit from restored grasslands include San Joaquin kit fox, salt marsh harvest mouse, riparian brush rabbit, tricolored blackbird, western burrowing owl, greater sandhill crane, Swainson's hawk, white-tailed kite, giant garter snake, western pond turtle, California red-legged frog, California tiger salamander, heartscale, brittlescale, San Joaquin spearscale, and Carquinez goldenbush. See Appendix 2.A*, Covered Species Accounts*, for specific life-history requirements met by the grasslands natural community.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM8. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM8 on covered species will be avoided or minimized. Refer to Chapter 5, Section 5.4.13, *Cultivated Lands*, for a description of potential effects of grassland restoration.

3.4.8.1 Problem Statement

Although California native grassland originally covered approximately 25% of the state land area (Barbour et al. 2007; Stromberg et al. 2007), it has been identified as one of the 20 most endangered ecosystems in the United States (Noss et al. 1995). Grasslands in California are now highly fragmented and dominated by nonnative annual grasses and other nonnative plant species.

The ecological values and current condition of the grassland natural community in the Plan Area are described in Chapter 2, *Existing Ecological Conditions*, and Section 3.3, *Biological Goals and Objectives*. Section 3.3*,* also describes the need for restoration as a component of the conservation strategies for the grassland community and associated covered species, based on the existing conditions and ecological values of these resources.

Grassland habitat is distributed around the upland margin of the Sacramento-San Joaquin Delta and Suisun Bay system, and much has been lost to development and conversion to agriculture. Grassland loss and fragmentation has contributed to the decline of San Joaquin kit fox, western burrowing owl, and California tiger salamander. Some covered activities will further remove the grassland natural community. Grassland restoration offers a way to offset these losses while improving habitat connectivity and increasing the diversity of grassland species.

3.4.8.2 Implementation

The Implementation Office will restore 2,000 acres of grassland in Conservation Zones 1, 8, and/or 11 by implementing site-specific restoration projects. Prior to construction of each restoration project, preparatory actions will include interagency coordination, feasibility evaluations, site acquisition, development of restoration plans (Section 3.4.3.4.2, *Site-Specific Restoration Plans*), and potentially additional environmental compliance. Construction of each restoration project will then occur consistent with the site-specific restoration plan, and will be monitored and adaptively managed to ensure that the success criteria outlined in the restoration plan are met. This restoration planning and preparation process is described further in *CM3 Natural Communities Protection and Restoration*.

3.4.8.2.1 Grassland Restoration Approach

Grassland restoration will involve converting nongrassland areas (e.g., ruderal or cultivated lands) into grassland. Grasslands restored as a component of vernal pool complexes will also count toward the 2,000-acre restoration target for CM8. Grassland restoration will increase the extent, distribution, and density of native perennial grasses intermingled with other native species, taking into consideration current knowledge, limitations of grassland restoration techniques, and site suitability. The historical extent and composition of California native grasslands is unknown, making the goal of restoring grassland to a presettlement condition unrealistic (Barry et al. 2006; Keeley 1993). Furthermore, establishment of native grassland can be difficult and costly (Barry et al. 2006); this is especially the case in areas where soils and other site conditions are not suitable for native grasslands. Soil and site conditions will be considered when identifying appropriate locations for grassland restoration.

Because creation and maintenance of large areas of native grassland are very costly and often unsuccessful and because most native flora and fauna—including covered species such as San Joaquin kit fox, California tiger salamander, and western burrowing owl—do not require grasslands dominated by native grasses and forbs, the restored grasslands will be planted with native species and managed to encourage native biodiversity but will not require a predominance of natives for the restored lands to contribute to the 2,000-acre target. As long as the restored grasslands have some native component (i.e., they can still be dominated by nonnative species), and they are not dominated by nonnative species that substantially reduce grassland function, the grassland restoration will count towards the restoration requirement.

Rather than completely eliminating nonnatives, grassland restoration focuses on increasing native biodiversity by planting natives, controlling or removing nonnative invasive species, and improving native wildlife habitat functions by increasing habitat extent and connectivity. The grassland restoration strategy may be adjusted as described in Section 3.4.8.3, *Adaptive Management and Monitoring*, with the development of new restoration techniques and other pertinent information as it becomes available.

3.4.8.2.2 Siting and Design Considerations

Restoration will be prioritized where it improves connectivity and increases the habitat functions of existing grassland plant and wildlife habitats, including linking or providing wildlife movement corridors to larger habitat areas immediately outside of the Plan Area or providing upland refugia for wildlife adjacent to emergent wetland and riparian natural communities. The most strategically important areas are listed below.

- Areas where restoration would connect small patches of grasslands in Conservation Zones 1 and 11 with larger expanses of grassland in the Jepson Prairie area.
- Areas where restoration would connect grasslands in Conservation Zone 8 to other high-value grassland habitat to the west and southwest of the Plan Area, and support the conservation lands assembled for the Eastern Contra Costa County HCP/NCCP and the San Joaquin County MSHCP.
- Uplands adjacent to restored tidal brackish emergent wetlands in Suisun Marsh (beyond the transitional uplands protected to accommodate sea level rise)[23], to provide refugia for salt marsh harvest mouse and other wildlife.
- Areas adjacent to riparian brush rabbit and riparian woodrat habitat along the upper margins of restored floodplains that are expected to be flooded infrequently, and along the outside edges of levees adjacent to floodplain restoration.
- Areas adjacent to restored freshwater emergent wetland restored (*CM10 Nontidal Marsh Restoration*), to provide basking sites and upland refugia for giant garter snake.

Grassland restoration will focus on creating a mosaic of different grassland vegetation alliances, reflecting localized water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical site conditions. Grassland restoration sites will be selected that support soils suitable for grassland restoration and are adjacent to existing high-value grassland natural community (i.e., supporting covered species or high biodiversity) (Keeley 1993).

Grasslands restored along the upper margins of seasonally inundated floodplain in Conservation Zone 7 will be designed to provide foraging habitat values and upland refugia for riparian brush rabbit. Creeping wild rye (*Elymus triticoides*) will be incorporated as a dominant species in planting mixes adjacent to riparian areas that provide riparian brush rabbit habitat. Creeping wild rye is one of the only floodplain grasses native to the Central Valley that can be easily established through grassland restoration. This flood-tolerant grass allows for the formation of tunnel-like rabbit runways, and thus provides good cover for the riparian brush rabbit (Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat*).

Grasslands restored in Suisun Marsh will be at least 200 feet wide (Williams and Faber 2004) beyond the sea level rise accommodation. Restoration in this area will establish grassland plant species such as salt grass and creeping wild rye that provide adequate cover for salt marsh harvest mouse and other native wildlife that may be vulnerable to predation as they seek high ground during extreme high-tide events.

Grasslands restored adjacent to freshwater emergent wetland (*CM10 Nontidal Marsh Restoration*) will provide sufficient cover for giant garter snake. USFWS recommends using a seed mix that includes native grass seeds such as annual fescue (*Vulpia* spp.), California brome (*Bromus carinatus*),

[23] A 200-foot band of riparian or upland habitat suitable for providing cover for Suisun Marsh species will be maintained adjacent to restored tidal marsh within the transitional uplands, above and beyond the 2,000 acres of restored grassland. This 200-foot band will shift in location with sea level rise and continue to be maintained as suitable upland habitat. The grasslands to be restored as a component of CM8 will be located above the elevation necessary for sea level rise accommodation.

blue wildrye (*Elymus glaucus*), and needlegrass (*Nassella* spp.), and some native forb seeds. The ultimate seed mix will be based on the best information available at the time of implementation regarding giant garter snake upland habitat needs.

3.4.8.2.3 Restoration Techniques

The following techniques may be applied to grassland restoration projects, although the Implementation Office is not limited to these techniques. Other approaches and techniques may be applied to grassland restoration projects based on the best information available at the time the restoration project is being planned and designed, and approaches that have been proven successful for past restoration projects. See *CM11 Natural Communities Enhancement and Management* for a description of techniques for grazing and invasive plant control to promote establishment of native grassland species in nonnative grasslands.

Sites that have been highly disturbed may require pretreatment before grassland restoration techniques are applied. For example, invasive weeds may need to be removed using a variety of techniques such as livestock grazing, herbicide treatment, tilling, soil removal and treatment (to remove the weed seed bank), or a combination of these or other treatments. Restoration may also require the recontouring of graded land as appropriate.

Native grasses grow better if the seeds are collected from a nearby site (Stromberg and Kephart 1996). Seed sown on grassland restoration sites will be collected from the nearest practicable natural site with similar ecological conditions. Seed nurseries may be established in some of the restored grasslands to produce seed for subsequent restoration projects.

Seeding will be done in fall or early winter after the first rains. Many California native grasses can be successfully started when seeded at about 3 to 4 pounds per acre (Stromberg and Kephart 1996). The seed may be broadcast using a tractor-mounted or handheld broadcast seeder, or a seed drill may be used. Plugs may be used rather than seeding in some areas, especially on steep hillsides. Survivorship for plugs is often 95% or better, as the critical time period for native grasses is the seedling stage (Stromberg and Kephart 1996).

Once seedlings are established, the restored grasslands will be managed consistent with long-term, site-specific management plans. Grassland management techniques are described in *CM11 Natural Communities Enhancement and Management*.

3.4.8.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting in a GIS database the extent of grassland successfully restored, and mapping restored habitat for each covered species predicted by habitat models to use this natural community.

Effectiveness monitoring will be conducted to evaluate progress toward advancing the landscape-scale and natural community objectives discussed below in Section 3.4.8.4, *Consistency with the Biological Goals and Objectives*. If necessary, the implementation actions described above will be adjusted through adaptive management to meet these objectives.

Effectiveness monitoring will consist of verifying that restoration sites are performing the expected ecological functions as prescribed by success criteria in the site-specific restoration plans. See Section 3.4.3.4.2, *Site-Specific Restoration Plans*, for a description of the elements to be incorporated into site-specific restoration plans. Table 3.4.8-1 lists monitoring actions, metrics, success criteria, and schedules relevant to CM8, for incorporation into site-specific restoration plans, as appropriate. The actual monitoring actions, success criteria, metrics, and timing will be based on the best available information at the time of implementation and may be adjusted or supplemented over time through adaptive management, provided such modifications will still allow comparison of data collected throughout the permit term and between sites across the reserve system.

If success criteria are not met within the specified schedule, contingency measures will be implemented as described in the restoration plan. Contingency measures to be implemented if restoration is unsuccessful may include, but are not limited to, plantings or management changes (e.g., invasive species control, changing grazing regime, or temporarily fencing areas to exclude cattle). After the grasslands have been successfully restored, effectiveness monitoring and research actions will be implemented as described for the protected grassland natural community in *CM11 Natural Communities Management and Enhancement*.

No key uncertainties or research needs have been identified in connection with this conservation measure. There is high confidence that this conservation measure will be effective as planned.

Table 3.4.8-1. Effectiveness Monitoring Relevant to CM8

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM8-1	GIS mapping and tracking acreages	Acres successfully restored	1,000 acres restored by year 10 and 2,000 acres (cumulative) restored by year 25	Update maps and acres successfully restored at least once every 5 years
CM8-2	GIS mapping and documenting location relative to reserve system	Location relative to fragmented grassland patches or adjacency to riparian or emergent wetland natural communities	Connectivity with grassland patches, and provision of upland adjacent to riparian or emergent wetland natural communities	Update at least once every 5 years
CM8-3	Vegetation sampling	Percent cover of vegetation dominated by species that compose California annual grassland series or native grassland series as defined by Sawyer et al. (2009, or latest edition)	Minimum percent cover as defined in site-specific plan	Prior to restoration, and annually for first 5 years or until success criteria are met, whichever is longer
CM8-4	Vegetation sampling	Percent cover of noxious weeds and bare ground	Maximum percent cover defined in site specific plan	Prior to restoration, then annually for first five years or until success criteria are met, whichever is longer
CM8-5	Vegetation sampling, mapping and tracking acreages	Extent, distribution, and number of native vegetation alliances across the reserve system	Increase	Every 5 years throughout permit term
CM8-6	Vegetation sampling	Native species richness[a] and species diversity[b]	Maintain or increase	Every 5 years throughout permit term

[a] "Species richness" is the number of different species represented in a set or collection of individuals. Species richness is simply a count of species and does not take into account the abundances of the species or their relative abundance distributions. In contrast, species diversity takes into account both species richness and species evenness.

[b] "Species diversity" is the effective number of different species that are represented in a collection of individuals (a dataset). The effective number of species refers to the number of equally abundant species needed to obtain the same mean proportional species abundance as that observed in the dataset of interest (where all species may not be equally abundant). Species diversity consists of two components: species richness and species evenness.

3.4.8.4 Consistency with the Biological Goals and Objectives

CM8 will advance the biological goals and objectives as identified in Table 3.4.8-2. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals

1 and objectives are met. Table 3.4.8-2 also identifies the monitoring actions associated with each
2 objective as it relates to CM8.

3 **Table 3.4.8-2. Biological Goals and Objectives Addressed by CM8 and Related Monitoring Actions**

Biological Goal or Objective	How CM8 Advances Biological Objective	Monitoring Action(s)
Goal L1: A reserve system with representative natural and seminatural landscapes consisting of a mosaic of natural communities that is adaptable to changing conditions to sustain populations of covered species and maintain or increase native biodiversity.		
Objective L1.5: In restored floodplains, provide a range of elevations that transition from frequently flooded (e.g., every 1 to 2 years) to infrequently flooded (e.g., every 10 years or more) areas to provide a range of habitat conditions, upland habitat values, and refugia from flooding during most flood events.	Grasslands will be restored along the upper margins of restored floodplains or adjacent to the outside of levees adjacent to restored floodplain in Conservation Zone 7 to provide upland refugia for riparian brush rabbit.	CM3 compliance monitoring
Goal L3: Capacity for movement of native organisms and genetic exchange among populations necessary to sustain native fish and wildlife species in the Plan Area.		
Objective L3.1: Protect and improve habitat linkages that allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area.	Grassland restoration will improve habitat linkages for covered and other native species that use grasslands by locating restoration projects between existing grasslands.	CM3 compliance monitoring, CM8-2
Goal GNC1: Extensive grasslands composed of large, interconnected patches or contiguous expanses.		
Objective GNC1.2: Restore 2,000 acres of grasslands to connect fragmented patches of protected grassland and to provide upland habitat adjacent to riparian, tidal, and nontidal natural communities for wildlife foraging and upland refugia.	The restoration of 2,000 acres of grasslands will be prioritized in areas that connected existing fragmented patches of protected grassland.	CM8-1, CM8-2, CM8-3, CM8-4
Objective GNC1.4: Of the 8,000 acres of grassland protected under Objective GNC1.1 and 2,000 acres of grassland restored under Objective GNC1.2, protect or restore grasslands adjacent to restored tidal brackish emergent wetlands to provide at least 200 feet of adjacent grasslands beyond the sea level rise accommodation.	A portion of the grassland restored under CM8 may be designed specifically to meet this objective.	Compliance monitoring
Goal GNC2: Biologically diverse grasslands that are managed to enhance native species and sustained by natural ecological processes.		
Objective GNC2.1: Restore and sustain a mosaic of grassland vegetation alliances, reflecting localized water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.	Grassland planting and seeding will be designed to include a mosaic of grassland vegetation alliances to meet this objective. See *Siting and Design Considerations.*	CM8-5
Objective GNC2.2: Increase the extent, distribution, and density of native perennial grasses intermingled with other native species, including annual grasses, geophytes, and other forbs.	Grassland restoration will be designed to meet this objective, as described in *Siting and Design Considerations.*	CM8-6

Biological Goal or Objective	How CM8 Advances Biological Objective	Monitoring Action(s)
Goal RBR1: Suitable habitat available for the future growth and expansion of riparian brush rabbit populations.		
Objective RBR1.6: Of the 8,000 acres of grasslands protected under Objective GNC1.1 and the 2,000 acres of grasslands restored under Objective GNC1.2, protect or restore grasslands on the landward side of levees adjacent to restored floodplain to provide flood refugia and foraging habitat for riparian brush rabbit.	A portion of the grassland restored under CM8 may be designed specifically to meet this objective.	Compliance monitoring
Goal GGS1: Well-connected high-value upland and aquatic giant garter snake habitat in Conservation Zones 4 and/or 5.		
Objective GGS1.2: Of the 8,000 acres of grassland protected under Objective GNC1.1 and 2,000 acres restored under Objective GNC1.2, create or protect 200 acres of high-value upland giant garter snake habitat adjacent to the at least 600 acres of nontidal tidal perennial habitat being restored and/or created in Conservation Zones 4 and/or 5 (Objective GGS1.1).	A portion of the grassland restored under CM8 may be designed specifically to meet this objective.	Compliance monitoring
Objective GGS2.2: Of the 8,000 acres of grasslands protected under Objective GNC1.1 and the 2,000 acres restored under Objective GNC1.2, create or protect at least 200 acres of high-value upland habitat adjacent to the at least 600 acres of nontidal marsh habitat created in Conservation Zone 2 outside of Yolo Bypass (Objective GGS2.1).	A portion of the grassland restored under CM8 may be designed specifically to meet this objective.	Compliance monitoring

3.4.9 Conservation Measure 9 Vernal Pool and Alkali Seasonal Wetland Complex Restoration

Under *CM9 Vernal Pool and Alkali Seasonal Wetland Complex Restoration,* the Implementation Office will restore vernal pool complex and alkali seasonal wetland complex in Conservation Zones 1, 8, or 11 to achieve no net loss of vernal pool and alkali seasonal wetland acreage from covered activities. The restored vernal pool complex will consist of vernal pools and swales within a larger matrix of grasslands. Similarly, the alkali seasonal wetland complex will consist of alkali seasonal wetlands within a larger matrix of grasslands. The Implementation Office will select specific restoration sites in Conservation Zones 1, 8, or 11 based on the suitability of available lands for restoration, biological value, and practicability considerations. Vernal pool and alkali seasonal wetland complex restoration under CM9 is intended to contribute toward achieving biological goals and objectives for the vernal pool and alkali seasonal wetland complex natural communities. The vernal pool complex natural community goals and objectives are detailed in Section 3.3.6.8, *Vernal Pool Complex.* The alkali seasonal wetland complex goals and objectives are detailed in Section 3.3.6.7, *Alkali Seasonal Wetland Complex*. CM9 consistency with relevant goals and objectives is further described in Section 3.4.9.5, *Consistency with the Biological Goals and Objectives.*

Restoration is one component of the conservation strategy for the vernal pool and alkali seasonal wetland natural communities. The strategies for these natural communities also include protection and management of existing vernal pool and alkali seasonal wetland complexes. Refer to *CM3 Natural Communities Protection and Restoration* and *CM11 Natural Communities Management and Enhancement* for these other components of the vernal pool complex and alkali seasonal wetland complex conservation strategies.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM9. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM9 on covered species will be avoided or minimized. Refer to Chapter 5, Section 5.4.11, *Grassland*, and Section 5.4.13, *Cultivated Lands*, for potential effects of CM9 on these natural communities.

3.4.9.1 Purpose

The purpose of CM9 is to ensure that there is no net loss of vernal pool and alkali seasonal wetland ecosystem function and no net loss of acreage of these habitat types in the Plan Area resulting from covered activities. Restoration of vernal pool and alkali seasonal wetland complexes, as described here, will offset the loss of vernal pool and alkali seasonal wetland complexes resulting from covered activities and provide for the conservation and management of associated covered species in the Plan Area. Restored vernal pool complex and alkali seasonal wetland complex will complement other restoration and protection in the reserve system as well as existing conservation lands. In conjunction with protection of 600 acres of existing vernal pool complex and 150 acres of alkali seasonal wetland complex, restoration actions will contribute to the establishment of a large, interconnected vernal pool complex and alkali seasonal wetland complex reserve in the Plan Area. Establishment of a large reserve will prevent further habitat fragmentation that can otherwise disrupt hydrologic processes and gene flow (Cushman 2006). A large, interconnected reserve is also important to provide sufficient upland habitat for the protection of vernal pool and alkali seasonal wetland plant pollinators, provide for dispersal of vernal pool and alkali seasonal wetland plants and animals, and sustain important predators of herbivores such as rodents and rabbits (U.S. Fish and Wildlife Service 2005).

The vernal pool complex reserve system, including both restored and protected vernal pool complex, will benefit the following vernal-pool-dependent covered species.

- Conservancy fairy shrimp
- Vernal pool fairy shrimp
- Vernal pool tadpole shrimp
- Midvalley fairy shrimp
- California linderiella
- California tiger salamander
- Alkali milk-vetch
- Legenere
- Heckard’s peppergrass
- San Joaquin spearscale
- Boggs Lake hedge-hyssop

- Dwarf downingia

The restored and protected alkali seasonal wetland complex reserve system will also benefit the following alkali-seasonal-wetland-dependent covered species:.

- Heartscale
- Brittlescale
- Carquinez goldenbush

The federal government (USFWS and other federal resource agencies) has a no–net-loss policy for wetlands, meaning that wetland losses must be offset by wetland gains and, to the extent possible, ecosystem function (U.S. Fish and Wildlife Service 1994). In addition to meeting this no net loss policy, vernal pool and alkali seasonal wetland restoration will offset BDCP-related impacts on these natural communities and their associated covered species and help contribute to the recovery of those covered species (see below for a summary of benefits to covered species and Section 3.3.7, *Species Biological Goals and Objectives*, for a detailed description of benefits of the conservation strategy for each covered species). The restoration will supplement protection of 600 acres of vernal pool complex and 150 acres of alkali seasonal wetland complex (*CM3 Natural Communities Protection and Restoration*) to achieve biological goals and objectives for these natural communities and their associated covered species.

3.4.9.2 Problem Statement

For descriptions of the ecological implications and current condition of vernal pool complex in the Plan Area, see Chapter 2, Section 2.3.4.9, *Vernal Pool Complex*, and Section 3.3.6.8, *Vernal Pool Complex*. For the alkali seasonal wetland complex descriptions, see Chapter 2, Section 2.3.4.8, *Alkali Seasonal Wetland Complex*, and Section 3.3.6.7, *Alkali Seasonal Wetland Complex*. Sections 3.3.4.7 and 3.3.4.8 also describe the need for a restoration program as a component of the conservation strategies for vernal pool complex and alkali seasonal wetland complex natural communities associated covered species, based on the existing conditions and ecological values of these resources. Restoration will be needed if covered activities result in loss of wetted acres of vernal pools or other wetland habitat occupied by vernal pool crustaceans, or loss of alkali seasonal wetlands, to meet a no-net-loss standard for these resources.

3.4.9.3 Implementation

3.4.9.3.1 Restoration Actions

Vernal Pool Complex

Vernal pool complex restoration will occur prior to or concurrent with impacts, as defined below. The amount of restoration will be determined during implementation based on the following criteria.

- If restoration is completed (i.e., restored natural community meets all success criteria) prior to impacts, then 1.0 wetted acre of vernal pools will be restored for each wetted acre directly affected (1:1 ratio).

- If restoration takes place concurrent with impacts (i.e., restoration construction is completed, but restored habitat has not met all success criteria, prior to impacts occurring), then 1.5 wetted acres of vernal pools will be restored for each wetted acre directly affected (1.5:1 ratio).

Restoration must offset loss of any wetland features exhibiting the hydrologic and vegetative characteristics of vernal pools (see Chapter 2, Section 2.3.4.9, *Vernal Pool Complex*, for a description of these characteristics) whether or not they are occupied by covered species. Vernal pool complex restoration must also offset loss of wetland features that do not exhibit typical vernal pool hydrology and vegetation, but only if they are occupied by covered vernal pool crustaceans. No more than 10 wetted acres of vernal pools or vernal pool crustacean habitat will be removed as a result of covered activities (as described in *AMM12 Vernal Pool Crustaceans* in Appendix 3.C, *Avoidance and Minimization Measures*).

The restored vernal pools and surrounding grasslands will be protected and managed *in perpetuity*. The surrounding grasslands will consist of existing or restored grasslands.[24] The protected lands will include sufficient watershed surrounding the restored vernal pools to sustain the hydrology characteristic of this natural community, at a density representative of intact vernal pool complexes in the vicinity of the restoration site. In lieu of restoration, an equivalent amount of vernal pool restoration credit may be purchased at a USFWS- and CDFW-approved mitigation bank if the bank occurs in the Plan Area and meets the site selection criteria described below.

Alkali Seasonal Wetland Complex

Alkali seasonal wetland complex restoration will occur prior to or concurrent with impacts, as defined below. The amount of restoration will be determined during implementation based on the following criteria.

- If restoration is completed (i.e., restored natural community meets all success criteria) prior to impacts, then 1.0 wetted acre of alkali seasonal wetlands will be restored for each wetted acre directly affected (1:1 ratio).
- If restoration takes place concurrent with impacts (i.e., restoration construction is completed, but restored habitat has not met all success criteria, prior to impacts occurring), then 1.5 wetted acres of alkali seasonal wetlands will be restored for each wetted acre directly affected (1.5:1 ratio).

Restoration must offset loss of any wetland features exhibiting the hydrologic and vegetative characteristics of alkali seasonal wetlands (see Chapter 2, Section 2.3.4.8, *Alkali Seasonal Wetland Complex*, for a description of these characteristics) whether or not they are occupied by covered species. No more than 72 acres of alkali seasonal wetland complex will be removed as a result of covered activities. The restored alkali seasonal wetland complex will contain alkali seasonal wetlands at densities comparable to those where alkali seasonal wetlands are lost as a result of covered activities. The restored alkali seasonal wetlands and surrounding upland natural community will be protected and managed *in perpetuity*. The surrounding upland natural community will consist of existing or restored grasslands.[25] The protected lands will include

[24] The surrounding grasslands will be a component of restored vernal pool complex and will not count toward the target acreages for grassland protection or restoration.

[25] The surrounding grasslands will be a component of restored vernal pool complex and will not count toward the target acreages for grassland protection or restoration.

sufficient watershed surrounding the restored alkali seasonal wetlands to sustain the hydrology characteristic of this natural community, at a density representative of intact alkali seasonal wetland complex in the vicinity of the restoration site. In lieu of restoration, an equivalent amount of alkali seasonal wetland restoration credit may be purchased at a USFWS- and CDFW-approved mitigation bank if the bank occurs in the Plan Area and meets the site selection criteria described below.

3.4.9.3.2 Siting Criteria

Vernal Pool Complex

Vernal pool restoration sites will meet the following site selection criteria.

- The site is in Conservation Zone 1, 8, or 11.
- The site has evidence of historical vernal pools based on soils, remnant topography, remnant vegetation, historical aerial photos, or other historical or site-specific data.
- The site supports suitable soils and landforms for vernal pool restoration.
- The adjacent land use is compatible with restoration and long-term management to maintain natural community functions (e.g., not adjacent to urban or rural residential areas).
- Sufficient land is available for protection to provide the necessary vernal pool complex restoration and surrounding grasslands to provide the local watershed for sustaining vernal pool hydrology, with a vernal pool density representative of intact vernal pool complex in the vicinity of the restoration site.

Acquisition of vernal pool restoration sites will be prioritized based on the following criteria.

- The site will contribute to establishment of a large, interconnected vernal pool and alkali seasonal wetland complex reserve system (e.g., adjacent to existing protected vernal pool complex or alkali seasonal wetland complex).
- The site is close to known populations of covered vernal pool species.

Alkali Seasonal Wetland Complex

Alkali seasonal wetland complex restoration sites will meet the following site selection criteria.

- The site is in Conservation Zone 1, 8, or 11.
- The site has evidence of historical alkali seasonal wetlands based on soils, remnant topography, remnant vegetation, historical aerial photos, or other historical or site-specific data.
- The site supports suitable soils and landforms for alkali seasonal wetland restoration.
- The adjacent land use is compatible with restoration and long-term management to maintain natural community functions (e.g., not adjacent to urban or rural residential areas).
- Sufficient land is available for protection to provide the necessary alkali seasonal wetland complex restoration and surrounding grasslands to provide the local watershed for sustaining alkali seasonal wetland hydrology, with an alkali seasonal wetland density representative of intact alkali seasonal wetland complex in the vicinity of the restoration site.

Acquisition of alkali seasonal wetland restoration sites will be prioritized based on the following criteria.

- The site will contribute to establishment of a large, interconnected vernal pool complex and alkali seasonal wetland complex reserve system (e.g., adjacent to existing protected vernal pool complex or alkali seasonal wetland complex).
- The site is close to known populations of covered alkali seasonal wetland species.

3.4.9.3.3 Restoration Techniques

Vernal Pool Complex

The following restoration techniques will be implemented for vernal pool restoration.

- Remnant natural vernal and swale topography will be restored by excavating or recontouring historical vernal pools and swales to natural bathymetry based on their characteristic visual signatures on historical aerial photographs, other historical data, and the arrangement and bathymetry of vernal pools and swales at a reference site.
- The reference site will consist of existing nearby, natural (i.e., unmodified by human activities) vernal pool complex supporting covered vernal pool species.
- To provide for high-functioning habitat, restored vernal pool complex will be vegetated with hand-collected seed from appropriate areas in the same conservation zone. Soil inocula will not be used to establish vernal pool plants and animals in these conservation zones unless the source vernal pools are free of undesirable nonnative plant species such as perennial pepperweed, waxy mannagrass, swamp timothy, and Italian ryegrass. These nonnative species establish more rapidly than native species, and create dense populations that are likely to reduce the establishment success of the native plants and also create thatch problems in the vernal pools (see Baraona et al. 2007 for problems of nonnative species thatch buildup due to soil inocula).
- Vernal pool invertebrates are expected to be passively introduced into the restored vernal pools through the movement of other animals from pool to pool. If monitoring shows that passive introduction is insufficient for meeting restoration success criteria, active propagule (cyst) introduction may be implemented. Any introduction of propagules of covered vernal pool invertebrate species will be sourced from vernal pool soils that are free of undesirable nonnative species such as perennial pepperweed, swamp timothy, and Italian ryegrass.

Alkali Seasonal Wetland Complex

The following restoration techniques will be implemented for alkali seasonal wetland complex restoration.

- Remnant natural vernal and swale topography will be restored by excavating or recontouring historical alkali seasonal wetlands and swales to natural bathymetry based on their characteristic visual signatures on historical aerial photographs, other historical data, and the arrangement and bathymetry of alkali seasonal wetlands and swales at a reference site.
- The reference site will consist of existing nearby, natural (i.e., unmodified by human activities) alkali seasonal wetland complex supporting covered species.
- To provide for high-functioning habitat, restored alkali seasonal wetland complex will be vegetated with hand-collected seed from appropriate areas in the same conservation zone. Soil inocula will not be used to establish alkali seasonal wetland plants and animals in these

conservation zones unless the source wetlands are free of undesirable nonnative plant species such as perennial pepperweed, waxy mannagrass, swamp timothy, and Italian ryegrass. These nonnative species establish more rapidly than native species, and create dense populations that are likely to reduce the establishment success of the native plants and also create thatch problems in the alkali seasonal wetlands (see Baraona et al. 2007 for problems of nonnative species thatch buildup due to soil inocula).

3.4.9.3.4 Establishment of Covered Plant Occurrences

The Implementation Office will establish two currently unprotected occurrences of Heckard's peppergrass in Conservation Zones 1, 8, or 11, consistent with Objective VPP1.2, if lands with unprotected occurrences are unavailable for acquisition. Plant occurrences will be established in restored vernal pool complex using seed from the same conservation zone as the restored vernal pool complex. The methods for establishing each occurrence, as well as monitoring methods, success criteria, and contingency measures, will be detailed in the site-specific restoration plan. Occurrences may also be established in protected vernal pool complex, as described in *CM3 Natural Communities Protection and Restoration*.

3.4.9.3.5 Site-Specific Restoration Plans

A site-specific restoration plan will be developed for each vernal pool restoration site. The restoration plan will include the following elements.

- A description of the aquatic functions, hydrology/topography, soils/substrate, and vegetation, for the design reference site, the existing condition of the restoration site, and the anticipated condition of the restored site.
- Success criteria for determining whether vernal pool or alkali seasonal wetland functions have been successfully restored, including relevant criteria provided in Table 3.4.9-1.
- A description of the restoration monitoring, including methods and schedule consistent with relevant monitoring actions, metrics, and timing and duration provided in Table 3.4.9-1, for determining whether success criteria have been met.
- An implementation plan and schedule that includes a description of site preparation, seeding, and irrigation.
- A description of maintenance activities and a maintenance schedule to be implemented until success criteria are met.
- A description of contingency measures to be implemented if success criteria are not met within the established monitoring timeframe.

3.4.9.3.6 Protection and Management

Restoration sites will be acquired, in fee-title or through conservation easements, and protected *in perpetuity* (see Chapter 8, *Implementation Costs and Funding Sources*, for a description of the funding for protection *in perpetuity*). Each restoration site will be managed and maintained consistent with the site-specific restoration plan until restoration success criteria have been met, and will henceforth be managed *in perpetuity* in the manner described in *CM11 Natural Communities Enhancement and Management.*

3.4.9.4 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting in a GIS database the extent of vernal pool complex and alkali seasonal wetland complex successfully restored and mapping restored habitat for each covered species predicted by habitat models to use these natural communities.

Effectiveness monitoring will be conducted to evaluate progress toward meeting the objectives discussed in Section 3.4.9.5, *Consistency with the Biological Goals and Objectives.* If necessary, the implementation actions described above will be adjusted via adaptive management, described in Section 3.6, to meet these objectives.

Effectiveness monitoring will consist of verifying that restoration sites are performing the expected ecological functions as prescribed by success criteria in the site-specific restoration plans. See Section 3.4.3.4.2, *Site-Specific Restoration Plans*, for a description of the elements to be incorporated into site-specific restoration plans. Table 3.4.9-1 lists monitoring actions, metrics, success criteria, and schedules relevant to CM9, for incorporation into site-specific restoration plans, as appropriate. The actual monitoring actions, success criteria, metrics, and timing will be based on the best available information at the time of implementation and may be adjusted or supplemented over time through adaptive management, provided such modifications will still allow comparison of data collected throughout the permit term and between sites across the reserve system.

If success criteria are not met within the specified schedule, contingency measures will be implemented as described in the restoration plan. Contingency measures to be implemented if restoration is unsuccessful may include, but are not limited to, topographic modification, plantings, management changes (e.g., changing grazing regime or temporarily fencing pools to exclude cattle) or constructing additional pools at a new location. The latter measure will only be implemented if other options have been exhausted. After the vernal pools have been successfully restored, effectiveness monitoring and research actions will be implemented as described for the protected vernal pool complex natural community (*CM11 Natural Communities Enhancement and Management*).

No key uncertainties or research needs have been identified in connection with this conservation measure. There is high confidence that this conservation measure will be effective as planned.

Table 3.4.9-1. Effectiveness Monitoring Relevant to CM9

ID#	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM9-1	Vegetation sampling	Species dominance	Dominant species (with a Braun-Blanquet cover scale of 3 or greater) will be "vernal pool indicators," "vernal pool associates," or vernal pool generalists that occur in the reference pools[a].	Annually until success criteria are met and then once every 5 years for 10 years
CM9-2	Vegetation sampling	The percentage of relative cover attributable to native vernal pool species	As specified in site-specific restoration plan and comparable to reference pools	Annually until success criteria are met and then once every 5 years for 10 years
CM9-3	Monitor hydrology	Pool depth and duration	As specified in site-specific restoration plan and comparable to reference pools	Annually until success criteria are met and then once every 5 years for 10 years
CM9-4	Plant count	Number of individuals	Annual average number of individuals measured over a 5-year period meets or exceeds number necessary for viable population based on best available scientific information.	Annually for 10 years or until success criteria are met, whichever is longer

[a] "Vernal pool indicators" and "vernal pool associates" as defined in CDFWs list: *Catalog of Plant Species Known to be Associated with Vernal Pools* (California Department of Fish and Game 1998) or as native species present in reference pools.

3.4.9.5 Consistency with the Biological Goals and Objectives

CM9 will advance the biological goals and objectives as identified in Table 3.4.9-2. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. These goals and objectives relate to vernal pool complex restoration only; the vernal pool complex conservation strategy includes additional biological objectives (Section 3.3.6.9, *Vernal Pool Complex*) that would be achieved through protection and management as described in *CM3 Natural Communities Protection and Restoration* and *CM11 Natural Communities Enhancement and Management*. Progress in meeting these biological goals and objectives would be measured using the monitoring metrics identified in Table 3.4.9-1. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Table 3.4.9-2 also identifies the monitoring actions associated with each objective as it relates to CM8.

Table 3.4.9-2. Biological Goals and Objectives Addressed by CM9 and Related Monitoring Actions

Biological Goal or Objective	How CM9 Advances a Biological Objective	Monitoring Action(s)
Goal VPNC1: Vernal pool complexes composed of large, interconnected, or contiguous expanses that represent a range of environmental conditions**.**		
Objective VPNC1.2: Restore vernal pool complex in Conservation Zones 1, 8, and/or 11 to achieve no net loss of vernal pool acreage (up to 67 acres of vernal pool complex restoration, assuming that all anticipated impacts [10 wetted acres] occur and that the restored vernal pool complex has 15% density of vernal pools).	This objective will be fully met by implementing CM9, as described in Section 3.4.9.3, *Implementation.*	CM9-1, CM9-2, CM9-3
Objective VPNC1.3: Increase the size and connectivity of protected vernal pool complex in the Plan Area and increase connectivity with protected vernal pool complex adjacent to the Plan Area.	Vernal pool complex restoration will be sited in areas that maximize opportunities for meeting this objective.	Compliance monitoring
Goal ASWNC1: A reserve system including alkali seasonal wetland complex within a mosaic of grasslands and vernal pool complex.		
Objective ASWNC1.2: Restore or create alkali seasonal wetlands in Conservation Zones 1, 8, and/or 11 to achieve no net loss of wetted acres (up to 72 acres of alkali seasonal wetland complex restoration, assuming all anticipated impacts occur).	This objective will be fully met by implementing CM9, as described in Section 3.4.9.3, *Implementation.*	CM9-1, CM9-2, CM9-3
Goal VPP1: A reserve system that protects vernal pool plant populations.		
Objective VPP1.2: Maintain no net loss of Heckard's peppergrass in Conservation Zones 1, 8, or 11 within restoration sites or within the area of affected tidal range of restoration projects.	Establishment of occurrences will be met by implementing CM9, as described in Section 3.4.9.3.4, *Establishment of Covered Plant Occurrences.* (Refer to CM3 *Natural Communities Protection and Restoration* regarding protection of occurrences.)	CM9-4

3.4.10 Conservation Measure 10 Nontidal Marsh Restoration

Under *CM10 Nontidal Marsh Restoration,* the Implementation Office will restore 1,200 acres of nontidal marsh in Conservation Zones 2, and 4 and/or 5 by year 40. CM10 actions will be phased, with 400 acres restored by year 10, 600 acres by year 20, and 1,200 (cumulative) acres restored by year 40. Additional nontidal marsh may be restored to contribute toward the requirements for protection or restoration of rice land or equivalent-value habitat for giant garter snake under Objectives GGS1.4 and GGS3.1. This conservation measure also provides for creation of 500 acres of managed wetlands consisting of greater sandhill crane roosting habitat in the Greater Sandhill Crane Winter Use Area (Figure 2.A.19-3, *Greater Sandhill Crane Foraging Habitat and Associated Value Rankings*, in Appendix 2.A) in Conservation Zones 3, 4, 5, or 6 by year 10 (250 acres during years 1 through 5 and 250 acres during years 6 through 10).

The primary purpose of CM10 is to restore nontidal freshwater emergent wetland and nontidal perennial aquatic natural communities to create additional foraging and breeding habitat for giant garter snake, western pond turtle, and other native wildlife and plant species characteristic of these natural communities. The feasibility of restoring nontidal marsh is evidenced by other nontidal marsh restoration projects that have been successfully implemented in the Plan Area, as described in Table 3.4.3-1 (*CM3 Natural Communities Protection and Restoration*). The location and extent of nontidal marsh to be restored is based primarily on the recovery needs of giant garter snake, as determined through coordination with USFWS and CDFW, based on a recovery plan for the species that is in preparation at the time of this writing.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM10. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM10 on covered species will be avoided or minimized. Refer to Chapter 5, Section 5.4, *Effects on Natural Communities*; Section 5.5, *Effects on Covered Fish*; and Section 5.6, *Effects on Covered Wildlife and Plant Species*), for effects of CM10 on natural communities and covered species. A list of nontidal marsh restoration projects that have been implemented in and around the Plan Area is provided in Table 3.4.3-1 (*CM3 Natural Communities Protection and Restoration*).

3.4.10.1 Problem Statement

For descriptions of the ecological values and current condition of nontidal marshes in the Plan Area, see Chapter 2, Section 2.3.4.6, *Nontidal Perennial Aquatic*; Section 2.3.4.7, *Nontidal Freshwater Emergent Wetland*; and Section 3.3.6.6, *Nontidal Perennial Aquatic and Nontidal Freshwater Emergent Wetland*. Section 3.3.6.6, *Nontidal Perennial Aquatic and Nontidal Freshwater Perennial Emergent Wetland*, also describes the need for restoration as a component of the conservation strategies for nontidal marsh and associated covered species, based on the existing conditions and ecological values of these resources.

Nontidal marsh occurs in highly fragmented and small patches in and adjacent to the Plan Area. The extent, distribution, and condition of nontidal freshwater emergent wetland natural community has been substantially reduced throughout the Central Valley and along the perimeter of the Delta (Gilmer et al. 1982; The Bay Institute 1998). This reduction in the extent, distribution, condition, and diversity of this natural community has resulted in similar declines in available habitat for many native species, including the giant garter snake.

Giant garter snake is known primarily from nontidal marsh in the interior of the Central Valley, including along the eastern perimeter of the Delta. Agricultural conversion and stream channelization have removed nontidal marsh, leading to widespread giant garter snake population declines and restriction of extant populations to degraded habitats, such as irrigation channels and rice fields. A lack of nontidal marsh limits the ecological benefits to fish and wildlife by limiting important ecological gradients and ecosystem functions that these habitats would provide, particularly in association with other native habitats including grassland and riparian habitats. Restoring nontidal marsh and incorporating aquatic, riparian, and upland transitional habitats are expected, along with BDCP conservation of other natural communities, to reestablish more natural ecological gradients. Nontidal marsh restoration will also increase the abundance and distribution of associated covered and other native species, improve connectivity among habitat areas in and adjacent to the Plan Area, improve genetic interchange among native nontidal freshwater emergent wetland species' populations, and contribute to the long-term conservation of giant garter snake and other native species. In addition to giant garter snake, covered species associated with nontidal marsh include tricolored blackbird, California black rail, western pond turtle, and greater sandhill crane.

Creation of greater sandhill crane roosting habitat is necessary to offset adverse effects to roosting habitat resulting from covered activities, and to further contribute to the conservation of this species. In the Delta region, the conversion of suitable roosting habitat to unsuitable cover types, particularly orchards and vineyards, has altered the distribution and behavior of wintering greater sandhill cranes.

3.4.10.2 Implementation

3.4.10.2.1 Restoration Actions

Nontidal Marsh

The Implementation Office will create 1,200 acres of nontidal marsh in three conservation zones. The restored nontidal marsh will consist of two blocks: 600 acres in Conservation Zone 2 outside the Yolo Bypass and 600 acres in Conservation Zone 4 or 5 (or both). In Conservation Zones 4 or 5, restoration will be contiguous with the 1,500 acres of rice land or equivalent giant garter snake habitat protected or restored consistent with Objective GGS1.4. Additional nontidal marsh may be restored in Conservation Zones 1, 2, 4, and/or 5 to contribute toward the requirements for protection or restoration of rice land or equivalent-value habitat for giant garter snake under Objectives GGS1.4 and GGS3.1.[26]

Restored nontidal marsh will be designed and managed primarily to support giant garter snake, but also to support other native wildlife functions, including waterfowl foraging, resting, and brood habitat, and shorebird foraging and roosting habitat, to the extent that management for these species does not reduce habitat value for the giant garter snake. Design measures will also be incorporated for western pond turtle, as described below. Although the restored nontidal marsh may provide nesting habitat value for tricolored blackbird, it will not be designed specifically for this species (which prefers large, dense patches of emergent vegetation). Instead, restoration sites will provide a mosaic of open water and relatively open emergent vegetation for the primary benefit of giant garter snake. Upland habitat consisting of grasslands will be restored or protected adjacent to restored freshwater emergent wetland to provide upland habitat for giant garter snake and western pond turtle and nesting habitat for waterfowl; this will be credited toward the 8,000 acres of grassland to be protected (Objective GNC1.1) or the 2,000 acres of grassland to be restored (Objective GNC1.2). To ensure the feasibility and function of these dual restoration/protection actions, it is recommended that they be pursued jointly by the Implementation Office; in some cases, protected grassland may already exist adjacent to restored nontidal marsh, so protection or restoration of grassland by the BDCP would be unnecessary.

[26] The rice land or equivalent giant garter snake habitat may consist of tidal or nontidal marsh, if rice land is not available for protection in the locations specified under Objective GGS1.4. Use of tidal marsh to satisfy Objectives GGS1.4 and GGS3.1 is described in *CM4 Tidal Natural Communities Restoration.* If nontidal marsh is used to satisfy Objective GGS1.4 or GGS3.1, the acreage applied to this objective will be consistent with the siting and design considerations described below, but will be above and beyond the 1,200 acres specified under Objective NFEW/NPANC1.1.

Project planning and preparation actions for restoration of all natural communities are described in *CM3 Natural Communities Protection and Restoration*. In addition, actions to restore nontidal freshwater emergent wetland natural community, as appropriate to site-specific conditions, include, but are not limited to, the following.

- Secure sufficient annual water to sustain habitat function.
- Establish connectivity with the existing irrigation and drainage conveyance system (i.e., agricultural ditches and canals) and habitats occupied by giant garter snakes.
- Prepare site, plant native marsh vegetation, and maintain plantings.
- Control nonnative invasive plants that impair achievement of reserve system objectives.

Managed Wetlands

At least 500 acres of managed wetlands will be created for greater sandhill crane to meet requirements under Objectives GSHC1.3 and GSHC1.4. The restored wetlands will be protected in association with other protected natural community types (excluding nonhabitat cultivated lands) at a 2:1 upland-to-wetland ratio to provide buffers around the wetlands. The protected uplands will count toward protection requirements for other natural communities. Sites for restoration will be selected that are not expected to be affected by sea level rise. Sites will also be selected to avoid areas that experience local seasonal flood events that may be incompatible with the habitat management needs for greater sandhill crane.

At least 320 of the 500 acres of managed wetlands will be created to meet Objective GSHC1.3. These will consist of greater sandhill crane roosting habitat in minimum patch sizes of 40 acres within the Greater Sandhill Crane Winter Use Area (Figure 2.A.19-3, *Greater Sandhill Crane Foraging Habitat and Associated Value Rankings*, in Appendix 2.A) in Conservation Zones 3, 4, 5, or 6.

At least 180 of the 500 acres of managed wetlands will be created to meet Objective GSHC1.4. This will consist of two 90-acre wetland complexes within the Stone Lakes National Wildlife Refuge project boundary[27] (Figure 3.3-6). The complexes will be no more than 2 miles apart and will help provide connectivity between the Stone Lakes and Cosumnes greater sandhill crane populations. Each complex will consist of at least three wetlands totaling at least 90 acres of greater sandhill crane roosting habitat. One of the 90-acre wetland complexes may be replaced by 180 acres of cultivated lands (e.g., cornfields) that are flooded following harvest to support roosting cranes and provide highest-value foraging habitat, provided such substitution is consistent with the long-term conservation goals of Stone Lakes National Wildlife Refuge for greater sandhill crane.

3.4.10.2.2 Siting and Design Considerations

Nontidal Marsh

Nontidal marsh restoration sites will be designed to support the range of habitat conditions necessary for giant garter snake. By designing the restoration specifically for giant garter snake and ensuring adequate open basking opportunities, the restored nontidal marsh is also is expected to provide suitable habitat for western pond turtle.

[27] The project boundary delineates the area surrounding the existing refuge for which the refuge has authority to acquire land or easements.

Existing cultivated lands will be converted to nontidal marsh in areas where hydrology and soils are suitable. Restoration may include creating wetland topography by site grading or creation of depressions to hold water. Grading will establish an elevation gradient to support open water, perennial aquatic habitat intermixed with shallower marsh habitat. Additional issues that will be addressed in each site-specific restoration plan include preventing fish from becoming stranded in the ponds (e.g., by the use of fish screens or other appropriate devices), if the hydrology source is a perennial water body that supports fish.

As described in *CM3 Natural Communities Protection and Restoration* and *CM8 Grassland Natural Community Restoration*, grassland natural community will be protected or restored adjacent to restored nontidal freshwater emergent wetland natural community to provide upland habitat for giant garter snakes and other native wildlife. The restored tidal marsh will consist of a combination of emergent, tule-dominated vegetation and open water, with variable bank slopes.

Coarse woody debris or anchored basking platforms will be installed in open-water areas to improve habitat for western pond turtles (Hays et al*.* 1999). This will increase habitat value in locations with existing western pond turtles and in newly created ponds where it is hoped that new pond turtle populations will establish.

Nontidal freshwater emergent wetland natural community will be allowed to naturally reestablish along the edges of nontidal perennial aquatic natural community but will also be planted as needed to facilitate marsh development and to manage species composition. Approximately two-thirds of the restored nontidal marsh is expected to consist of nontidal perennial aquatic natural community, and approximately one-third is expected to consist of nontidal freshwater emergent wetland, although this proportion may shift as needed based on site conditions and as necessary to optimize habitat value for giant garter snake. The choice of plant species for the nontidal freshwater emergent wetland natural community restoration sites will be based on a palette of native wetland plants including freshwater emergent and aquatic species. The palette will be specified in each site restoration plan. The plants will preferentially be grown from soil, seed, or plant stock from local wetland sites. In addition, vegetation is expected to change after the original planting such that other native species may colonize the wetland over time. Colonization by undesirable nonnative invasive plants is also likely, so restoration plans will address management of nonnative invasives.

The nontidal marsh will be designed in conjunction with restored or protected grasslands to meet giant garter snake habitat requirements as follows.

- The restored nontidal marsh should be characterized by sufficient water during the giant garter snake's active summer season (March–October) to supply constant, reliable cover and sources of food such as small fish and amphibians.
- The restored nontidal marsh should consist of still or slow-flowing water over a substrate composed of soil, silt, or mud characteristic of those observed in marshes, sloughs, or irrigation canals.
- Designs will not create large areas of deep, perennial open water that would support nonnative predatory fish. The restored marsh should be characterized by a heterogeneous topography providing the range of depths and vegetation profiles consisting of emergent, herbaceous aquatic vegetation required to provide suitable foraging habitat and refuge from predators at all tide levels.

- Site topography will include areas of terrestrial refuge (grasslands, as specified in Objectives GNC1.1 and GNC1.2) with ample exposure to sunlight to facilitate snake thermoregulation, and with low vegetation, bankside burrows, holes, and crevices providing critical shelter for snakes throughout the day. Terrestrial features will be sited fewer than 200 feet from aquatic foraging habitats.
- Aquatic margins or shorelines will transition to uplands consisting of grassy banks, with the dense grassy understory required for sheltering. These margins should consist of approximately 200 feet of high ground or upland habitat above the annual high water mark to provide cover and refugia from floodwaters during the dormant winter season.

Managed Wetlands

Greater sandhill crane roost sites will be created as managed seasonal wetlands using the following specifications. A site-specific management plan will be prepared for each roost site, which will include details on water management, plant composition, timing of flood-up and drawdown, vegetation management and control, access, and spring-summer management.

- Roost sites will be developed as a series of shallow, open ponds separated by a system of checks and levees. Small upland islands can also be created within the ponds. Cranes often congregate to roost or loaf on the checks and other areas of higher ground and forage in the shallow water contained within the ponds.
- The checks, levees, and other upland sites will be designed with sloping banks, which allow cranes to walk from the flooded pond to the adjacent uplands.
- In addition to the presence of water, food availability, and loafing opportunities, selection of roosting sites by greater sandhill cranes is based in part on predator avoidance. Therefore, the development of the ponds and checks will consider the ability of predators to access roosting cranes along checks and levees.
- Selected roost sites will have direct access to sufficient irrigation water to maintain required water depths.
- The wetlands will be maintained as described in *CM11 Natural Communities Enhancement and Management.*

3.4.10.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting in a GIS database the extent of native nontidal marsh successfully restored and mapping restored habitat for each covered species expected, based on habitat models, to use this natural community.

Effectiveness monitoring will be used to evaluate progress toward advancing the biological goals and objectives described in Section 3.4.10.4, *Consistency with the Biological Goals and Objectives.* Monitoring will consist of surveys to ensure successful regeneration of native marsh plant species and other appropriate habitat conditions for the target covered species. Monitoring also will be used to determine whether nonnative vegetation control is needed to facilitate the establishment of native marsh vegetation or if restoration success could be improved with supplemental plantings of native species. If so indicated, nonnative vegetation control measures and supplemental plantings will be implemented. If necessary, the implementation actions described above will be adjusted to meet these objectives in accordance with the adaptive management procedures described in Section 3.6, *Adaptive Management and Monitoring Program*.

Restoration of nontidal marsh will be monitored consistent with the site-specific restoration plan to determine whether success criteria have been met. See Section 3.4.3.4.2, *Site-Specific Restoration Plans*, for a description of the elements to be incorporated into site-specific restoration plans. Table 3.4.10-1 lists monitoring actions, metrics, success criteria, and schedules relevant to CM10, for incorporation into site-specific riparian restoration plans, as appropriate.

No key uncertainties or research needs have been identified in connection with this conservation measure. The actual monitoring actions, success criteria, metrics, and timing will be based on the best available information at the time of implementation and may be adjusted or augmented over time through adaptive management.

If success criteria are not met within the specified schedule, contingency measures will be implemented as described in the restoration plan. Contingency measures to be implemented if restoration is unsuccessful may include, but are not limited to, plantings or management changes (e.g., invasive species control, changing water regime). After the nontidal marsh has been successfully restored, effectiveness monitoring and research actions will be implemented as described for the protected nontidal marsh in *CM11 Natural Communities Management and Enhancement*.

Table 3.4.10-1. Effectiveness Monitoring Relevant to CM10

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM10-1	Site-level assessment	Total and relative cover of native, nontidal marsh vegetation within a mosaic of open water.	As specified in site-specific restoration plan	As specified in site-specific restoration plan
CM10-2	Monitor greater sandhill crane use of roost sites in vicinity of covered activities	Presence of roosting cranes	Cranes have not abandoned roost sites	During construction activities in vicinity of roost sites, annually for 3 years after construction is completed, and during the season of expected occupancy every 5 years thereafter.

3.4.10.4 Consistency with the Biological Goals and Objectives

CM10 will advance the biological goals and objectives as identified in Table 3.4.10-2. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Table 3.4.10-2 also identifies potential monitoring actions associated with each objective as it relates to CM10.

Table 3.4.10-2. Biological Goals and Objectives Addressed by CM10 and Related Monitoring Actions

Biological Goal or Objective	How CM10 Advances a Biological Objective	Monitoring Action(s)
Goal NFEW/NPANC1: Nontidal marsh consisting of a mosaic of nontidal freshwater emergent perennial wetland and nontidal perennial aquatic natural communities, and providing habitat for covered and other native species.		
Objective NFEW/NPANC1.1: Create 1,200 acres of nontidal marsh consisting of a mosaic of nontidal perennial aquatic and nontidal freshwater emergent wetland natural communities, with suitable habitat characteristics for giant garter snake and western pond turtle.	CM10 will achieve this objective by year 40. The Implementation Office will create 1,200 acres of nontidal freshwater emergent wetland and nontidal perennial aquatic natural communities in locations and with habitat components to support giant garter snake and western pond turtle in the Plan Area.	Compliance monitoring
Goal GSHC1: Protection and expansion of greater sandhill crane winter range.		
Objective GSHC1.3: Create 320 acres of managed wetlands consisting of greater sandhill crane roosting habitat in minimum patch sizes of 40 acres within the Greater Sandhill Crane Winter Use Area[28] in Conservation Zones 3, 4, 5, or 6, with consideration of sea level rise and local seasonal flood events. The wetlands will be located within 2 miles of existing permanent roost sites and protected in association with other protected natural community types (excluding nonhabitat cultivated lands) at a ratio of 2:1 upland to wetland to provide buffers around the wetlands.	CM10 will achieve this objective as described in Section 3.4.10.2, *Implementation.*	Compliance monitoring

[28] Important geographically defined greater sandhill crane wintering areas in the Central Valley (Pogson and Lindstedt 1988; Littlefield and Ivey 2000; Ivey pers. comm.) (Figure 2A.19-2).

Biological Goal or Objective	How CM10 Advances a Biological Objective	Monitoring Action(s)
Objective GSHC1.4: In addition to the at least 320 acres of created managed wetland greater sandhill crane roosting habitat (Objective GSHC1.3), create two wetland complexes within the Stone Lakes National Wildlife Refuge project boundary[29]. The complexes will be no more than 2 miles apart and will help provide connectivity between the Stone Lakes and Cosumnes greater sandhill crane populations. Each complex will consist of at least three wetlands totaling 90 acres of greater sandhill crane roosting habitat, and will be protected in association with other protected natural community types (excluding nonhabitat cultivated lands) at a ratio of at least 2:1 uplands to wetlands (i.e., two sites with 90 acres of wetlands each). One of the 90-acre wetland complexes may be replaced by 180 acres of cultivated lands (e.g., cornfields) that are flooded following harvest to support roosting cranes and provide highest-value foraging habitat, provided such substitution is consistent with the long-term conservation goals of Stone Lakes National Wildlife Refuge for greater sandhill crane.	CM10 will achieve this objective as described in Section 3.4.10.2, *Implementation.*	CM10-2
Goal GGS1: Well-connected high-value upland and aquatic giant garter snake habitat in Conservation Zones 4 and/or 5.		
Objective GGS1.1: Of the 1,200 acres of nontidal marsh created under Objective NFEW/NPANC1.1, create at least 600 acres of aquatic habitat for the giant garter snake that is connected to the 1,500 acres of rice land or equivalent-value habitat (Objective GGS1.4).	CM10 will meet this objective by year 40. The Implementation Office will create 600 acres of nontidal freshwater emergent wetland and nontidal perennial aquatic natural communities in Conservation Zones 4 and/or 5, in locations consistent with the objective, with habitat components to support giant garter snake and western pond turtle in the Plan Area.	Compliance monitoring, CM10-1
Objective GGS1.4: Create connections from the White Slough population to other areas in the giant garter snake's historical range in the Stone Lakes vicinity by protecting, restoring, and/or creating 1,500 acres of rice land or equivalent-value habitat (e.g., perennial wetland) for the giant garter snake in Conservation Zones 4 and/or 5. Any portion of the 1,500 acres may consist of tidal freshwater emergent wetland and may overlap with the at least 24,000 acres of tidally restored freshwater emergent wetland if it meets specific giant garter snake habitat criteria described in *CM4 Tidal Natural Communities Restoration*. Up to 500 (33%) of the 1,500 acres may consist of suitable uplands adjacent to protected or restored aquatic habitat.	Nontidal marsh restoration under CM10, beyond the 600 acres required under Objective GGS1.1, may be implemented to contribute toward this objective.	Compliance monitoring

[29] The project boundary delineates the area surrounding the existing refuge for which the refuge has authority to acquire land or easements.

Biological Goal or Objective	How CM10 Advances a Biological Objective	Monitoring Action(s)
Goal GGS2: Expansive high-value upland and aquatic giant garter snake habitat in Conservation Zone 2 located outside the Yolo Bypass.		
Objective GGS2.1: Of the 1,200 acres of nontidal marsh created under Objective NFEW/NPANC1.1, create at least 600 acres of connected aquatic giant garter snake habitat outside the Yolo Bypass in Conservation Zone 2.	CM10 will meet this objective by year 40. The Implementation Office will create 1,200 acres of nontidal freshwater emergent wetland and nontidal perennial aquatic natural communities in Conservation Zone 2, in locations consistent with the objective, with habitat components to support giant garter snake and western pond turtle in the Plan Area.	Compliance monitoring, CM10-1
Goal GGS3: At least 1 acre of giant garter snake habitat conserved for each acre of loss.		
Objective GGS3.1: Protect, restore, and/or create 2,740 acres of rice land or equivalent-value habitat (e.g., perennial wetland) for the giant garter snake in Conservation Zones 1, 2, 4, or 5. Up to 500 acres may consist of tidal freshwater emergent wetland and may overlap with the at least 5,000 acres of tidally restored freshwater emergent wetland in the Cache Slough ROA if this portion meets giant garter snake habitat criteria specified in *CM4 Tidal Natural Communities Restoration*. Up to 1,700 acres may consist of rice fields in the Yolo Bypass, if this portion meets the criteria specified in *CM3 Natural Communities Projection and Restoration*, (Section 3.4.3.3.2, *Siting and Reserve Design*, *Reserve Design Requirements by Species*). Any remaining acreage will consist of rice land or equivalent-value habitat outside the Yolo Bypass. Up to 915 (33%) of the 2,740 acres may consist of suitable uplands adjacent to protected or restored aquatic habitat.	Nontidal marsh restoration under CM10, beyond the 1,200 acres required under Objectives GGS1.1 and GGS2.1, may be implemented to contribute toward this objective.	Compliance monitoring

3.4.11 Conservation Measure 11 Natural Communities Enhancement and Management

Under *CM11 Natural Communities Enhancement and Management,* the Implementation Office will prepare and implement management plans for protected natural communities, and for the covered species habitats that are found within those communities throughout the reserve system. This section describes the enhancement and management actions that will, based on the best available information, achieve applicable biological goals and objectives for natural communities and covered species other than fish, and provides management principles, guidelines, and techniques to be applied across the reserve system and for each natural community.

Implementation of this conservation measure will begin upon permit issuance and will extend over time to cover new reserves as they are acquired (*CM3 Natural Communities Protection and Restoration*). All lands in the reserve system will be managed and, in some cases, enhanced consistent with this conservation measure.

See Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM3 and CM11. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM11 on covered species will be avoided or minimized. Refer to Chapter 5, Section 5.4, *Effects on Natural Communities*, Section 5.5, *Effects on Covered Fish*, and Section 5.6, *Effects on Covered Wildlife and Plant Species*), for effects of CM11 on natural communities and covered species.

The primary purpose of CM11 is to enhance and manage natural communities and covered species habitats as detailed in Section 3.4.11.4, *Consistency with the Biological Goals and Objectives*. Natural communities that are protected or restored will be enhanced for the purposes of increasing native biodiversity and improving habitat quality for native species, particularly covered species. Natural communities will be managed for the purposes of maintaining native biodiversity and habitat quality, and for sustaining populations of covered species in the reserve system.

3.4.11.1 Problem Statement

Natural communities and covered species habitat in the Plan Area have been degraded as a result of many human-related activities such as flood control and hydrologic alteration, urban and agricultural runoff, and introduction of invasive plant and wildlife species. Enhancement of natural communities and covered species habitat is necessary to reverse historical trends, and management is necessary to prevent further degradation in the reserve system. For descriptions of the ecological values and current condition of natural communities in the Plan Area, see Chapter 2, *Existing Ecological Conditions*. Section 3.3, *Biological Goals and Objectives*, describes in detail the need for enhancing and managing each natural community as a component of the conservation strategies for these communities and associated covered species, based on the existing conditions and ecological values of these resources.

3.4.11.2 Implementation

3.4.11.2.1 Enhancement and Management Principles

The following principles apply to all enhancement and management activities.

- **Manage at multiple scales.** Biological processes occur at a wide variety of scales across the landscape. Enhancement and management activities will be planned and executed with these multiple scales in mind. For example, the enhancement of covered plant occurrences will likely occur at a relatively small scale due to the small size of many populations. Microhabitats for covered plants such as soil texture, soil depth, rockiness, and nearest neighbor plants will be considered when designing appropriate management techniques. However, other processes operating at larger scales—such as the spread of invasive species, hillside erosion or deposition, and the patterns of wildfires—will also affect plant habitat enhancement. To be successful, management actions will consider and anticipate processes operating at multiple spatial scales.
- **Balance conflicting species' needs.** Management actions at some sites will need to focus on enhancing habitat for certain covered species and those actions may preclude other covered species from using these sites. For instance, dense emergent vegetation around pond margins can provide good habitat for tricolored blackbird and California red-legged frog but may not provide appropriate habitat for California tiger salamander or western pond turtle. The large size of the reserve system will allow disparate actions to occur in different places and achieve net benefit for all of the covered species.

- **Account for inherent variability.** Chance events can often exert strong effects on species and natural systems. The most common chance events are associated with weather (e.g., rainfall, temperature, timing of seasons, drought, and the unknown ramifications of global climate change). Other chance events are associated with species populations themselves; these may include reproductive success and dispersal. Such inherently uncontrollable variables and their effects on covered species are best offset by maintaining within the reserve system a variety of microsites, environmental gradients, and management treatments. This ensures that covered species can take advantage of suitable habitat during favorable conditions and find refugia in unfavorable conditions.
- **Maintain and Enhance natural processes.** Natural processes (e.g., hydrologic regimes, wildfire) create and maintain habitat for covered species. Therefore, management actions will focus on defining, maintaining, and enhancing these natural processes. If this is not feasible, the effects of those processes can be duplicated by alternative management actions.
- **Use adaptive management.** Flexibility and adaptation are needed in making management decisions and improving restoration and enhancement activities within natural communities. Adaptive management principles (Section 3.6.5, *The Adaptive Management Process*) will apply across the range of general principles as well as to the specific management techniques and tools described below.
- **Minimize adverse effects.** Management actions are designed to provide long-term benefits to the covered species. However, some actions may have short-term adverse effects on a subset of covered species (Chapter 5, *Effects Analysis*). Management actions will be selected or implemented in such a way that minimizes any adverse effects on covered species. See *CM22 Avoidance and Minimization Measures,* and Appendix 3.C, *Avoidance and Minimization Measures*, for details.

3.4.11.2.2 Reserve Unit Management Plans

The Implementation Office will prepare and implement management plans for protected natural communities and covered species habitats that are found within those communities. Management plans will be prepared by reserve unit, which may be an individual reserve or multiple reserves in a specified geographic area that share common management needs. Within 2 years of acquiring parcels, the Implementation Office will conduct surveys to collect the information necessary to assess the ecological condition and function of conserved species habitats and supporting ecosystem processes (preacquisition surveys will have been conducted to identify natural communities and covered species present or potentially present, as described in Section 3.4.3.3.2, *Siting and Reserve Design, Preacquisition Surveys and Assessments*). Based on the results, the Implementation Office will identify actions necessary to achieve the applicable biological objectives related to management and enhancement of the reserve. The management plans will provide the information necessary to guide these enhancement and management actions.

Reserve unit management plans will be prepared in collaboration with the fish and wildlife agencies and submitted to those agencies for approval within 4 years of the first acquisition within each reserve unit. This schedule is designed to allow time for site inventories and identification of appropriate management techniques. During the interim period, management of the reserve will occur using best practices and based on successful management at the same site prior to acquisition or based on management at other similar sites. The plans will be working documents that are updated and revised as needed to incorporate new acquisitions within the same reserve unit and to document new BMPs. However, all reserve unit management plans will be formally reviewed and updated by the Implementation Office at least every 5 years to ensure that the BDCP adaptive management and monitoring program (Section 3.6, *Adaptive Management and Monitoring Program*) and the results of the latest research are being applied to management in each reserve unit.

The reserve unit management plans will include, but not be limited to, descriptions of the following elements.

- The biological goals and objectives to be achieved with the enhancement and management of the reserves.
- Baseline ecological conditions (e.g., habitat maps, assessment of covered species habitat functions, occurrence of covered and other native wildlife species, vegetation structure and composition, assessment of nonnative species abundance and effect on habitat functions, occurrence and extent of nonnative species).
- Vegetation management actions that benefit covered communities, habitats, and species and reduce fuel loads, as appropriate, and that are necessary for implementing natural community and species-specific conservation measures.
- A fire management plan developed in coordination with the appropriate agencies and, to the extent practicable, consistent with achieving the biological goals and objectives (Section 3.4.11.2.3, *General Enhancement and Management Actions, Fire Management*).
- If recreational uses will be allowed in the reserve unit, a recreation plan developed in coordination with the appropriate agencies and consistent with achieving the biological goals and objectives (Section 3.4.11.2.3, *General Enhancement and Management Actions, Recreation*).
- Infrastructure, hazards, and easements.
- Existing and adjacent land uses and management practices and their relationship to covered species habitat functions.
- Applicable permit terms and conditions.
- Terms and conditions of conservation easements when applicable.
- Management actions and schedules.
- Monitoring requirements and schedules.
- Established data acquisition and analysis protocols.
- Established data and report preservation, indexing, and repository protocols.
- Adaptive management approach.
- Any other information relevant to management of the preserved parcels.

Reserve unit management plans will be periodically updated to incorporate changes in maintenance, management, and monitoring requirements as they may occur over the term of the BDCP.

Based on the assessment of existing site conditions (e.g., soils, hydrology, vegetation, occurrence of covered species) and site constraints (e.g., location and size), and depending on biological objectives of the reserves, reserve unit management plans will specify measures for enhancing and maintaining habitat as appropriate.

3.4.11.2.3 General Enhancement and Management Actions

Enhancement and management actions to be implemented throughout the reserve system are described below. Enhancement and management actions specific to natural communities are described in Sections 3.4.11.2.4 through 3.4.11.2.8.

Fire Management

Fire management will be a component of each reserve unit management plan. Several natural communities in the Plan Area are adapted to fire (e.g., grasslands, vernal pool complex). Therefore, some wildfires will be allowed to burn naturally to provide periodic disturbances that will benefit natural communities and covered species, within the larger land-use context. In other instances, fire suppression will be needed to avoid damage to structure and to minimize adverse effects on natural communities and covered species. Aggressive suppression can damage topsoil or cause excessive erosion, particularly if heavy machinery or chemical treatments are used to create firebreaks or suppress flames.

The fire management component will include a clear decision system to determine when a wildfire will be left to burn and when it must be partially or wholly contained to prevent damage to structures, protect human health and safety, or avoid excessive disturbance to natural communities or covered species. The fire management component will include coordination with the California Department of Forestry and Fire Protection (Cal Fire) and local firefighting agencies on the use of biologically appropriate management response measures for fire events. Fire management for the reserve system will be based, in part and as applicable, on an agreement with USFWS and CDFW on firefighting techniques. The fire management component will include a range of fire response, from full suppression when wildfires compromise public safety and personal property, to less than full suppression in predetermined areas where public safety and personal property are not compromised and fire-dependent natural communities are present. The plans may include controlled-burn and let-burn components. The goal of such components would be to reduce fuel loads and decrease fire intensity while promoting fire-dependent natural community regeneration and a natural successional process where feasible.

The fire management component will describe minimum impact suppression tactics (also known as MIST[30]). Many plans using these techniques and plans with low-impact rehabilitation (restoration) techniques have been developed in recent years. The goal of minimum impact suppression tactics is to safely suppress wildfire using environmentally sensitive suppression methods. Examples of minimum impact suppression tactics guidelines and actions that will be implemented include the following.

- Use environmentally sensitive methods (i.e., procedures, tools, equipment) designed to minimize resource damage and reduce costs.
- Establish equipment wash stations to remove noxious weed seeds from tires and vehicle undersides prior to their first use in a reserve.
- If there is a risk that a hose coming directly from a local unit's cache is contaminated with noxious weed seeds, obtain fresh hose from the regional cache.

[30] For example, see <http://www.wildfirelessons.net/documents/GB_MIST_Guidelines.pdf> or the National Wildfire Coordinating Group at <www.nwcg.gov>.

- Establish mobilization and demobilization areas outside the reserve to minimize spread of noxious weeds or diseases.
- Consider the use of helibucket with water or foam before calling for airtankers and retardant.

In order to ensure that the reserve unit management plans are followed during fires, the Implementation Office will develop a wildfire local operating agreement for the reserve system with Cal Fire and with any other firefighting agency that has responsibility for lands within the reserve system. The operating agreement will ensure that the fire management components are implemented, that minimum impact suppression tactics are used, and that postfire restoration is carried out. An example of a local operating agreement that has been developed and used successfully is the Henry W. Coe State Park agreement with Cal Fire (California State Parks 2007).

The wildfire local operating agreement will be in place by year 4. This will allow time for the fire management component of reserve unit management plans to be developed and for the Implementation Office to work closely with Cal Fire to develop the operating agreement. Specifically, the wildfire local operating agreement for the reserve system will serve the following functions, at a minimum.

- Inform the firefighting agencies of reserve system fire policies and sensitive resources.[31]
- Inform the Implementation Office of functions within the Incident Command System (Cal Fire) with respect to wildland fire.
- Be the local working agreement between the Implementation Office and firefighting agencies for all activities related to wildland fires in the reserve system.
- Designate responsibilities and guidelines for all activities related to wildland fires.
- Allow the Implementation Office to be a resource advisor in the incident command system and an onsite monitor in the event of a wildfire.
- Identify minimum impact suppression tactics during and after wildland fires to ensure the minimum possible environmental impacts.
- Identify biologically appropriate and complete postfire restoration and rehabilitation responsibilities.

Following a fire, the Implementation Office will initiate remedial measures as described in Chapter 6, Section 6.4.2, *Changed Circumstances*.

To ensure successful fire management, as described here, the Implementation Office will hire staff with expertise in managing controlled burns using minimum-impact fire suppression techniques. Staff with this expertise will also help to ensure clear and frequent communication with Cal Fire, which is essential to proper implementation of these techniques during a wildfire. Staff with this expertise will also help to ensure immediate assessment and possible responses following detection of wildfires in the reserve system. For a description of guidelines and techniques for prescribed burns, see the section below on the grassland natural community.

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[31] The Implementation Office will update the appropriate local firefighting agencies regarding sensitive resources in the reserve system as the reserve system grows.

Recreation

Recreational uses allowed in reserves include pedestrian use (walking, hiking, running), dogs on leashes, backpacking, nonmotorized bicycle riding on designated trails, horseback riding, boating, fishing, hunting, wildlife observation and photography, and environmental education and interpretation on designated trails at appropriate sites. Other uses may be allowed by the Implementation Office as long as they are compatible with the biological goals and objectives, CDFW and USFWS concur, and users obtain appropriate permissions for conducting activities if needed (e.g., parks departments for some counties may require approvals for some types of activities).

Public access for recreation will be provided on all reserves owned in fee title by a public agency. Public access to privately owned land under conservation easement will only be permitted with the landowner's consent. AMM37 (Appendix 3.C, *Avoidance and Minimization Measures)* provides measures to avoid and minimize effects on covered species and natural communities that could result from recreational activities in the reserve system.

All public access to reserves will be managed according to a recreation plan that will be integrated into the applicable reserve unit management plan (Section 3.4.11.2.2, *Reserve Unit Management Plans*). The recreation plan will address lands that are acquired for or incorporated into a reserve unit where the Implementation Office and the land owner determine that recreational uses are compatible with the conservation strategy. Each recreation plan will apply to the portion of the reserve unit for which the recreation plan was developed, including existing conservation land that is incorporated into the unit (existing conservation land selected for the reserve system that was chosen, in part, for its recreational uses that are compatible with the biological goals and objectives).

Each recreation plan is required to describe, at a minimum, the items listed below.

- Identification of sites within the reserve unit where recreational use is compatible with the biological goals and objectives.
- Identification of acceptable forms of recreation for each site.
- Identification of sites within the reserve unit that contain sensitive land cover types or suitable or occupied habitat for covered species.
- Maps of existing and proposed recreational trails, staging areas, and facilities and of habitat types affected.
- Appropriate avoidance and minimization measures from AMM37 (Appendix 3.C).
- Site-specific methods of recreational use controls.
- Trail and use monitoring methods, schedules, and responsibilities.
- Trail operation and maintenance guidelines and responsibilities. This includes control of active off-trail recreational activities determined inappropriate by the Implementation Office and fish and wildlife agencies.
- A framework for enforcement of recreational restrictions and permitting process for restricted recreational uses.
- An evaluation determining if the impact of planned recreational use is within the limits established in the Plan and EIR/EIS, and if planned recreation is compatible with the biological goals and objectives.

- Clear triggers for use restrictions or closure based on sensitive biological indicators (e.g., seasonal closures of some trails on the basis of activity periods of covered or sensitive species).

Land acquired for reserves will be closed to all recreational uses until a recreation plan is developed and approved as part of a reserve unit management plan. Existing recreational uses on land incorporated into the reserve system from existing conservation lands (e.g., CDFW) will continue until the reserve unit management plan and associated recreation plan are completed. Existing conservation lands selected for the reserve system may be chosen, in part, because they provide recreation uses that are compatible with the conservation strategy. Until the reserve unit management plan is completed, no additional recreational uses beyond what is currently allowed will occur on that existing conservation lands incorporated into the reserve system.

Recreational uses in the reserve system will be designed to minimize impacts on biological resources and must adhere to the requirements listed below.

- Recreation will only be allowed where it is compatible with the biological goals and objectives.
- Recreational use will be consistent with necessary mitigation measures described in the EIR/EIS and with the avoidance and minimization measures described in AMM37 (Appendix 3.C).
- Recreational use and impacts will be monitored by the landowner and the Implementation Office to ensure that uses do not exceed expected effects on and permitted take of covered species. If any use is found to contribute to such exceedance, that use will be discontinued until the use can be modified so as to eliminate the exceedance. The Implementation Office will make decisions about discontinuing or modifying recreational uses in close consultation with the landowner or other applicable reserve management agency or organization.
- Allowable recreational uses will be controlled and restricted by area and time to minimize impacts on natural communities and covered species. For example, trails will be closed during flood events or immediately following heavy rains and annually winterized to minimize erosion and sedimentation.
- Activities will be allowed in keeping with the ecological needs of the given habitat. Any off-trail activities and other active recreation not listed at the beginning of this section (e.g., outdoor sports, geocaching) are prohibited, unless otherwise authorized by the Implementation Office. Recreational uses will be allowed only during daylight hours and designated times of the year (i.e., limited seasonal closures to protect sensitive covered species; see AMM37 in Appendix 3.C) unless explicitly authorized by the Implementation Office.
- New staging areas will be sited to the extent possible in areas that are not within the reserve system. If a staging area is sited within a reserve, it will be sited in a location that does not contribute to the biological objectives for covered species and/or natural communities, and done in such a way as to create minimal impact on covered species.
- No motorized vehicles will be allowed in reserves, except for use by the reserve manager staff or with the prior approval of the reserve manager (e.g., contractors implementing implementation actions such as natural community restoration and monitoring, grazing tenants, fire-suppression personnel, and maintenance contractors). For reserves under conservation easements, vehicle use will be allowed as part of the regular use of the land (e.g., agricultural operations, permanent residents, utilities, police and fire departments, other easement holders), as specified in the easement.

- When compatible with the biological goals and objectives, dogs may be allowed during daylight hours in designated reserves or in designated areas of reserves. Leash law restrictions will be strictly enforced by reserve managers and staff because of the potential impact of dogs on covered species such as San Joaquin kit fox, western burrowing owl, California red-legged frog, and California tiger salamander. Leash enforcement may include citations and fines. Dogs used for herding purposes by grazing lessees must be under verbal control and have proof of vaccination.
- Recreational hunting or fishing within reserves will be allowed in designated locations. Landowners who have hunted large game (e.g., deer, elk, turkey, or pigs) on their property that becomes part of the reserve system through a conservation easement will be allowed to continue this use as long as it is consistent with the biological goals and objectives. Similarly, hunting for management purposes (e.g., feral pigs) is encouraged where it will contribute to achieving the biological goals and objectives. The Implementation Office will develop management hunting protocols on new reserve lands in coordination with other agencies who utilize hunting for management purposes (e.g., CDFW).
- No irrigated turf or landscaping will be allowed in picnic areas. To the extent feasible, picnic areas will be located on the perimeter of reserves and will be sited in already disturbed areas. No vehicles will be allowed in picnic areas except in limited circumstances approved by the Implementation Office such as special events. Maintenance and emergency vehicles will be permitted access to picnic areas.
- Backpack camps will be limited to use by no more than 25 people at each site. In coordination with the reserve manager, the Implementation Office will monitor use and maintenance of backpack camps and may implement a reservation and permitting process for use of backpack camps.
- With the exception of fishing and hunting allowances described above, public collecting of native species will be prohibited within reserves.
- Trails will not be paved, except as required by law, and will be sited and designed so that they do not contribute to erosion and do not interfere with habitat connectivity or permeability. To provide trail access for a range of user capabilities and needs (including persons with physical limitations) in a manner consistent with state and federal regulations, the landowner will site and design new, paved trails in areas within reserves that are already disturbed and do not have the potential to affect sensitive habitat. As common practice, these types of whole-access trails will be sited near staging areas.
- Recreational uses will be controlled using a variety of techniques including fences, gates, clearly signed trails, educational kiosks, trail maps and brochures, interpretive programs, electronic surveillance, and patrol by land management staff.
- Signs and informational kiosks will be installed to inform recreational users of the sensitivity of the resources in the reserve, the need to stay on designated trails, and the danger to biological resources of introducing wildlife or plants into the reserve.
- Construction of recreational facilities within reserves will be limited to those structures necessary to directly support the authorized recreational use of the reserve. Existing facilities will be used where possible. Facilities that support recreation and that may be compatible with the reserve include parking lots (e.g., small gravel or paved lots), trails (unpaved or paved as required by law), educational and informational kiosks, up to one visitor center located in a

disturbed or nonsensitive area, and restroom facilities located and designed to have minimal impacts on habitat. Playgrounds, irrigated turf, off-highway vehicle trails, and other facilities that are incompatible with the biological goals and objectives will not be constructed.

- When compatible with the biological goals and objectives, recreation plans for reserves adjacent to existing public lands will provide consistency in recreational uses across open space boundaries to minimize confusion. Reserves adjacent to existing conservation lands or other public lands that are not part of the reserve system with different recreational uses will provide clear signage to explain these differences to users that cross boundary lines. The Implementation Office will be responsible for securing and signing reserve boundaries.

Rare exceptions to the guidelines listed above will be considered and approved by the Implementation Office and the fish and wildlife agencies on a case-by-case basis. Exceptions will be approved only if they are consistent with the biological goals and objectives. Any exceptions will be clearly identified in the recreation plan.

Invasive Plant Control

Some nonnative plants pose a serious threat to ecosystem function, native biological diversity, and many covered plant species. However, many nonnative plants cannot be effectively controlled because of their great abundance, high reproduction rate, and proficient dispersal ability; the high cost of control measures; or unacceptable environmental impacts of control measures. Therefore, control efforts in the reserve system will focus on new infestations that are relatively easy to eradicate or the most ecologically damaging nonnative plants for which effective suppression techniques are available. Avoidance and minimization measures described in Appendix 3.C will be implemented in association with invasive plant control activities to ensure that take of covered species is minimized. Control of invasive aquatic plants is addressed in detail in *CM13 Invasive Aquatic Vegetation Control*; therefore, this conservation measure focuses on the control of terrestrial invasive plants

The Implementation Office will address the control of invasive plants as a component of each reserve unit management plan. Control of invasive plants on reserve lands will begin immediately after acquisition if infestations are serious, even if the management plan is not finalized. This early invasive plant control will include measures to minimize effects on covered species based on results of preacquisition surveys (*CM3 Natural Communities Protection and Restoration*). Efforts to control invasive plants will be evaluated and revised as needed. Formal evaluations and revisions will take place at least every 5 years[32].

Each reserve unit management plan will include a goal to control the spread of noxious weeds[33], and invasive plants[34] into new areas and to control existing infestations of these plants. The major elements listed below will be included in each reserve unit management plan.

- An assessment of the nonnative plants likely to be invasive within the reserve unit. Each assessment will include the following components.

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[32] This is the approximate interval at which the list of invasive plants in California is updated by the California Invasive Plant Council.

[33] As defined by the California Department of Food and Agriculture;

[34] List maintained by the California Invasive Plant Council (2007).

- ○ Maps and descriptions, based on site surveys, of the distribution and abundance of nonnative plants.
- ○ Description of the known or potential effects of the nonnative plants found onsite on ecosystem function, native biological diversity, sensitive natural communities, and covered species.
- ○ Analysis of the potential mechanisms and risk that these nonnative plants will spread to other areas within and outside the reserves.
- ○ The cost, feasibility, and effectiveness of available control measures for each species.

- An assessment of invasive plants not currently found in the reserves but found nearby, that might invade the reserves in the future with undesirable effects. The assessment will include a description of known or potential effects on ecosystem function, native biological diversity, and sensitive natural communities and covered species.
- The development and application of criteria for establishing invasive plant control priorities. This may include use of Weed Heuristics: Invasive Population Prioritization for Eradiction Tool (WHIPPET) (Skurka Darin et al. 2011), a tool that can be customized to assist in prioritizing invasive plant infestations for control. These criteria will determine the conditions under which active control will be applied. High priority for active control will be given to invasive plant populations that interfere with meeting a biological objective, and for which passive control such as a standard grazing regime is ineffective. Primary criteria will include ecological impact, invasiveness potential, current and potential distribution, and feasibility of control (Skurka Darin et al. 2011).
- The integration and coordination of invasive plant control efforts in the reserve system with the efforts of other ongoing invasive plant control efforts in the Plan Area.
- A description of methods to control and prevent the establishment of invasive plants and criteria for evaluating the suitability of application of these methods based on site-specific conditions.
- A description of a process by which future invasive plants can be evaluated quickly to determine the best course of action for their effective removal or control.
- Applicable avoidance and minimization measures from Appendix 3.C.

Development of the invasive plant component of the reserve unit management plans will be coordinated with other major resource management agencies in the Plan Area including CDFW, USFWS, DBW, operating regional HCPs and NCCPs, and counties with jurisdictions over parks. Because control of many invasive plants in the Plan Area is a regional issue, coordination with these agencies is essential. Coordination could include sharing costs, staff, and equipment and conducting joint management programs to address the regional problem of invasive plants. Management to control invasive plants will prioritize invasive plants with the greatest effects on covered species.

Additional invasive plant control specific to natural communities is described under the natural community sections below.

Invasive Plant Control Guidelines and Techniques

A combination of methods may be implemented to control invasive plants in the reserve system, including prevention, manual control, mechanical control, prescribed burning, grazing, and chemical control. These are described below.

- **Prevention.** This method involves taking precautions to prevent invasive plants from entering the reserve system. This method can be effective in areas vulnerable to invasive weed infestations, such as where ground disturbance has occurred. Recently disturbed areas will be reseeded with native vegetation to encourage establishment of desired rather than invasive plant species. Equipment used for natural community enhancement or management will be cleaned prior to entering the reserve system and before moving between locations within the reserve system to minimize the risk of spreading nonnative seeds or other propagules. (For the prevention of the spread of invasive aquatic plants, see *CM20 Recreational Users Invasive Species Program*.)
- **Manual control.** This method involves hand-pulling or digging up weeds using hand tools such as weed wrenches, shovels, or loppers. This can be an effective technique when infestations and plant species are young and root systems are not fully developed, and in areas where disturbance needs to be minimized such as within rare plant populations.
- **Mechanical control.** This method involves the use of machinery such as bulldozers, backhoes, cable yarders and loaders, and may be used where invasive plant density is high and it would not result in adverse effects on sensitive resources such as rare plant populations or critical habitat for vernal pool species.
- **Prescribed burning.** This method consumes above-ground vegetation and kills seeds of some invasive plant species, or breaks seed dormancy, which assists in later plant removal. Prescribed burning also encourages growth of native flora to support its natural resistance to invasion by nonnative species. Prescribed burning will be implemented consistent with the fire management component of reserve unit management plans, as described above.
- **Grazing.** Livestock grazing can be an effective means of controlling invasive plant infestations. However, some invasive species are toxic or undesirable to livestock; also, other effects of livestock grazing may be incompatible with management objectives.
- **Chemical control.** Herbicide application is most successfully used when combined with other methods and not as the primary control method. Herbicides may be necessary to control heavy infestations of certain invasive plants (e.g., Transline herbicide is effective in controlling yellow starthistle). Certified personnel will conduct any herbicide application. Herbicides will be used with great caution, especially near seeps, creeks, wetlands, and other water resources. Herbicide use will be reserved for instances where no other eradication techniques are effective. See also *Pesticides*, below.

Nonnative Animal Control

Control of nonnative animals will be specific to the following natural communities. Feral pigs will be controlled as needed in protected and restored aquatic and emergent wetland natural communities (Section 3.4.11.2.4, *Aquatic and Emergent Wetland Natural Communities*), riparian natural community (Section 3.4.11.2.5, *Riparian Natural Community*), and managed wetlands (Section 3.4.11.2.8, *Managed Wetlands*). Norway rat, feral cats, and red fox will be controlled in emergent wetland natural communities (Section 3.4.11.2.4) and riparian natural community (Section

3.4.11.2.5). Cowbirds will be controlled as needed in protected and restored riparian natural community, primarily to benefit nesting least Bell's vireo (Section 3.4.11.2.5). Feral dogs and cats will be controlled in occupied riparian brush rabbit and riparian woodrat habitat in the reserve system (Section 3.4.11.2.5). Bullfrogs and nonnative fish that prey on California red-legged frog and California tiger salamander larvae and young giant garter snakes will be controlled in stock ponds and seasonal wetlands associated with grasslands (Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities*) and in restored nontidal marsh (Section 3.4.11.2.4, *Aquatic and Emergent Wetland Natural Communities*). Control of nonnative fish in the Plan Area is described in *CM15 Localized Reduction of Predatory Fishes.* For the prevention of the spread of invasive aquatic invertebrates, see *CM20 Recreational Users Invasive Species Program*.

If the Implementation Office determines, through monitoring of covered species populations in the reserve system, that other nonnative predatory species are adversely affecting covered species such as California black rail or California clapper rail, then the establishment and abundance of nonnative predatory species will be controlled with habitat manipulation techniques or trapping.

Mosquito Abatement

Enhancement of aquatic and wetland habitats must be balanced with the need to minimize mosquito production to protect human health. Encouraging adequate populations of mosquito predators such as native frogs, swallows, and bats offers an approach to mosquito control that is compatible with management for covered species. Wetlands will be designed to minimize mosquito production by minimizing suitable habitat for mosquitoes (primarily *Culex torsalis*) and other human disease vectors, particularly between mid-July and late September or October when mosquito productivity is highest. Any mosquito control activities to be performed on reserve system land will be addressed in the reserve unit management plan in consultation with the local vector control district. The reserve unit management plan will detail the nature of mosquito control activities and explain specific measures implemented to avoid and minimize effects on covered species consistent with the BDCP. The Natomas Basin HCP is an example of a local conservation plan that has created and managed extensive wetlands in a successful partnership with a local vector control agency.

Pesticides

Pesticides would be used only to achieve biological goals and objectives (e.g., invasive plant or invasive animal control), in accordance with label instructions, and in compliance with state and local laws. Additional restrictions may be placed by USFWS, NMFS and CDFW during their review of reserve unit management plans. Any pesticide use must comply with the October 2006 stipulated injunction disallowing use of certain pesticides within habitats and buffer zones established around certain habitats for California red-legged frog and the May 2010 stipulated injunction disallowing use of certain pesticides within habitat and buffer zones established for California tiger salamander and San Joaquin kit fox.

Levee Maintenance

Each reserve unit management plan for areas containing levees will incorporate levee maintenance procedures. All levee maintenance that involves ground-disturbing activities will implement relevant measures described in Appendix 3.C, *Avoidance and Minimization Measures*, to avoid and minimize adverse effects on natural communities and covered species. Levees in the reserve system will be maintained in a manner that balances wildlife and habitat needs with the need to maintain the structural integrity of the levees. Levee maintenance managers are generally concerned that uncontrolled vegetation on levees is a potential hazard. Trees with extensive root systems may create pathways for the piping of water through the levee, potentially leading to levee failure. If large trees are toppled by the wind, they may dislodge large segments of the levee with their fall. Dense vegetation may impair visual inspection of levees. Burrowing animals such as beavers, muskrats, and ground squirrels can pose a direct threat to levee stability (Bay Delta Oversight Council 2002). Wildlife values will be maximized on levees in the reserve system while recognizing these constraints.

Levee maintenance procedures specified in reserve unit management plans will incorporate the following considerations.

- Trees and shrubs will naturally establish and grow on the faces of levees. Typically, a one-lane gravel road is maintained on the crest of a levee to provide access to tide gates and allow for levee repairs. Specific sites with known erosion potential may also need to be kept clear of trees, but ecological function is best met by encouraging dense, natural revegetation of native varieties of trees and shrubs, particularly waterward of levees. Vegetated areas above the intertidal zone provide important habitat functions, including decreased bank erosion and increased bank stability.
- Recent evidence demonstrates that frequent stripping, burning, mowing, grazing, or other practices creating large areas of sparse vegetation actually encourage rather than discourage ground squirrel populations. Increasing vegetative cover for predator hiding and perching may be more effective in controlling ground squirrels on levees (Bay Delta Oversight Council 2002).
- Rodent control may kill nontarget species; reduces burrow availability for burrowing owls, amphibians, and reptiles; and removes a food source for Swainson's hawk, white-tailed kite, giant garter snakes, and other predators.
- Vegetation burning or nonselective herbicide use kills elderberry shrubs required by the valley elderberry longhorn beetle. More selective methods are preferred. For example, managed goat grazing may be an effective and biologically preferred vegetation management method along levees (with goat herds used to limit grazing on desirable species).

Levee maintenance practices will vary depending on the covered species being conserved near the levee. For example, levees adjacent to giant garter snake aquatic habitat will be kept clear of riparian vegetation and will instead be maintained with low-growing grasses and herbaceous vegetation. Levees in managed wetlands within Suisun Marsh will, to the extent possible given the levee stability considerations described above, retain sufficient vegetation to provide cover for salt marsh harvest mouse and breeding or roosting waterfowl.

Reserve System Connectivity and Permeability

One important measure of the reserve system's success will be the degree to which it allows native wildlife species to move freely within the reserve system and to other habitat outside the reserve system. In landscape ecology, permeability and functional connectivity differ from physical connectivity in that physical connectivity refers to creating connections between existing large protected areas of species habitat (described in *CM3 Natural Communities Protection and Restoration*), while functional connectivity and permeability refer to the relative potential for a species to move across a landscape (Singleton et al. 2002). For example, removal of a fence or other barrier to species movement would increase landscape permeability.

The permeability of the reserve system will be increased by the actions listed below, where applicable. While these measures are targeted toward wildlife movement, it is assumed that they will also enhance opportunities for plant dispersal and population expansion.

- Removing fences that serve as barriers or hazards to wildlife movement, or retrofitting them to allow wildlife movement (some fencing will be needed to help manage and control livestock, as well as for human-access controls).
- Improving culverts and other road crossing points to make them more attractive to and safer for wildlife.
- Collecting data on wildlife movement throughout the Plan Area to better inform the location and type of structures that will facilitate safe movement.
- Managing grassland vegetation and thatch to facilitate dispersal of amphibians, such as California tiger salamander, for which dense vegetation may hinder movement.

Most fences in the reserve system will remain and will be used for management purposes, such as grazing management. Those that are unnecessary will be removed to increase reserve system permeability. Additional fences may be installed to better manage grazing timing and locations. Most existing roads in the reserve system will be used for management or monitoring purposes, but those that are unnecessary will be removed and decommissioned (i.e., returned to a natural condition) to reduce hazards to wildlife and the erosion potential associated with dirt and gravel roads. Additional roads may be added to establish access for management or monitoring purposes. These access routes will conform to the natural contours of the surrounding landscape and will only be maintained to the extent necessary for access.

Culverts that create a one-way barrier[35] along waterways will be removed or retrofitted if feasible to allow movement of fish and aquatic amphibians both upstream and downstream. In most cases, retrofitting involves replacing small obstructive culverts with larger, straight culverts to allow species to move through more readily. In some instances culverts may be replaced with clear-span bridges to increase the habitat quality of the waterway where it flows under the roadway. This approach enhances the habitat (both aquatic and terrestrial) under the roadway for animal movement. In addition, existing culverts or bridges may be enhanced to increase wildlife movement through or under these permanent barriers. For example, fencing could be installed along the roadway to guide wildlife species away from the roadway and through undercrossings.

Access Control

Access to lands in the reserve system will be controlled in areas that are vulnerable to disturbance by humans and pets. In particular, human and pet access will be restricted in vernal pool and alkali seasonal wetland complexes, nontidal marsh restored for giant garter snake, greater sandhill crane roost sites, and locations that support rare plant populations. Signs will be posted to inform the public of the access restrictions. Access to areas that support nesting covered bird species will be restricted during the nesting season.

[35] One-way barriers occur when species can move in one direction, but not the other (e.g., fish moving downstream but not upstream).

3.4.11.2.4 Aquatic and Emergent Wetland Natural Communities

This section describes the management and enhancement actions, and related guidelines and techniques, that will be implemented in the aquatic and emergent wetland natural communities in the reserve system, including tidal brackish emergent wetland, tidal freshwater emergent wetland, nontidal freshwater perennial emergent wetland, and nontidal perennial aquatic. Tidal perennial aquatic natural community management is addressed in other conservation measures, including *CM13 Invasive Aquatic Vegetation Control*, *CM15 Localized Reduction of Predatory Fishes*, and *CM20 Recreational Users Invasive Species Program*. Applicable management and enhancement actions, described in Section 3.4.11.2.3, *General Enhancement and Management Actions*, will also be implemented. If those actions conflict with community-specific actions described in this section, the community-specific actions will be implemented.

Enhancement and Management Actions

The following actions will be included in each reserve unit management plan addressing aquatic and emergent wetland natural communities in the reserve system.

- **Invasive plant control and native diversity.** The relative cover of nonnative invasive plant species that are undesirable in the reserve system, including but not limited to perennial pepperweed, bull thistle, and annual grasses, will be reduced and then maintained to levels that do not substantially degrade covered species habitat. Through nonnative plant control and supplemental plantings of native vegetation, as needed, tidal freshwater emergent wetlands will be enhanced to restore and sustain a diversity of marsh vegetation that reflects historical species compositions and high structural complexity. Tidal mudflats will also be maintained by reducing distribution and abundance of invasive plant species.
- **Upland refugia for wildlife.** Grasslands within 200 feet of tidal marshes will be maintained to serve as refugia for salt marsh harvest mouse, Suisun shrew, and other covered species during high-tide events (Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities*, *Enhancement and Management Guidelines and Techniques*, *Maintenance of Upland Refugia*). Grasses in these areas will not be grazed to the extent of grasslands throughout the reserve system; they will be allowed to grow to a sufficient height to provide cover for salt marsh harvest mouse and Suisun shrew.
- **Nonnative wildlife control.** The distribution and abundance of nonnative wildlife that threatens covered species in emergent wetland natural communities will be reduced (see *Nonnative Wildlife Control* under *Enhancement and Management Guidelines and Techniques* below).
- **Vegetation composition and structure**. Vegetation composition and structure will be enhanced and maintained in Suisun Marsh to support appropriate habitat conditions for covered species (see *Vegetation Management* under *Enhancement and Management Guidelines and Techniques* below).
- **Topographic heterogeneity.** Topographic heterogeneity will be enhanced as needed and maintained in restored tidal emergent wetlands to provide variation in inundation characteristics and vegetative composition.
- **California black rail habitat enhancement and management.** At the ecotone that will be created between restored tidal freshwater emergent wetlands and transitional uplands (Objectives L1.3 and TFEW1.1), 1,700 acres of California black rail habitat will be maintained to

consist of shallowly inundated emergent vegetation at the upper edge of the marsh (within 50 meters of upland refugia habitat) with adjacent riparian or other shrubs that will provide upland refugia, and other moist soil perennial vegetation.

- **Suisun thistle and soft bird's-beak seed and nursery stock conservation.** Seed banking and nursery stock for soft bird's-beak and Suisun thistle will be implemented in Suisun Marsh as described in *Vegetation Management*, under *Enhancement and Management Guidelines and Techniques* below.
- **Salt marsh harvest mouse habitat enhancement and management.** The at least 1,500 acres of restored middle and high marsh in Suisun Marsh (Objective TBEWNC1.2) will be managed to provide "Viable Habitat Areas" for salt marsh harvest mouse defined in the Final Tidal Marsh Recovery Plan and to meet population capture efficiency targets described in that plan. Management to meet this objective may include invasive plant control, supplemental plantings, or topographic enhancements to provide elevations suitable for establishment of appropriate vegetation.
- **Giant garter snake habitat enhancement and management.** The following management actions will be implemented for aquatic giant garter snake habitat to be restored in the reserve system.
  - Manage vegetation density (particularly nonnatives such as water primrose) and composition, water depth, and other habitat elements to enhance habitat values for giant garter snakes.
  - Maintain upland refugia (islands or berms) within the restored marsh (Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities*, *Enhancement and Management Guidelines and Techniques*, *Maintenance of Upland Refugia*).
  - Maintain permanent buffer zones at least 200 feet wide around all restored nontidal freshwater emergent wetland habitats to provide undisturbed (uncultivated) upland cover and overwintering habitat immediately adjacent to aquatic habitat.
  - Manage bank slopes and upland buffer habitats to enhance giant garter snake use, provide cover, and encourage burrowing mammals for purposes of creating overwintering sites for giant garter snake.
  - Control bullfrogs and nonnative fish (e.g., largemouth bass) that prey on giant garter snake.
- **Tricolored blackbird nesting habitat enhancement and management.** Management and enhancement of tricolored blackbird nesting habitat will be consistent with the recommendations provided by Kyle (2011). The following criteria will guide site selection and management of emergent wetland habitat to benefit tricolored blackbird.
  - Select bulrush/cattail marsh habitat located adjacent to high-value foraging habitat. Breeding tricolored blackbird forage in habitats that provide abundant insect prey, such as grasslands, seasonal wetlands, pasturelands, and alfalfa and other hay crops. Sites with tricolored blackbird nesting activity recorded over the previous 15 years are preferred.
  - Select wetland marsh habitat that contains standing water to a depth of 1 foot in most years from late January through late July to encourage dense development of cattail and bulrush vegetation and to provide protection from predators until nesting is completed.

- Burn, mow, or disc bulrush/cattail vegetation every 2 to 5 years to remove dead growth and encourage the development of new vegetative structure.
- Maintain large continuous stands of bulrush/cattail that are at least 30 to 45 feet wide to provide adequate space for breeding as well as protection from predators.
- Provide a 50:50 to 60:40 ratio of bulrush/cattail marsh to open water in areas intended to support tricolored blackbird nesting.
- Establish seasonal buffer zones around restored emergent wetlands that provide tricolored blackbird nesting habitat to reduce disturbance and improve foraging habitat for tricolored blackbirds.

- **Greater sandhill crane roosting habitat management.** Wetland roosts for greater sandhill crane will be managed as follows.
  - Water depth will be maintained throughout the winter season at an average depth of 10 centimeters, but should range across the roost site between 5 and 10 centimeters (Ivey et al. in prep.).
  - Flood-up of roosts will begin by September 1 and drawdown will begin no earlier than March 15.
  - Vegetation at roosting sites will be managed to ensure no more than 50% cover of tall emergent plants, such as tules (*Schoenoplectus* spp.), cattails (*Typha* spp.), trees, and large shrubs.
  - To enhance food value, moist soil management techniques will be employed to achieve and maintain substantial stands of high-value plants such as native smartweed (*Polygonum* spp.) and swamp timothy (*Crypsis schoenoides*). A variety of other plant species may also be used, including grasses and clovers. A menu of plant species will be included in each site-specific management plan. Moist soil management may also require occasional irrigation during the dry spring and summer months as well as periodic summertime discing.
  - Bulrush/cattail vegetation will be burned, mowed, or disced every 2 to 5 years to remove dead growth and encourage the development of new vegetative structure.

Enhancement and Management Guidelines and Techniques

Emergent Wetland Invasive Plant Control

Invasive plants in emergent wetlands include, but are not limited to, perennial pepperweed, fennel, Russian thistle, bull thistle, and giant reed (*Arundo donax*). These species can form dense monocultures that eliminate native plants and degrade wildlife habitat. Additionally, some small nonnative annuals, such as barbgrass (*Hainardia cylindrica*) and annual beardgrass (*Polypogon monspeliensis*), affect soft bird's-beak (a hemiparasite) by functioning as ineffective host plants (i.e., they reach full maturity and die prior to full completion of the soft bird's-beak's life cycle) (Grewell 2005). These plants will be controlled as necessary, as described above (*Invasive Plant Control* and *Enhancement and Management Actions, Invasive Plant Control and Native Biodiversity*).

Perennial pepperweed will be controlled to less than 10% cover in Suisun Marsh where it threatens habitat for California clapper rail, Suisun thistle, and soft bird's-beak, and other covered species. Small nonnative annuals such as barbgrass (*Hainardia cylindrical*) and rabbitsfoot grass (*Polypogon monspeliensis*) will also be controlled in the reserve system, particularly where they threaten soft bird's-beak populations (Grewell 2005). Other invasive plants in emergent wetlands will be controlled as necessary to meet Objective L2.6, as described above (*Invasive Plant Control* and *Enhancement and Management Actions, Invasive Plant Control and Native Biodiversity*), to meet the biological goals and objectives. While methods have been developed to reduce the cover of invasive species in the short term, there are no long-term control solutions and effective management of invasive species will require an uninterrupted long-term commitment. Control methods may include hand or mechanical removal, spot application of herbicides, controlled burn, or targeted grazing.

Maintenance of Tidal Mudflats

Tidal mudflats occur within a matrix of tidal aquatic and tidal emergent wetland natural communities. These mudflats will be maintained by reducing invasive plant species such as *Salsola soda* that would otherwise diminish the extent or degrade the function of mudflats. See *CM13 Invasive Aquatic Vegetation Control* for treatments, site selection, and other guidelines on the control of submerged and floating invasive aquatic vegetation.

Nonnative Wildlife Control

Feral pigs have the potential to adversely affect emergent wetlands in the Plan Area, especially at the western edge of the Plan Area where feral pigs are currently known to occur. The impact of rooting activities in ponds, seasonal wetlands, and emergent wetland natural communities may be reduced by fencing, although fencing to exclude feral pigs will need to be built for that purpose and maintained frequently to be effective. If fencing is used, it must be constructed so as not to restrict wildlife movement routes or corridors. In cases where livestock access to ponds and surrounding uplands is desired but feral pigs are degrading habitat, a feral pig control program could be initiated to improve pond habitats. Feral pig control has been effective on San Francisco Public Utility Commission land in the adjacent Alameda Creek watershed (Koopman pers. comm.) and through an ongoing program in Henry W. Coe State Park (Sweitzer and Loggins 2001). Feral pig control will be focused on parts of the reserve system where the concentrations of feral pigs are high and impacts on native communities have been observed. It would be difficult to census the exact number of feral pigs in the reserve system without an extensive effort; however, rooting disturbance can be monitored. Pig populations will be controlled during the permit term as long as their disturbance (i.e., rooting disturbance) adversely affects the Implementation Office's ability to successfully implement the conservation strategy.

Other nonnative animals potentially adversely affecting covered species and native biodiversity in emergent wetland communities include aquatic predators such as bullfrogs and nonnative fish, feral cats, nonnative red foxes, nonnative rats, and red-eared sliders (which compete for resources with western pond turtle). Active control programs will be implemented if nonnative animals are found (through research) to adversely affect covered species populations. Water management may be implemented to control aquatic predators as needed. For example, ponds may be dried down in late fall to eradicate bullfrogs.

Vegetation Management

Vegetation management is a critical component of optimizing the emergent wetland habitat function for covered species. Emergent wetland vegetation will be managed depending on the site-specific conditions of individual wetlands, and management will largely depend on the individual species or group of species targeted for enhancement (or removal in the case of invasive species). Vegetation management will involve several techniques, often used in concert, to achieve the species composition and habitat structure necessary to benefit covered and other native species.

- **Prescribed burning.** Prescribed burning has been used as a management tool in tidal emergent wetlands in other areas, such as Blackwater National Wildlife Refuge in Maryland and McFadden National Wildlife Refuge in Texas, to favor the growth of vegetation preferred by waterfowl and other wildlife (70 *Federal Register* (FR) 49380–49458). Prescribed burns may be used to achieve similar benefits for tidal wetlands in the reserve system, although any plans for prescribed burns must be based on expected contribution to achieving the biological goals and objectives and must consider potential adverse effects on covered species. Pilot projects will be implemented to assess the relative benefits and potential adverse effects of prescribed burning prior to implementation of any large-scale prescribed burning plans in emergent wetlands in the Plan Area.
- **Livestock control**. Cattle grazing can be a beneficial tool in vegetation management; however, livestock must be excluded in particularly sensitive areas. Cattle will be excluded from occupied Carquinez goldenbush, Suisun thistle, and soft bird's-beak habitat. Cattle movement will be managed with exclusionary fencing to protect other sensitive emergent wetland areas. Overgrazing by cattle and rooting by feral pigs can cause trampling of vegetation, soil compaction, development of "cow contours," and bank destabilization. Fencing wetlands has been shown to be a rapid, successful, and cost-effective method of enhancing some wetlands. After fencing, vegetation cover and wetland species diversity can increase substantially in stock ponds and other permanent or near-permanent freshwater wetlands that have been degraded by cattle grazing (Contra Costa Water District 2002). Fencing locations and specifications in each reserve unit management plan will depend on several factors, including site-specific conditions and the biological objectives that are being addressed.
- **Seed banking and nursery stock.** Seed banking is an important conservation tool used to protect against local extirpation or extinction and to support enhancement and restoration of rare plant populations[36]. Seed banking of "all existing populations and representative genetic diversity" is a delisting requirement in the *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* for Suisun thistle and soft bird's beak (U.S. Fish and Wildlife Service 2010). A cultivated population of Suisun thistle will be founded from collected wild seed to provide additional seed as well as nursery stock for enhancing existing populations or establishing new ones.

  In addition to Suisun thistle and soft-bird's beak, seed banking will also be performed for slough thistle and delta button celery. Seed banking for slough thistle and delta button celery will be undertaken to protect the genetic diversity of northern San Joaquin Valley populations within the Plan Area. If seeds cannot be sourced from a local population, seeds from proximate geographic locales will be collected, banked, and ultimately propogated to support conservation efforts in the Plan Area. Seed collection will consider genetic implications based on collaboration with species experts and wildlife agency staff.

  The *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (U.S. Fish and Wildlife Service 2010) proposed the following general guidelines for seed collection efforts

[36] Seed banking is an implementation action and is not meant to compensate for the direct loss of occurrences or individuals associated with covered activities.

to support banking, which will be used as a starting point to develop protocols for the applicable covered plants.

- In general, seeds should be collected in years of peak abundance; however, for Suisun thistle or other plants of extreme rarity, small collections could also occur during adverse population conditions.
- Collection protocols will follow basic scientific guidelines (Center for Plant Conservation 1991); however, in the case of Suisun thistle, manipulation of randomly selected seed parents would be appropriate, including the protection against seed predation by the introduced thistle weevil by muslin bagging of maturing flowering heads.
- Seed collection will not exceed 1% of the estimated total population seed output.
- Collected seed will be stored at two facilities: a seed storage facility approved by the Center for Plant Conservation and a local research or vegetation management/restoration institution with greenhouse and nursery facilities that could propagate seed using conservation techniques and protocols approved by the Center for Plant Conservation.

Banked seeds, cultivated seeds, or nursery stock could be made available through partnerships for public or private efforts to enhance existing populations or to create new ones. Actions to expand or establish populations will be implemented in close coordination with expert and wildlife staff. To the extent practicable, prior to broadcasting seed or outplanting nursery stock, biologists will work to address critical uncertainties identified by the California Native Plant Society (1992): microhabitat selection, fecundity, essential pollinators, community relationship, and other important biological characteristics.

3.4.11.2.5 Riparian Natural Community

This section describes management and enhancement actions, and related guidelines and techniques, that will be implemented in riparian natural community reserves. Applicable management and enhancement actions, described in Section 3.4.11.2.3, *General Enhancement and Management Actions*, will also be implemented. If those actions conflict with community-specific actions described in this section, the community-specific actions will be implemented.

These actions will be implemented to achieve the biological goals and objectives, as described in Section 3.4.11.4, *Consistency with the Biological Goals and Objectives*. Specific covered species are mentioned below only where they have species-specific objectives related to riparian management. The remaining covered species that use the riparian natural community will benefit from management at the natural community level, and, therefore, are not discussed below.

Enhancement and Management Actions

The following measures will be implemented in riparian natural community reserves.

- **Management and enhancement of riparian structural diversity.** The structure and composition of restored riparian areas will be managed and enhanced to help meet the objectives established for the riparian natural community and associated covered species (see Section 3.4.11.2.5, *Riparian Natural Community, Enhancement and Management Guidelines and Techniques*).
- **Riparian invasive plant control.** Invasive plant control in riparian areas will focus on reducing or eliminating those species that threaten habitat values. Himalayan blackberry, giant reed,

perennial pepperweed, black locust, and fig are common invasive plant species in the riparian natural community in the Plan Area. These species will be controlled as necessary, as described in Section 3.4.11.2.3, *General Enhancement and Management Actions, Invasive Plant Control*. The Implementation Office will consider habitat needs for yellow-breasted chat and tricolored blackbird before removing stands of Himalayan blackberry from riparian areas; these species frequently nest in Himalayan blackberry thickets, which provide valuable nesting substrate and cover. **Riparian woodrat (San Joaquin Valley) habitat enhancement and management.** The 300 acres of suitable riparian woodrat habitat that will be restored, as described in *CM7 Riparian Natural Community Restoration*, will be maintained to sustain appropriate habitat characteristics for this species. Additionally, flood refugia created for riparian woodrat, as described in CM7, will be monitored and maintained to ensure that they retain their functional value as flood refugia for this species. The habitat characteristics to be maintained for this species are described in CM7.

- **Riparian brush rabbit habitat enhancement and management.** The 800 acres of suitable riparian brush rabbit habitat that will be restored (300 of which will have very specific habitat requirements), as described in *CM7 Riparian Natural Community Restoration*, and the 200 acres of existing occupied habitat to be protected, as described in *CM3 Natural Communities Protection and Restoration*, will be maintained to sustain appropriate habitat characteristics for this species. The 200 acres of protected occupied habitat may be further enhanced to establish favorable habitat characteristics for riparian brush rabbit. Flood refugia created for riparian brush rabbit, as described in CM7, will be monitored and maintained to ensure that they retain their functional value for this species. Habitat characteristics to maintain for this species are described in CM7.

- **Riparian nonnative animal control.** Brown-headed cowbirds, feral predators, and feral pigs will be controlled in the riparian natural community as described below in *Enhancement and Management Guidelines and Techniques, Invasive Animal Control.*

- **Maintenance of rare plant alliances.** Through nonnative plant control and supplemental plantings, abundance and distribution of riparian natural community vegetation alliances that are rare or uncommon as recognized by CDFW (California Department of Fish and Game 2010a), such as *Cephalanthus occidentalis* (button willow thickets) alliance and *Sambucus nigra* (blue elderberry stands) alliance, will be maintained or increased (Objective VFRNC3.1) through supplemental plantings.

- **Stream and channel bank enhancement and management.** Stream channels and channel banks associated with the riparian natural community will be managed and enhanced to increase the diversity of microhabitats, improve hydrologic conditions that support the regeneration of riparian vegetation, and improve habitat functions for aquatic species, as described below, under *Enhancement and Management Guidelines and Techniques, Stream Channel Enhancement and Management*.

- **Plant occurrence creation, enhancement, and management.** Two occurrences each of delta button celery and slough thistle will be established within alkaline wetlands expected to form within the restored floodplain/riparian matrix along the San Joaquin River. These occurrences are required to be self-sustaining. For the purposes of the BDCP, a “self-sustaining” population is, on average, stable or increasing over time and able to withstand stochastic events without persistent, active management. To increase the probability of successfully establishing occurrences within the restored floodplain, and to reduce the necessity of ongoing enhancement and management, the site location for occurrence establishment must reflect what is known about species-specific habitat requirements such as soil chemistry, inundation frequency and duration, light, pollination, and other relevant factors.

Establishing occurrence for these two species is experimental and only to be undertaken in the absence of the ability to manage two known or discovered existing occurrences. When and if existing occurrences in the Plan Area are identified, the first priority will be to enhance and manage those populations.

Enhancement and management of existing or established populations could include the control of nonnative plant species, the collection and banking of seed, the propagation of nursery stock, the manipulation of seed heads to promote dispersal or minimize predation, and other proven or experimental methods used to promote sustainable plant occurrences. Control of invasive plant species to promote the stability of established occurrences will be undertaken as described in Section 3.4.11.2.3, *General Enhancement and Management Actions, Invasive Plant Control*. Protocols for seed collection, banking, and nursery propagation are described in Section 3.4.11.2.4 , *Aquatic and Emergent Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Seed Banking*. Additional, experimental activities to establish and enhance and manage occurrences will be done as part of the adaptive management and monitoring program as indicated in Table 3.4.11-1.

Enhancement and Management Guidelines and Techniques

Riparian Structural Diversity

The reserve system must support 1,000 acres of early- to midsuccessional riparian vegetation (Objective VFRNC2.2).[37] The flow management changes proposed under *CM1 Water Facilities and Operation*, including increased frequency and duration of pulse flows and bypass flows, are expected to improve scouring and deposition to help maintain and enhance early- to midsuccessional riparian vegetation in restored floodplains. If fluvial disturbance is not sufficient to meet this objective, additional enhancement and management described below will be implemented. Additionally, riparian restoration, as described in *CM7 Riparian Natural Community Restoration*, will include areas restored specifically to meet suitable habitat characteristics for riparian woodrat, riparian brush rabbit, and western yellow-billed cuckoo, and active vegetation management may be necessary to sustain these appropriate habitat characteristics for these species. Once these riparian restoration sites have met their success criteria, riparian vegetation management would occur consistent with this conservation measure to maintain and enhance riparian woodland and suitable habitat characteristics for the target covered species.

The riparian management strategy recognizes the spatially and structurally dynamic nature of the riparian natural community. As flooding along rivers results in scouring and fluvial disturbances, vegetation is cleared from some areas that then go through a process from early-successional (low, dense shrubs and young trees) toward late-successional (high, dense canopy) vegetation. Periodic disturbance thus results in a mosaic of vegetation characteristics that shifts over time. As such, early- to midsuccessional riparian vegetation is not expected to remain in one location. Instead, this requirement will be met throughout the reserve system as riparian vegetation matures and is

[37] Of the 1,000 acres, 800 acres will be within the range of the riparian brush rabbit (Conservation Zone 7), in areas that are adjacent to or that facilitate connectivity with occupied or potentially occupied habitat.

disturbed in different locations. Riparian vegetation in the reserve system will be monitored annually to ensure that there are 1,000 acres of early- to midsuccessional and 500 acres of mature forest throughout the reserve system. Similarly, the 800 acres of suitable habitat for riparian brush rabbit (300 of which will provide very specific habitat requirements) and 300 acres of suitable riparian woodrat habitat may spatially shift over time, within the limits set by the locational criteria for these species. (See Table 3.4.3-1 and Table 3.4.7-1 for further clarification with regard to these acreage requirements.) Active vegetation management will only be implemented if necessary to meet the biological objectives for the riparian community and associated covered species.

Structural heterogeneity of riparian vegetation in the reserve system will be maintained and enhanced. Vegetation structure can be defined as the foliage volume (or cover of foliage) by height for a given area (Riparian Habitat Joint Venture 2009). Structural complexity—including understory (low shrubs), midstory (large shrubs and small trees), and overstory (upper canopy formed from large trees)—is important to provide habitat requirements for a diversity of wildlife species. Appropriate structure will also be maintained for riparian brush rabbit and riparian woodrat, as described below.

Active vegetation management may include girdling trees, mechanical vegetation removal, plantings, moving sediment and gravel, or other techniques for managing physical processes and vegetation to provide the appropriate vegetation structural characteristics. The Implementation Office will consider the biological needs of covered fishes and other covered species, and apply the avoidance and minimization measures described in Appendix 3.C, *Avoidance and Minimization Measures*, when choosing the appropriate vegetation management techniques and applying them to managed sites.

Stream Channel Enhancement and Management

CM6 Channel Margin Enhancement describes channel modifications that would be undertaken to sustain favorable ecological conditions within and adjacent to stream channels.

Livestock Management

Cattle often concentrate their use in riparian zones, which provide shade, water, and succulent vegetation (Bryant 1982). Adverse effects of cattle in riparian areas include acceleration of erosion and sedimentation into surface water and destruction of aquatic and streamside vegetation. Livestock exclusion has been shown to allow the successful reestablishment of riparian vegetation along California streams (Reichard 1989). As part of the grazing management program, the Implementation Office will exclude livestock along targeted stream segments in the reserve system using exclusion fencing, off-channel water sources, and other potential actions as needed. Fencing wetlands may not be appropriate in locations where retaining unvegetated, open water for species such as western pond turtle is an objective, as cattle grazing will help to maintain appropriate habitat conditions.

Invasive Animal Control

- **Cowbird control.** Cowbird trapping is an effective short-term management tool in recovery of endangered riparian birds (Kus and Whitfield 2005). Cowbird trapping has proven successful in reversing downward population trends for avian species such as least Bell's vireo. Annual trapping in southern California eliminated or reduced cowbird parasitism relative to pretrapping rates and thereby enhanced productivity of nesting pairs, resulting in an eightfold increase in vireo numbers between 1986 and 2005 (Kus and Whitfield 2005). For cowbird trapping to be effective, it must be implemented on an annual basis for a sustained period. When cowbird trapping is not necessary to improve native bird populations or has minimal benefits, the funds and resources used for trapping could be used for other, more beneficial conservation efforts (U.S. Fish and Wildlife Service 2002a). Furthermore, sustained cowbird trapping might result in cowbirds developing either learned or genetic resistance to trapping, and in the capture of some nontarget species (U.S. Fish and Wildlife Service 2002a). For these reasons, cowbird trapping will only be implemented under limited circumstances, as described below; alternative methods to reduce cowbird nest parasitism will also be implemented in the reserve system.

Landscape-level management may be employed to minimize risk of cowbird parasitism on riparian birds in the reserve system. Cowbirds typically feed in areas with short grass and in the presence of ungulates such as domesticated livestock. They also feed in areas associated with anthropogenic influences such as golf courses and suburban lawns with bird feeders. Cowbirds commute on a daily basis from these feeding areas to riparian areas where they parasitize native birds (U.S. Fish and Wildlife Service 2002a). Therefore, proximity to potential cowbird feeding areas will be a consideration in siting riparian restoration projects. The reserve system may also be managed to discourage grazing and other activities that could attract cowbirds near riparian areas that support nesting least Bell's vireos or yellow-breasted chats.

Habitat-level management may also be an effective tool in minimizing cowbird parasitism on riparian songbirds. Parasitism rates and cowbird densities usually decline with increases in the density of vegetation; therefore, cowbird parasitism might be reduced by measures that result in denser vegetation, such as supplemental plantings of vegetation that tends to grow in dense patches (U.S. Fish and Wildlife Service 2002a; Sharp and Kus 2006).

Cowbird control may be an important aspect of managing the reserve system for least Bell's vireo. This species was previously thought to be extirpated from the Plan Area, but has recently been discovered in and near the Plan Area (Appendix 2.A, *Covered Species Accounts*), and a population may become reestablished as a result of habitat restoration and management. This species is particularly vulnerable to nest parasitism by brown-headed cowbirds (Sharp and Kus 2006). Because only a small number of least Bell's vireos, if any, are expected to nest in the Plan Area in the near term, nest monitoring and removal or addling of cowbird eggs, if present, are likely to be the most cost-effective method for reducing cowbird parasitism on the species. This method has the added benefit of providing information on the extent to which parasitism threatens nesting vireos in the Plan Area. Addling is preferred over egg removal, because the host might abandon a nest if the combined volume of eggs is reduced below a certain value by removal of cowbird eggs (U.S. Fish and Wildlife Service 2002a).

Cowbird trapping may be necessary, if the least Bell's vireo population in the reserve system has grown to a level at which cowbird egg addling or removal is no longer cost-effective, but monitoring determines that parasitism is threatening the population (at least 25% parasitism rate, or based on the best available information and consultation with species experts). Cowbird trapping will not be implemented unless pretrapping data indicate that cowbird parasitism may be threatening the least Bell's vireo population and cowbird egg removal or addling is determined to be less cost-effective. Prior to initiating cowbird trapping, a trapping plan will be developed that includes clear goals for the program, criteria for determining when trapping will be discontinued, and a siting strategy for placement of traps in locations expected to result in the greatest success in reducing parasitism on least Bell's vireo (U.S. Fish and Wildlife Service

2002a). The number of cowbirds or eggs removed, parasitism rate, and vireo nesting success will be documented to determine whether the program goals have been met.

- **Feral predator control in occupied riparian brush rabbit and riparian woodrat habitat.** Predation threats by feral predators (dogs and cats) will be minimized at all sites in the reserve system that are occupied by the riparian brush rabbit and riparian woodrat through installation of barriers, live trapping and removal of feral cats, patrolling and removal of feral dogs, or other management actions determined based on the best available scientific and technical information.
- **Feral pig control.** Feral pigs have the potential to adversely affect the riparian natural community in the Plan Area; however, feral pigs are currently known to occur only at the western edge of the Plan Area, whereas most of the riparian restoration and protection are expected to occur in the southern and eastern portions of the Plan Area. The impact of rooting activities in the riparian natural community may be reduced by fencing, although fencing to exclude feral pigs will need to be built for that purpose and maintained frequently to be effective. If fencing is used, it must be constructed so as not to restrict wildlife movement routes or corridors. In cases where livestock access to streams or rivers and surrounding uplands is desired but feral pigs are degrading habitat, a feral pig control program could be initiated to improve pond habitats. Feral pig control has been effective on San Francisco Public Utility Commission land in the adjacent Alameda Creek watershed (Koopman pers. comm.) and through an ongoing program in Henry W. Coe State Park (Sweitzer and Loggins 2001). Feral pig control will be focused on parts of the reserve system where the concentrations of feral pigs are high and impacts on native communities have been observed. It would be difficult to census the exact number of feral pigs in the reserve system without an extensive effort; however, rooting disturbance can be monitored. Pig populations will be controlled during the permit term as long as their rooting disturbance adversely affects the Implementation Office's ability to successfully implement the conservation strategy.

3.4.11.2.6 Grasslands and Associated Seasonal Wetland Natural Communities

This section describes the management and enhancement actions, and related guidelines and techniques, that will be implemented for grasslands and associated natural communities in the reserve system, including vernal pool complex, alkali seasonal wetland complex, and other seasonal wetlands. Applicable management and enhancement actions, described in Section 3.4.11.2.3, *General Enhancement and Management Actions*, will also be implemented. If those actions conflict with the community-specific actions described in this section, the community-specific actions will be implemented.

Enhancement and Management Actions

- **Vegetation management.** Vegetation will be enhanced and managed to reduce fuel loads for wildfires, reduce thatch, minimize nonnative competition with native plant species, increase biodiversity and provide suitable habitat conditions for covered species (see *Enhancement and Management Guidelines and Techniques*, below).
- **Burrow availability.** Grasslands (including the grassland natural community and grasslands within vernal pool complex and alkali seasonal wetland complex natural communities) will be enhanced and managed to increase the availability of overwintering and nesting burrows for

western burrowing owl, California red-legged frog, and California tiger salamander; and to increase prey availability for San Joaquin kit fox, Swainson's hawk, white-tailed kite, and other native wildlife predators (see *Enhancement and Management Guidelines and Techniques, Ground-Dwelling Mammals*, below).

- **Artificial nesting burrows and structures.** Where appropriate, artificial nesting burrows will be installed or elevated berms, mounds, or debris piles will be created for western burrowing owl to facilitate use of unoccupied areas (see below, *Enhancement and Management Guidelines and Techniques, Structures for Covered Wildlife*). Perching structures will be installed to facilitate use by western burrowing owl, Swainson's hawk, and white-tailed kite (see below, *Enhancement and Management Guidelines and Techniques, Structures for Covered Wildlife Species*).
- **Woody debris in stock ponds.** Woody debris will be installed in stock ponds to provide cover and basking opportunities for western pond turtle (see below, *Enhancement and Management Guidelines and Techniques, Structures for Covered Wildlife Species*).
- **Vernal pool, alkali seasonal wetland, and stock pond hydrology.** The hydrology of vernal pool complex and alkali seasonal wetland complex natural communities and stock ponds will be enhanced and managed as described below in *Enhancement and Management Guidelines and Techniques, Hydrologic Functions of Vernal Pools, Seasonal Wetlands, and Stock Ponds*.
- **Invasive wildlife.** Bullfrogs and other nonnative predatory species that limit the abundance of covered amphibians in vernal pools, alkali seasonal wetlands, and ponds will be controlled (see below, *Enhancement and Management Guidelines and Techniques, Bullfrogs and Nonnative Predatory Fish*).
- **Vernal pool pollinators.** Vernal pool complexes will be enhanced and managed to sustain suitable conditions for vernal pool pollinators (see *Enhancement and Management Guidelines and Techniques, Vernal Pool Pollinators*).

Enhancement and Management Guidelines and Techniques

Enhancement and management of grasslands and associated seasonal wetland natural communities in the reserve system will require application of many of the management techniques described below concurrently at different sites and on different spatial and temporal scales to create a mosaic of grassland conditions. This will maximize habitat heterogeneity across the landscape and will tend to increase native biological and structural diversity (Fuhlendorf and Engle 2001). For example, the buildup of dead plant material, or thatch, has been implicated in the suppression of native annual forbs in unmanaged wet grasslands in California (Hayes and Holl 2003). Techniques to reduce thatch (e.g., livestock grazing, prescribed burning, raking) will be applied only where the treatment is expected to benefit native grassland species. Techniques to reduce thatch will be discontinued if they are demonstrated to promote expansion of invasive species or encroachment of nonnative grassland into native grassland areas. These management techniques can also be effective at reducing the overall biomass of nonnative invasive species and increasing the annual success of native grassland species.

Managers must consider the impacts of management treatments on other covered species. For example, if burns occur in grassland habitat, treatments may affect covered plants in both positive and negative ways (Gillespie and Allen 2004); accordingly, it is important to monitor several life stages to determine the net effect of management actions.

Mowing or grazing will not be implemented in the 200-foot-wide band of grasslands or other uplands that will be maintained in transitional uplands adjacent to the restored tidal brackish emergent wetland natural community. This band of vegetation will be allowed to grow to sufficient height to provide cover for salt marsh harvest mouse, Suisun shrew, and other native species occurring in the tidal brackish emergent wetlands.

Site conditions (both physical and biological) and land use history are important in developing biologically appropriate management techniques to attempt to enhance native grassland alliances (Stromberg and Griffin 1996; Hamilton et al. 2002; Harrison et al. 2003). For example, some species of native grasses may occur primarily on steep north- or east-facing slopes where soil moisture tends to be higher (Jones & Stokes Associates 1989). Management strategies at these sites will differ from sites on more level topography and drier, south-facing slopes.

Guidelines and techniques for grassland vegetation management are described below.

- **Pilot experiments.** To minimize uncertainty about the appropriate management regime necessary to maintain and enhance each grassland type, pilot experiments will be conducted to test the effects of management actions. The experiments will be designed to test a range of reasonable management alternatives under appropriate spatial scales and seasonal weather patterns. Long-term monitoring programs will also include the following three components: experimental plots that generate information describing the long-term trends of management actions, experimental treatments for most likely management alternatives, and appropriate controls.
- **Livestock grazing.** Grazing by livestock and native herbivores is proposed for implementation in the reserve system to enhance grasslands by creating structural diversity and increasing the abundance of native grassland species. The flora of the Plan Area evolved under the influence of prehistoric herbivores, including large herds of deer, elk, antelope, and other grazing animals, and without the competition from nonnative annuals, which dominate much of the Plan Area today. At present, appropriate livestock grazing using cattle, sheep, and goats can be useful for range management, as a vegetation management tool to promote native plants and animals, and to reduce fuel loads for wildfires. One study found that grazing increased the diversity of native plant species on serpentine grasslands but decreased native diversity on nonserpentine grasslands (Harrison et al. 2003). In addition, grazing and ranch land management practices have been demonstrated to benefit California tiger salamander and California red-legged frog.

  Livestock grazing can be used to manage vegetation for purposes of maintaining and improving habitat conditions for resident plants and animals and to reduce fuel loads for wildfires. Different grazers and different grazing intensities result in different impacts on vegetation. The Implementation Office will develop an appropriate grazing program for enhancing and maintaining habitat for covered species for each protected area based on site-specific characteristics of the community and covered species, the spatial location of important ecological features in each pasture, the history of grazing on the site, species composition of the site, grazer vegetation preference, and other relevant information. Grazing exclusion will be used as a management alternative where appropriate. Grazing practices in effect in each pasture for the 5 years prior to acquisition will be continued unless there is a specific conservation-related need to alter them, or site-specific information suggests that alternate management actions would better advance the site's conservation goals. Grazing in certain native grassland communities, however, may need to be reduced to maintain or enhance these communities. Note that midsummer grazing may be effective in controlling invasive grassland plant species, because most native perennial grasses would be dormant in summer and not substantially damaged by grazing.

Several factors, including timing, stocking rate, rotation type, and grazing species, may affect the success of a grazing program (Sotoyome Resource Conservation District 2007). These are described below.

- **Timing.** Varying the timing (i.e., seasonal timing, annual timing) of grazing generally produces different effects across the landscape. Short-term winter grazing following burning may help to control invasive grasses, which germinate after winter rains; whereas mid-summer grazing may promote native perennial grasses, because they are dormant at that time and not substantially damaged by grazing. These tradeoffs will need to be considered as reserve unit management plans are developed.
- **Stocking rate.** The stocking rate refers to the number of cattle grazing at a given site for a given period of time. The stocking rate will be consistent with known or experimentally derived rates that promote native plants without adversely affecting covered species or causing long-term rangeland degradation.
- **Rotation type.** Rotation of cattle on different pastures within and between years can influence the success of a grazing program. Current rotations will be monitored and only shifted if monitoring results indicate that the lands or covered species are adversely affected under the existing timing.
- **Grazing species.** Different herbivorous species have different preferences and abilities to be selective grazers and, therefore, have different impacts on vegetation. Reserve unit management plans will take these differences into consideration.

Effects on all covered species are not quantified or fully understood, and it is possible that in some cases the effects of grazing on some covered plants may be detrimental. Potential adverse effects on covered species will be considered when developing grazing plans, and careful monitoring and adaptive management will be implemented to protect covered species and ensure the biological goals and objectives for these species are met.

Livestock grazing will be introduced or continued at some vernal pools, seasonal wetlands and stock ponds associated with grasslands. Allowing limited livestock access to these areas will help maintain their usefulness as habitat for covered species by preventing excessive plant growth that can lead to rapid sedimentation of ponds (U.S. Fish and Wildlife Service 2002b). Seasonally limited grazing can be effective at reducing competition for nonnative plant species in seasonal wetlands (Marty 2005). Grazing can eliminate or reduce cover of invasive plants and maintain wetlands and ponds by preventing excessive plant growth when such a technique is consistent with maintaining values for covered species. Grazing rotation and fencing can also reduce erosive impacts from livestock. In some cases, it may be necessary to exclude livestock from seasonal wetlands and ponds as described below.

- **Livestock control.** Grazers will be excluded from some sensitive vernal pool, seasonal wetland, ephemeral drainage, and pond areas. Complete or partial exclusion from ephemeral drainages with the appropriate alkaline soils in Conservation Zone 1 and Conservation Zone 11 will be considered in habitats known to have, or have potential to produce with exclusion (due to proximity to a known occurrence), occurrences of Carquinez goldenbush. Portions of stock ponds in Conservation Zone 8 will be fenced to prevent livestock entry, encourage emergent wetland growth, and facilitate California red-legged frog and California tiger salamander use. In addition, targeted studies examining grazing exclusion from specific terrestrial areas may be considered for sensitive plant species. However, because small-scale exclusion fences in potentially remote areas are expensive and labor-intensive to install and maintain, they will only be considered in areas where monitoring indicates that conservation targets are not being met or detrimental effects of grazing may actually hinder the survival of the species.

Fencing wetlands may not be appropriate in locations where retaining open water for species such as western pond turtle and California tiger salamander is an objective. In these locations, grazing is used as a management tool to reduce or eliminate emergent vegetation and provide suitable habitat conditions for these species. In such cases, fencing half of a pond or wetland (split fencing) may accommodate the needs of multiple covered species (U.S. Fish and Wildlife Service 2002b).

Another technique for minimizing livestock impacts on wetlands is to provide grazing animals with supplemental sources of water located in the uplands away from the wetlands.

- **Prescribed burning.** Prescribed burning may be implemented in grasslands to mimic historical disturbance regimes and promote native biodiversity. Fire played an important role in the development of the historical California native grassland community, and fire suppression following European settlement contributed to a loss of native diversity in California grasslands (Barry et al. 2006). Prescribed burning as a strategy to manage grasslands has been studied extensively in California and elsewhere (Harrison et al. 2003; Rice 2005). A review of existing literature in 2004 found that burning has mixed results depending on the starting condition of the ecosystem and on the timing and frequency of the burns (Rice 2005). Research indicates that in order for fire to successfully reduce nonnative and increase native plant cover, burns must be targeted toward the specific system and species conditions.

  Prescribed burning in late spring reduces nonnative seed production and increases native perennial grass seedling establishment due to litter removal and reduction of competition (Menke 1992). Additionally, summer burning can benefit grasslands by stimulating native perennial bunchgrasses to fragment into two or more vigorous daughter plants (Menke 1992). A prescribed burning program will be implemented with careful monitoring and adaptive management to ensure that it meets the objective of promoting native biodiversity.

  Prescribed burning can be used to mimic short interval fire regimes. Late spring and fall prescribed burning may be used in some grassland areas to increase native species cover in grasslands and reduce the cover of invasive species, repeating treatment onsite as needed. Grazing will be used in conjunction with prescribed burns where appropriate to control invasive grasses as they germinate after winter rains.

  If burns are implemented in the reserve system as a management tool, considerations will include the blooming and seeding times of the targeted nonnative species, the history of site use, and the likely condition of the native soil seed bank. Fires will be conducted at a time when the seeds of the targeted invasive plants will be destroyed. Single burns are generally unsuccessful at restoring native diversity and cover to grasslands; multiple burns are usually required. Burning can be used in conjunction with grazing or mowing to control infestations of invasive species. If native vegetation on a site has been particularly denuded, supplementary seeding of native species may be required.

  In particular, prescribed burning within the reserve system may be an effective tool to eradicate invasive species that are selectively avoided by grazing livestock. An example of this is barbed goatgrass (*Aegilops triuncialis*). Barbed goatgrass is avoided by livestock but can be controlled with prescribed burns that are appropriately timed (just after plants senesce but while seeds are still maturing) and repeated (probably at least 2 or 3 years in succession) (DiTomaso et al. 2001).

- **Mowing.** In some instances, mowing is a reasonable alternative to prescribed burns. Mowing can often be safer and easier to implement on small scales than fire. Like prescribed burning, mowing needs to be timed to target the blooming and seeding cycle of nonnative species. Mowing may be particularly useful and effective as a small-scale treatment in areas that cattle cannot access (such as steep or rocky slopes) or for other site-specific logistical reasons (for example, when removal of vegetation is required at a time other than the grazing timing currently in use). Discing as a management tool in grasslands is not recommended, because it often destroys burrows for covered and other native species (e.g., western burrowing owl, San Joaquin kit fox), increases soil erosion, and creates invasion sites for noxious weeds.

- **Seeding native forbs and grasses.** Highly degraded grasslands may need additional input of native seed to restore their functionality. Seeding may include covered plant species. Any seed supplements in native grasslands must use locally derived genetic stock. Where possible, seed sources of covered plants will come from within the same watershed. If no seed source is available from the same watershed, then the seed source will be from as close as possible. Decisions regarding where to introduce seed and from how far away to collect it will be made in light of all available information about the targeted species, the source population, and issues related to maintaining the genetic integrity of existing populations (California Native Plant Society 2001).

  To maximize the success of seed addition, pretreatment (e.g., burning 1 year prior to seeding to reduce weed seeds on the surface and in litter) may be required. Recent research conducted on grasslands in Santa Barbara suggests that seedlings of California native forbs can be excellent competitors when enough seeds are present to overcome the dominance in the seed pool of the invasive grasses and forbs (Seabloom et al. 2002). In a 5-year experiment, burning or mowing had no effect on the abundance or the proportion of native forbs without seeding. Targeted studies could test this approach by seeding grasslands with native and locally collected seeds within the reserves.

Ground-Dwelling Mammals

Increasing the density of ground-dwelling native mammals is an important goal of management on grasslands. Ground-dwelling mammals such as California ground squirrel provide a variety of important ecosystem functions and benefits to covered species such as prey for western burrowing owl, and Swainson's hawk and burrows for western burrowing owl, California red-legged frog, and California tiger salamander. Historically, ground squirrel populations were controlled by ranchers and public agencies. Eliminating ground squirrel control measures in the reserve system may be sufficient to increase squirrel populations in some areas. However, some rodent control measures will likely remain necessary in certain areas where dense rodent populations may compromise important infrastructure (e.g., pond berms, road embankments, railroad beds, levees, dam faces). The use of rodenticides or other rodent control measures will be prohibited in reserves except as necessary to address adverse impacts on essential structures in or immediately adjacent to reserves, including recreational facilities incorporated into the reserve system. The Implementation Office will introduce livestock grazing (where it is not currently used, and where conflicts with covered activities will be minimized) to reduce vegetative cover and thus encourage ground squirrel expansion and colonization. Burrow availability may also be increased on protected grasslands by encouraging ground squirrel occupancy through the creation of berms, mounds, edges, and other features designed to attract and encourage burrowing activity.

Where lands neighboring reserves require ground squirrel management to protect agricultural uses or public health, a buffer zone will be established in the reserve within which ground squirrel colonies will not be encouraged. The width of this buffer will be determined by the reserve manager in consultation with neighboring landowners and Implementation Office scientists. The buffer width will depend on site conditions, the size and density of the local ground squirrel population, and the intensity of control methods used adjacent to the reserve.

Structures for Covered Wildlife Species

Various types of structures may be installed and maintained within reserves supporting grasslands and associated wetlands to enhance habitat values for covered wildlife species. The location and type of structure to be installed will be based on expected benefits to covered species and likelihood that the species will occupy the enhanced lands.

Grasslands will be enhanced for western burrowing owl in unoccupied areas where suitable burrows or other microhabitat characteristics are lacking. Enhancement actions for this species may include installing artificial nesting burrows or creating elevated berms, mounds, or debris piles to facilitate use of unoccupied areas.

Perching structures may be installed in grasslands to facilitate use by western burrowing owl, Swainson's hawk, and white-tailed kite. Perches will be installed away from areas such as roads that are likely to experience frequent human disturbance.

Coarse woody debris or anchored basking platforms may be installed in stock ponds to improve habitat for western pond turtles (Hays et al. 1999). This modification will be implemented where it will increase the habitat value in locations with existing western pond turtles and where it is hoped that new pond turtle populations will establish. These structures may also enhance habitat for native amphibian species.

Maintenance of Upland Refugia

Grasslands will be protected or restored adjacent to restored brackish emergent wetland natural community to provide upland refugia for salt marsh harvest mouse, Suisun shrew, and other wildlife species that use the wetland communities. Similarly, grasslands will be protected and restored on the landward side of levees adjacent to restored floodplain to provide upland refugia for riparian brush rabbit. For these species, grasslands within 150 feet of the emergent wetland or riparian natural communities will not be grazed or will be lightly grazed, to allow for establishment of dense grasses that provide cover for the covered species.

Grasslands protected or restored adjacent to nontidal marsh to provide upland habitat for giant garter snake will be managed to sustain open, low-growing vegetation with an abundance of burrows, to provide basking and shelter opportunities for the snake. These areas will be managed in a manner similar to other grasslands to increase burrows created by ground-dwelling mammals, as described in *Ground-Dwelling Mammals*, above.

Hydrologic Function of Vernal Pools, Seasonal Wetlands, and Stock Ponds

Hydrologic functions to be maintained within vernal pool and alkali seasonal wetland complexes include surface water storage in the pool, subsurface water exchange, and surface water conveyance (Butterwick 1998:52). Aspects of surface water storage such as timing, frequency, and duration of inundation will be monitored, enhanced, and managed to benefit covered species. Techniques used to enhance and manage hydrology may include invasive plant control, removal of adverse supplemental water sources into reserves (e.g., agricultural or urban runoff), and topographic modifications.

Repairs may be made to improve water retention in stock ponds that are not retaining water due to leaks and, as a result, not functioning properly as habitat for covered species. Additionally, pond capacity and water duration can be increased (e.g., by raising spillway elevations) to support covered species populations.

To retain the habitat quality of stock ponds over time, occasional sediment removal may be needed to address the buildup of sediment that results from adjacent land use or upstream factors. Dredging will be conducted during the nonbreeding periods of covered species.

Bullfrogs and Nonnative Predatory Fish

Habitat management and enhancement will include trapping and other techniques to control the establishment and abundance of bullfrogs and other nonnative predators that threaten covered wildlife species in vernal pools, seasonal wetlands, and stock ponds. The Implementation Office will work to reduce and, where possible, eradicate invasive species that adversely affect native species. These efforts will include prescribed methods for removal of bullfrogs, mosquitofish, and nonnative predatory fish from stock ponds and wetlands in the reserve system[38].

The Implementation Office will work to reduce, and if possible eradicate, nonnative predators (e.g., bullfrogs, nonnative predatory fish) from aquatic habitat for covered amphibian species through habitat manipulation (e.g., periodic draining of ponds), trapping, hand-capturing, electroshocking, or other control methods. Draining ponds, sterilizing or removing subsoil, and removing bullfrogs can be effective at reducing predation by bullfrogs and other invasive species on covered amphibians and reptiles (Doubledee et al. 2003). Some ponds in the reserve system might be retrofitted with drains if the nonnative species populations cannot be controlled by other means. Ponds without drains and that do not drain naturally may need to be drained periodically using pumps. Drainage of stock ponds and other wetlands will be carried out during the summer or fall dry season. Population models predict that draining ponds every 2 years will increase the likelihood that California red-legged frogs will persist in ponds with bullfrogs (Doubledee et al. 2003).

Vernal Pool Pollinators

Protection of the entire vernal pool complex, including surrounding uplands (*CM3 Natural Communities Protection and Restoration*), is a key component to conserving vernal pool pollinators. Additionally, vernal pool complexes will be managed to sustain appropriate habitat characteristics

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[38] This conservation measure addresses removal of predatory fish from certain nontidally influenced waters in the Plan Area (vernal pools, other seasonal wetlands, and stock ponds). Removal of predatory fish from tidally influenced waters, where covered fish species are expected to be at least seasonally present, is addressed in *CM15 Localized Reduction of Predatory Fishes*.

for solitary bees and other native pollinators of vernal pool plants. To ensure sufficient upland is conserved, new vernal pools will not be excavated in existing, intact vernal pool complexes. Pesticides will be used as little as possible in vernal pool complexes (see also Section 3.4.11.2.3, *General Enhancement and Management Actions, Pesticides*). A buffer of at least 1 kilometer will be used for aerial spraying any insecticides (e.g., on adjacent cultivated lands) in the reserve system, during the active flight period of the specialist bees, which coincides with plant bloom. The vernal pool complexes should not be overgrazed, as cattle may trample nests of ground-nesting bees and consume and trample foliage that feeds larvae of pollinators such as butterflies and moths. When burning is prescribed for vernal pool complexes, it will be carefully timed to avoid the period when specialist bee species are active and host flower species are blooming (Hoffman Black et al. 2009).

3.4.11.2.7 Cultivated Lands

This section describes the management and enhancement actions, and related guidelines and techniques, that will be implemented in cultivated lands in the reserve system. Applicable management and enhancement actions, described in Section 3.4.11.2.3, *General Enhancement and Management Actions*, will also be implemented. If those actions conflict with the community-specific actions described in this section, the community-specific actions will be implemented.

Enhancement and Management Actions

The following management actions apply to all conserved cultivated lands.

- **Crop type maintenance and timing.** Crop types will be maintained to provide the required habitat acreages and values for covered species that use cultivated lands, consistent with species-specific objectives (see *Cropping Patterns* below). Foraging opportunities and habitat values for wintering sandhill cranes, waterfowl, and shorebirds will be enhanced through timing the flooding of corn fields (see *Timing and Flooding* below).
- **Buffers.** Uncultivated seasonal or permanent buffers will be maintained on cultivated lands in the reserve system that are adjacent to riparian and wetland habitats, to protect the integrity of the stream corridor and associated riparian vegetation, promote regeneration of riparian species, and reduce disturbance of nesting species such as tricolored blackbird, yellow-breasted chat, and least Bell's vireo (see *Buffers* below).
- **Canals and ditches.** Water in canals and ditches will be maintained during the activity period (early spring through mid-fall) for the giant garter snake, western pond turtle, and other covered species using waterways (see *Canals and Irrigation Ditches* below).
- **Pesticides.** Pesticide use will be minimized or discontinued as needed to reduce negative effects on wildlife including direct, lethal toxicity, reproductive failures, and other adverse effects (see also Section 3.4.11.2.3, *General Enhancement and Management Actions, Pesticides*).
- **Patches of natural communities and habitat features.** Existing patches of riparian, grassland, and other natural communities and habitat features that occur in the cultivated lands matrix will be retained. Existing trees will be retained and new trees will be planted to provide nesting habitat for Swainson's hawk and white-tailed kite (see *Associated Features* below). Hedgerows will be retained and planted on cultivated lands to provide refugia for rodents, thus increasing rodent prey populations for the Swainson's hawk and the white-tailed kite (see *Associated Features* below).

Cropping Patterns

Cropping patterns within the reserve system will be managed to address habitat requirements for greater sandhill crane, Swainson's hawk, and tricolored blackbird. These habitat requirements are set forth in the biological goals and objectives (Table 3.3-1) and summarized for each relevant species in Table 3.4.3-1. The specific habitat values are described for greater sandhill crane, Swainson's hawk, and tricolored blackbird in Table 3.4.3-2, Table 3.4.3-3, and Table 3.4.3-4, respectively. Cropping patterns will be managed on an annual basis to meet the acreage and habitat requirements set forth in the biological goals and objectives (Table 3.3-1), siting and reserve design requirements (Table 3.4.3-1), and to be in rough proportionality with impacts (Chapter 6, Section 6.1.2, *Maintaining Rough Proportionality*).

Crops with minimum acquisition requirements will need to be rotated to other crops types periodically. Based on previous use patterns, the reserve system is expected to always have enough land in nonessential crops (e.g., irrigated crops other than alfalfa, rice, or corn) to allow for rotation into essential crops to ensure that minimum standards for these essential crops are met. Land cultivation patterns will be monitored to determine the extent to which the needs of each covered species are being met at any point in time.

Emergency Spillway Associated with Glannvale Tract Forebay

An emergency spillway will be constructed in association with the intermediate forebay on the Glannvale tract. This spillway will prevent the intermediate forebay from overtopping by spilling into the approximately 125-acre inundation area. This area will only be flooded under emergency conditions, which are expected to be seldom if ever. Therefore, the basin will be cultivated and managed to provide roosting and foraging habitat for greater sandhill crane as described below in *Enhancement and Management Guidelines and Techniques, Timing and Flooding for Sandhill Crane*. Providing crane habitat in this area will not count toward the habitat targets under Objectives GSHC1.1 through GSHC1.5, because perpetual conservation cannot be guaranteed, as the spillway will be needed to prevent forebay overtopping in emergency situations. Rather, this additional greater sandhill crane habitat to be provided in the spillway will be above and beyond the minimum habitat requirements stipulated in the biological objectives for the crane. Enhancement and Management Guidelines and Techniques

Timing and Flooding for Greater Sandhill Cranes

Habitat management in areas conserved as foraging habitat for greater sandhill crane will include deferring the tilling of corn and grain fields until later in the fall to increase the amount and availability of forage for this species. Also, where feasible, a portion of corn or grain fields will be left unharvested to increase the quantity of forage available to greater sandhill cranes (forage gradually becomes available as senescent plant stalks fall over as a result of weathering).

To increase the foraging and roosting value of cultivated lands for greater sandhill cranes, some corn, grain, and irrigated pastures will be shallowly flooded during fall and winter. This will also improve foraging conditions for waterfowl and shorebirds. Cultivated land roosting habitat to meet Objective GSHC1.4 will consist of blocks of at least 180 acres that will be sequentially flooded to maintain a minimum of 40 acres of roosting habitat at any given time during the winter when cranes are present. This is intended to minimize disturbance and provide not only the roost water, but also new foraging opportunities throughout the season in close proximity to the roosting habitat. For example, if the field block is divided into two 90-acre parcels (180 acres total), half of one field may be flooded early in the fall and half of the other field may be flooded and maintained from mid-winter until the end of the season, while the first is drained or left to evaporate. Birds will benefit from having new foraging area close to the roost while it is being converted.

Buffers

Uncultivated buffers will be maintained on cultivated lands in the reserve system that are adjacent to the riparian natural community. Uncultivated buffers will also be maintained on cultivated lands in the reserve system around canals and ditches that support giant garter snake to reduce disturbance and possible mortality and to provide upland habitat for the snake during its dormant period. Where feasible, these buffers will extend 200 feet from the edge of the canal or ditch. Narrower buffers will be allowed only where there is no practicable alternative (e.g., because of access limitations or existing infrastructure).

Canals and Irrigation Ditches

The Implementation Office will retain or create connectivity of canals and irrigation ditches within and between giant garter snake reserves to facilitate dispersal and other movement of giant garter snake. Emergent vegetation will be retained in these canals and irrigation ditches within the reserve system to provide escape cover for giant garter snakes.

Pesticide Use

See Section 3.4.11.2.3, *General Enhancement and Management Actions, Pesticides,* regarding pesticide use on the reserve system. On cultivated lands managed as high- to very high-value foraging habitat for tricolored blackbirds (6,400 acres), use of insecticides will be minimized to the greatest extent practicable during the spring growing season until tricolored blackbird nestlings have fledged or it is documented that no nearby nesting is occurring. This is to insure that an abundant insect prey population is available to support egg development and feeding of the young, as well as to minimize the risk of pesticide toxicity effects.

Associated Features

The Implementation Office will retain wetlands, riparian communities, grassland edges, ponds, and other natural communities and habitat features that occur in the reserve system within the cultivated lands matrix. Conservation easements on cultivated lands will stipulate that these natural community features will be protected and managed to achieve the biological goals and objectives.

Tree rows, wood lots or other tree groves, and isolated trees will also be retained under conservation easements on cultivated lands to provide nesting habitat for Swainson's hawk and white-tailed kite. Small woodlots may also be planted in field corners or tree rows may be planted along field borders to provide nesting habitat for these species.

Native trees will be planted and maintained along roadsides and field borders within protected cultivated lands at a rate of at least one tree per 10 acres, to provide nest trees for Swainson's hawks. These may consist of single, isolated trees or clumps of trees. Trees to be planted will be sited in areas most likely to be used by nesting Swainson's hawks, adjacent to protected foraging habitat. Trees will not be planted in areas that are less suitable for nesting hawks, such as near high-activity areas or powerlines. Trees may be planted on cultivated lands to meet the requirements for near-term loss of Swainson's hawk and white-tailed kite nesting trees as described in AMM18 (Appendix 3.C, *Avoidance and Minimization Measures*).

Existing hedgerows will be retained and new hedgerows may be planted in association with cultivated lands in the reserve system. Hedgerows are expected to provide refugia for rodents, thus increasing rodent prey populations for Swainson's hawk, white-tailed kite, and western burrowing owl.

Burrowing owl habitat will be created and enhanced in association with cultivated lands in the reserve system. This will involve the retention or creation of grassland edges, levee slopes, berms, or patches that provide opportunities for burrowing owl breeding or wintering burrows. Burrowing owl habitat will also be enhanced along cultivated edges by managing vegetation height, installing perches and artificial nesting structures, where appropriate, and encouraging ground squirrel activity.

Where conditions permit, stands of emergent vegetation, native blackberry, or other native vegetation will be established along ditches and canals to provide suitable nesting substrate for tricolored blackbird. These stands will be located near foraging sites and, where feasible, within the dispersal range of existing tricolored blackbird nesting colonies.

3.4.11.2.8 Managed Wetlands

This section describes the management and enhancement actions, and related guidelines and techniques, that will be implemented in managed wetlands in the reserve system. Applicable management and enhancement actions, described in Section 3.4.11.2.3, *General Enhancement and Management Actions*, will also be implemented. If those actions conflict with the community-specific actions described in this section, the community-specific actions will be implemented.

Enhancement and Management Actions

The 8,100 acres of managed wetlands to be protected (*CM3 Natural Communities Protection and Restoration*) will be managed for covered species and native biodiversity. Of that acreage, the at least 1,500 acres of managed wetland to be protected in the Grizzly Island Marsh Complex will be enhanced and managed specifically for salt marsh harvest mouse. The remaining 6,600 acres will be managed for biodiversity of native species, including waterfowl and shorebirds. At least 5,000 of the 6,600 acres will be managed as seasonal wetlands (wetlands that are dry during summer and fall months) to increase food value and density for overwintering waterfowl. At least 1,600 acres will be managed as permanent wetlands (wetlands that maintain some ponded water all year) to benefit breeding waterfowl and shorebirds.

Salt Marsh Harvest Mouse

The at least 1,500 acres of managed wetland to be protected for salt marsh harvest mouse will be managed to provide "Viable Habitat Areas," as defined in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* and to meet population capture efficiency targets described in that plan. The protected managed wetlands will be enhanced to provide vegetation with structural diversity and food value for native wildlife. Structural diversity will be provided by management and enhancement actions that promote tall stands of pickleweed (*Salicornia*), which provide cover for the salt marsh harvest mouse and a substrate on which mice climb for refuge during high-tide events. Pickleweed will be promoted by implementing a water management schedule that allows manipulation of salinity levels favorable to pickleweed (and other important plants such as fat hen) development as described in the Conceptual Model for Managed Wetlands developed under the Suisun Marsh Plan (California Department of Fish and Game 2010b).

Both the at least 1,500 acres of managed wetlands to be protected for salt marsh harvest mouse and the at least 6,600 acres of managed wetlands to be protected for waterfowl and shorebirds will be managed in a manner to minimize adverse effects on salt marsh harvest mouse. To minimize adverse effects of discing on salt marsh harvest mouse and other native wildlife, no more than 20% of the managed wetlands in the reserve system will be disced each year (Suisun Resource Conservation District 1998). The salt marsh harvest mouse populations on the managed wetlands will be monitored, and management procedures will be modified as needed to reduce any adverse effects on the species. Although salt marsh harvest mouse is known to occur regularly in existing managed wetlands, the effects of management actions on species populations is unknown. Research will be implemented to address this critical uncertainty (Section 3.4.11.3, *Adaptive Management and Monitoring*).

Waterfowl and Shorebirds

The at least 6,600 acres of managed wetland protected and managed to benefit waterfowl and shorebirds will be managed as a mosaic of wetland and upland types. At least 5,000 acres of protected, seasonal wetlands will be managed to maximize food biomass and energetic value for overwintering waterfowl, and at least 1,600 acres will be managed as semipermanent and permanent wetlands to support summer nesting and brood-rearing habitat for waterfowl and shorebirds. A diversity of wetland types will be maintained to provide a variety of food that allow waterfowl to feed selectively and to obtain adequate nutrition from a variety of sites. Uplands will also be maintained, to provide waterfowl nesting and brooding sites. These uplands will also benefit salt marsh harvest mouse and Suisun shrew by providing refugia during flood events. Temporary ponds will be maintained to provide value for breeding shorebirds, while seasonal, semipermanent, and brackish wetlands will be maintained to provide foraging habitat for nesting and brood-rearing shorebirds. Water will be drawn down in the spring in areas adjacent to uplands to optimize foraging depths for migrating shorebirds (Suisun Resource Conservation District 1998).

The 6,600 acres of managed wetlands for waterfowl and shorebirds will also be managed, when and where such management does not conflict with the needs of waterfowl and shorebirds, to optimize habitat for covered species, specifically the salt marsh harvest mouse. These acres will be managed in a manner that avoids take of salt marsh harvest mouse and minimizes any adverse effects on this species (see *Enhancement and Management Guidelines and Techniques*, below). The primary focus of enhancement and management activities on the at least 5,000-acre managed wetland reserve will be to maximize food biomass and value for overwintering waterfowl and to increase vegetation heterogeneity for all native species. Controlling soil salinities is an important management goal for maximizing food biomass and value as well as increasing vegetation diversity. Soil salinities are controlled primarily through soil leaching and flood/drain cycles performed in late winter through spring. The control of the cover and extent of invasive plant species is also an important management technique for increasing native diversity. Enhancement and management activities on managed wetlands will include, but will not be limited to, the below-listed activities consistent with Section 3.4.11.2.3, *General Enhancement and Management Actions*.

- The manual, chemical, or mechanized removal of invasive vegetation.
- The maintenance, enhancement, and replacement of pumping infrastructure.
- The maintenance and enhancement of levees on reserve lands and on adjacent lands.

Two key uncertainties related to managed wetland management, identified in *Effects Analysis of BDCP Covered Activities on Waterfowl and Shorebirds in the Yolo, Delta, and Suisun Basins* (Ducks

Unlimited 2012), will be addressed through the adaptive management and monitoring program. Potential research actions for investigating these uncertainties are provided in Table 3.4.11-2. The results of the research actions will inform the composition of seasonal, semipermanent, and permanent wetlands within the at least 6,600-acre managed wetland reserve as well as the need for additional management and enhancement actions necessary to maximize native biodiversity on the at least 6,600-acre reserve.

Enhancement and Management Guidelines and Techniques

Salt Marsh Harvest Mouse

As mentioned above, the enhancement of the 1,500 acres of managed wetland on Grizzly Island to promote salt marsh harvest mouse habitat will be guided by the *Conceptual Model for Managed Wetlands* developed under the Suisun Marsh Plan. Specifically, a pickleweed water management schedule (possibly in conjunction with the similar fat hen water management schedule) will be implemented that includes a 4-month winter flooding period and an 8-month drawdown below pond levels. The extended drawdown period will encourage salts to rise to the surface, creating the higher salinity levels that allow pickleweed to outcompete less favorable vegetation. Also, other techniques may be implemented that promote development of pickleweed and other dense vegetation along dikes and levees to provide mouse refugia during the winter flooding period.

An important habitat component for salt marsh harvest mouse is the presence of upland areas to provide refugia from flood events. Resting islands will be created and maintained in association with ponds on managed wetlands to provide refuge for salt marsh harvest mouse and other terrestrial species. These islands will be vegetated low rises, from about 1 inch below to 6 inches above water level, in areas where wildlife has a clear line of vision for predators (Suisun Resource Conservation District 1998). While these islands will be a component of both the 1,500 acres to be managed specifically for salt marsh harvest mouse and the 6,600 acres to be managed with more of a waterfowl and shorebird emphasis, the 1,500 acres will be designed in a manner to optimize conditions for the mouse, with sufficient upland areas to provide flood refugia for this species. Additional measures to avoid net adverse effects on the salt marsh harvest mouse that might otherwise result from management activities on the 6,600 acres to be managed for waterfowl and shorebirds are described under *Waterfowl and Shorebirds*, below.

Waterfowl and Shorebirds

Native wildlife habitat maintenance and improvements to be implemented in managed wetlands will include water control and various types of wetland and upland manipulations. Vegetation will be manipulated to provide winter waterfowl food and habitat, and to provide breeding habitat for resident waterfowl. Vegetation manipulation activities may include, but are not limited to, flooding, discing, controlled burns, mowing, herbicide treatment, and planting. Guidelines and techniques for water control and wetland and upland manipulations are described below. Also described below are guidelines and techniques for avoiding effects on the salt marsh harvest mouse present in wetlands managed for waterfowl and shorebirds. Additional detail can be found in *A Guide in Waterfowl Habitat Management in Suisun Marsh* (Suisun Resource Conservation District 1998).

- **Water control.** Management and enhancement techniques for the 6,600 acres will be guided by flooding and drawdown regimes associated with the management of seasonal, semipermanent, and permanent wetlands. Seasonal wetlands are typically flooded sometime in mid- to late fall and then drawn down in late winter/early spring so as to maximize germination, sprouting, and growth of high-value plant species on which overwintering waterfowl forage. Semipermanent wetlands are also flooded in mid- to late fall but maintain some number of wetted acres into the late spring/early summer to support breeding waterfowl and shorebirds. Semipermanent wetlands are typically dry by mid- to late summer. Permanent wetlands are also flooded in mid- to late fall but maintain some ponded water throughout the year to support waterfowl and shorebird breeding and brooding. Managed wetland depth within the reserve system will be managed, when and where possible, to maximize the extent of wetlands with suitable foraging depths for shorebirds, especially in early fall when few wetlands are available for shorebird foraging and again in late spring and early summer (April through July) to support breeding and brooding. Water control schedules on the managed wetlands will be influenced by site-specific factors including wildlife habitat objectives, physical management constraints, annual environmental constraints, and regulatory constraints.

- **Soil salinity control.** The 6,600 acres of protected managed wetlands in Suisun Marsh will be managed to minimize soil salinities. Wetland units are flooded in the fall when migrating waterfowl and shorebirds begin to arrive. In the fall, water drawn for wetland flooding from adjacent sloughs and bays is typically somewhat saline. As water evaporates through the winter and spring, the salts remain in the wetland soils. Increased soil salinity decreases the diversity of plant species, including many important waterfowl forage species. To reduce soil salinities and increase plant diversity, spring-time flood and drain cycles are used to bring fresh water onto the unit, leach salt from the soil, and then remove the salt by draining the wetland unit. Water in the adjacent sloughs and bays is fresher in the spring after winter rains. To adequately control soil salinities, at least two or three leach cycles are usually necessary. As with all wetland management in Suisun Marsh, spring-time flood and drain cycles are influenced by site-specific factors including wildlife habitat objectives, physical management constraints, annual environmental constraints, and regulatory constraints. When and where possible, spring-time flood and drain cycles will be managed to maximize the temporal and spatial distribution of wetland acres at suitable foraging depths for shorebirds.

- **Enhancing shorebird breeding habitat.** Shorebirds in Suisun Marsh will use minimally vegetated islands, wetland edges, and levee slopes for breeding when in proximity to semipermanent or permanent wetlands with appropriate foraging depths. The slope of breeding islands, wetland edges, and levees within wetland units managed to support breeding shorebirds should be gradual (10 to 12 horizontal inches per vertical inch) Hickey and Shuford pers. comm.), either naturally or through enhancement. Levee maintenance during the breeding season, April through July, should be limited to emergency repairs with the exception of mowing the center or top of a levee; mowing down the center of a levee during the breeding season is allowed (Hickey and Shuford pers. comm.). Adding suitable nesting substrate to islands, wetland edges, or levees to improve nesting habitat conditions will be considered when and where feasible.

- **Managing waterfowl and shorebird breeding and brooding habitat.** Semipermanent and permanent wetlands will be managed to support waterfowl and shorebird breeding and brooding. The siting of semipermanent and permanent wetlands in the reserve system is described in *CM3 Natural Communities Protection and Restoration.*

- **Controlled burns.** Burning can be an effective means of quickly replacing soil nutrients, removing undesirable seeds from the seed bank, removing excess plant material from the pond bottom to accelerate the decaying process, and controlling undesirable plant species such as saltgrass, Baltic rush, and Phragmites. Control of these species is best achieved if burned just prior to a flood-up period, and if the area is flooded over the unburned stalks to deprive the plants of oxygen and carbon dioxide.

- **Discing.** Discing aids in the preparation of seedbeds for artificial planting and natural succession. Discing can open up dense, monotypic stands of vegetation and change the vegetative composition of a pond. Following a burn, discing can kill roots of undesirable plants by exposing them to the sun and can increase the speed of nutrient cycling. Leaving the soil surface rough following discing can improve the effectiveness of leaching during the first year. Cross discing, which involves making one pass across a field and then a second pass at a 90 degree angle to the first, is thought to be the most effective discing method.

  Discing should be selective and will be carefully monitored. Some plants, such as pepperweed and Phragmites, can reproduce from the chopped pieces of roots, so discing can increase production of these pest plants; such plants need to be sprayed with herbicide prior to discing. The managed wetlands should not be overdisced; overdiscing can break up the soil into fine particles that form impenetrable crusts when in contact with water. Overdiscing can also cause subsidence by increasing the exposure of soils to the atmosphere.

  Discing has the potential to harm wildlife including salt marsh harvest mouse and Suisun shrew, and to temporarily remove cover for these species. To minimize adverse effects of discing on salt marsh harvest mouse and other native wildlife, no more than 20% of the managed wetlands in the reserve system will be disced each year (Suisun Resource Conservation District 1998).

- **Mowing.** Mowing is an effective method of creating open areas and setting back monocultures to allow formation of diverse plant communities. Mowing can also be an effective means for controlling invasive plants. Mowing should be performed by either cutting vegetation in strips or by clearing the entire area around a pond. Mowing should be done after August to prevent disturbance of ground-nesting birds.

- **Avoiding loss or degradation of salt marsh harvest mouse habitat.** The salt marsh harvest mouse is known to occupy all wetland types throughout Suisun Marsh and to benefit from enhancement and management efforts to increase the extent of mixed vegetation stands (Sustaita et al. 2011), as will be implemented on the 6,600 acres to be managed for waterfowl and shorebirds. However, permanent wetlands within managed wetlands have lower habitat value for the species than seasonal wetlands. Therefore, to avoid the loss of occupied salt marsh harvest mouse habitat, seasonal wetlands will not be converted to semipermanent or permanent wetlands, and semipermanent wetlands will not be converted to permanent wetlands. See AMM26 (Appendix 3.C, *Avoidance and Minimization Measures*) for additional details related to avoiding effects on the salt marsh harvest mouse potentially resulting from management and protection of managed wetlands in the reserve system.

Invasive Animal Control

Feral pigs have the potential to adversely affect managed wetlands in the Plan Area, especially at the western edge of the Plan Area where feral pigs are currently known to occur. The impact of rooting activities in wetlands may be reduced by fencing, although fencing to exclude feral pigs will need to be built for that purpose and maintained frequently to be effective. If fencing is used, it must be constructed so as not to restrict wildlife movement routes or corridors. In cases where livestock access to ponds and surrounding uplands is desired but feral pigs are degrading habitat, a feral pig control program could be initiated to improve pond habitats. Feral pig control has been effective on San Francisco Public Utility Commission land in the adjacent Alameda Creek watershed (Koopman pers. comm.) and through an ongoing program in Henry W. Coe State Park (Sweitzer and Loggins 2001). Feral pig control will be focused on parts of the reserve system where the concentrations of feral pigs are high and impacts on native communities have been observed. It would be difficult to census the exact number of feral pigs in the reserve system without an extensive effort; however, rooting disturbance can be monitored. Pig populations will be controlled during the permit term as long as their disturbance (i.e., rooting disturbance) adversely affects the Implementation Office's ability to successfully implement the conservation strategy.

Invasive Plant Control

Invasive plants in managed wetlands include, but are not limited to, perennial pepperweed, pampas grass (*Cortaderia sellonana*), giant reed, common reed (*Phragmites australis*). These species can form dense monocultures that eliminate native plants and degrade wildlife habitat. These and other invasive plants will be controlled as necessary, as described above (*Invasive Plant Control* and *Enhancement and Management Actions, Invasive Plant Control and Native Biodiversity*).

3.4.11.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of listing management actions that occurred in each reserve unit as part of the annual report and documenting that required reserve unit management plans were prepared as required.

Effectiveness monitoring will be conducted to evaluate progress toward advancing the objectives listed in Section 3.4.11.4, *Consistency with the Biological Goals and Objectives.* If necessary, the implementation actions described above will be adjusted via adaptive management, as described in Section 3.6, to meet these objectives. Effectiveness monitoring will consist of verifying that natural communities and species habitats in the reserve system are performing the expected ecological functions as specified in Section 3.4.11.5. Table 3.4.11-1 provides potential monitoring actions, metrics, success criteria, and timing and duration relevant to CM11. These monitoring elements may be modified, as necessary, to best assess the effectiveness of CM11, based on the best available information at the time of implementation.

Table 3.4.11-1. Effectiveness Monitoring Relevant to CM11

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM11-1	Vegetation sampling, mapping invasive species infestations	Relative cover of invasive species, presence of infestations that threaten ecosystem and covered species habitat functions	As specified in reserve unit management plan	Within 6 months of site acquisition and every 5 years thereafter
CM11-2	Site-level assessment	Presence of obstacles to wildlife movement	No significant obstacles to wildlife movement in reserve system	Within 6 months of site acquisition and every 5 years thereafter

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM11-3	Freshwater emergent wetland vegetation sampling	Freshwater emergent wetland vegetation composition, diversity, and structural complexity	Reflective of historical conditions	Every 5 years after restoration is determined to be successful (See *CM4 Tidal Natural Communities Restoration* regarding restoration success criteria)
CM11-4	Riparian natural community vegetation sampling	Structural heterogeneity, successional stage, patch size, presence of rare and uncommon vegetation alliances	To be determined regarding structural heterogeneity; 1,000 acres early- to midsuccessional; 500 acres of mature riparian intermixed with early- to midsuccessional, in minimum 50-acre blocks	For protected riparian natural community, within 6 months of site acquisition and every 5 years thereafter. For restoration of riparian natural community, every 5 years after successful restoration (See *CM7 Riparian Natural Community Restoration* regarding restoration success criteria)
CM11-5	Hydrologic monitoring in alkali seasonal wetlands	Duration of wetland saturation or ponding	Hydrology characteristic of alkali seasonal wetlands supporting a diversity of endemic alkali seasonal wetland species, based on reference wetlands	Within 6 months of site acquisition and every 5 years thereafter
CM11-6	Vegetation sampling in grasslands	Extent, distribution, and density of native perennial grasses intermingled with other native species, including annual grasses, geophytes, and other	Increase above baseline	Within 6 months of site acquisition and every 5 years thereafter
CM11-7	Site-level assessment in grasslands	Burrow availability for burrow-dependent species	Increase above baseline	Within 6 months of site acquisition and every 5 years thereafter
CM11-8	Rodent live trapping and insect sampling, site-level assessment in grasslands	Prey abundance and accessibility (especially small mammals and insects) for grassland-dependent species.	Increase above baseline	Within 6 months of site acquisition and every 5 years thereafter
CM11-9	Hydrologic monitoring in vernal pools	Depth and duration of ponding	Hydrology characteristic of vernal pools supporting a diversity of endemic vernal pool species, based on reference wetlands	Within 6 months of site acquisition and every 5 years thereafter

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM11-10	Insect sampling in vernal pool complexes	Abundance of native solitary bees and other pollinators	Equal to or greater than baseline	Within 6 months of site acquisition and every 5 years thereafter
CM11-11	Survey foraging plant density and type	Food biomass density and energetic value	Equal to that which was lost	For 2 years prior to enhancement to determine baseline, for 3 years after enhancement to determine postrestoration condition; and once every 10 years thereafter
CM11-12	Mapping native grassland vegetation alliances	Distribution and diversity of native grassland vegetation alliances	A mosaic of alliances with consideration of historical sites	Immediately after site acquisition and every 10 years thereafter
CM11-13	Site-level assessment	Presence of suitable habitat features for riparian brush rabbit, including flood refugia	Meets habitat criteria as defined in *CM7 Riparian Natural Community Restoration* and Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit & Riparian Woodrat*	Within 6 months of site acquisition of protected habitat or after restoration is determined to be successful for restored habitat, and every 5 years thereafter
CM11-14	Site level surveys	Presence of feral predators (cats and dogs)	Absent from occupied riparian brush rabbit habitat	Annually in occupied riparian brush rabbit habitat
CM11-15	Site-level assessment	Presence of suitable habitat features for riparian woodrat, including flood refugia	Meets habitat criteria as defined in *CM7 Riparian Natural Community Restoration* and Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit & Riparian Woodrat*	Within 6 months of site acquisition and every 5 years thereafter
CM11-16	Vegetation sampling in middle and high brackish marsh	Plant species composition and relative cover	Consistent with "Viable Habitat Areas" for salt marsh harvest mouse defined in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*	Within 6 months of successful restoration of tidal brackish emergent wetland or of acquisition of managed wetland for salt marsh harvest mouse, and every 5 years thereafter
CM11-17	Small mammal live trapping	Salt marsh harvest mouse capture rate	Capture efficiency targets for salt marsh harvest mouse described in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*	Within 6 months of acquisition of managed wetland or after restoration of tidal brackish emergent wetland is determined to be successful, and every 5 years thereafter

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM11-18	Site-level assessment in tricolored blackbird nesting habitat	Age of vegetation	Young, lush stands of emergent vegetation, rather than senescent vegetation	Within 6 months of site acquisition and every 5 years thereafter
CM11-19	Site-level assessment in occupied Carquinez goldenbush habitat	Erosion and habitat degradation	Reverse any erosion or degradation trends	Within 6 months of site acquisition and every 5 years thereafter
CM11-20	Estimate of delta button celery population size	Population size	Stable or increasing	Within 1 year of determining that each occurrence has been successfully established, and every 5 years thereafter
CM11-21	Surveys for Mason's lilaeopsis and delta mudwort in suitable habitat	Numbers of occurrences in reserve system relative to numbers of occurrences lost as a result of covered activities	No net loss of occurrences	Within 6 months of site acquisition or successful restoration, and every 5 years thereafter
CM11-22	Surveys for Delta tule pea and Suisun Marsh aster in suitable habitat	Numbers of occurrences in reserve system relative to numbers of occurrences lost as a result of covered activities	No net loss of occurrences	Within 6 months of site acquisition or successful restoration, and every 5 years thereafter
CM11-23	Estimate of population size for slough thistle	Population size	Stable or increasing	Within 6 months of site acquisition and every 5 years thereafter
CM11-24	Monitor ponds in protected grasslands	Inundation depth and duration, vegetation cover	Suitable conditions for covered reptiles and amphibians	Every 5 years
CM11-25	Vegetation sampling	Percent cover of perennial pepperweed	10% or less	Annually for the first 5 years after restoration, and every 5 years thereafter
CM11-26	Vegetation sampling in tidal freshwater emergent wetland	Plant species composition and diversity	Diversity of vegetation adapted to a diversity of inundation characteristics	Within 6 months of successful restoration of tidal freshwater emergent wetland, and every 5 years thereafter

Table 3.4.11-2 lists key uncertainties and associated research actions relevant to CM11.

Table 3.4.11-2. Key Uncertainties and Potential Research Actions Relevant to CM11

Key Uncertainty	Potential Research Actions
What enhancement techniques are most effective for improving least Bell's vireo, yellow-breasted chat, and western yellow-billed cuckoo habitat?	Establish experimental vegetation plots and control plots, apply varying enhancement techniques and compare results with best available information regarding suitable habitat characteristics for the species. Also assess in terms of species occupation.
What enhancement techniques are most effective for improving riparian brush rabbit and riparian woodrat habitat?	Establish experimental vegetation plots and control plots, apply varying enhancement techniques, and compare results with best available information regarding suitable habitat characteristics for the species. Also assess in terms of species occupation.
Can self-sustaining occurrences of slough thistle and delta button celery be created?	Assess microhabitat requirements and planting methods (i.e., seed broadcast or outplanting) through experimental trials.
What habitat value, if any, do seasonal and semipermanent wetlands provide for the salt marsh harvest mouse?	Perform a capture and release tagging study to determine the abundance of salt marsh harvest mice within managed wetland managed to maximize waterfowl and shorebird productivity.
What is the waterfowl food availability and density on existing seasonal and semipermanent wetlands in Suisun Marsh, and how do these values differ with management and salinity?	Perform surveys to determine waterfowl diversity and abundance and waterfowl food quality and biomass density on a subset of managed wetlands within Suisun Marsh that represents the spectrum of management and salinity conditions.
What are the effects of various managed wetland management regimes on salt marsh harvest mouse habitat and populations?	Establish experimental plots, apply varying managed wetland management techniques and compare results with best available information regarding suitable habitat characteristics for salt marsh harvest mouse. Also assess in terms of species occupation and numbers.

Additionally, if riparian brush rabbits do not occupy habitat areas protected and restored specifically for this species, it may be necessary to use the Endangered Species Recovery Program's captive breeding program (Williams et al. 2002). This program has been a successful tool in the recovery of the riparian brush rabbit (Williams et al. 2008). The Adaptive Management Team will monitor the 200 acres of protected and 300 acres of restored riparian brush rabbit habitat for occupancy annually for the first 10 years after protection or restoration is in place. If monitoring efforts conclude that either the 200 acres of protected or the 300 acres of restored riparian brush rabbit habitat are not occupied by riparian brush rabbits for at least 3 consecutive years within the first 10 years after habitat protection or restoration, and if riparian brush rabbits are available for reintroduction through the Endangered Species Recovery Program's captive breeding program (Williams et al. 2002), then the Permitting Agencies may propose to the Adaptive Management Team that captive-bred brush rabbits be introduced into protected and restored riparian brush rabbit habitat in the Plan Area. The captive breeding program, however, is not the responsibility of the Implementation Office to maintain.

3.4.11.4 Consistency with the Biological Goals and Objectives

CM11 will advance the biological goals and objectives as identified in Table 3.4.11-3. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the

Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Table 3.4.11-3 also identifies the monitoring actions associated with each objective as it relates to CM11.

Table 3.4.11-3. Biological Goals and Objectives Addressed by CM11 and Related Monitoring Actions

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.		
Objective L2.1: Allow floods to promote fluvial processes, such that bare mineral soils are available for natural recolonization of vegetation, desirable natural community vegetation is regenerated, and structural diversity is promoted, or implement management actions that mimic those natural disturbances.	If natural flooding disturbance (*CM5 Seasonally Inundated Floodplain Restoration*) is not sufficient to achieve riparian structural objectives, mechanical vegetation management will be implemented as described in Section 3.4.11.2.5, *Riparian Natural Community, Enhancement and Management Actions*.	CM7-1, CM7-2, CM7-3, CM7-4, CM7-6 in restored floodplain
Objective L2.6: Increase native species diversity and relative cover of native plant species, and reduce the introduction and proliferation of nonnative species.	Invasive plant and wildlife control will be implemented in the reserve system to reduce competition, predation, and nest parasitism on native species, thereby improving conditions for native biodiversity. Livestock grazing is expected to help maintain or increase native plant diversity, following the reserve unit management plans described in this conservation measure.	CM11-1
Goal L3: Capacity for movement of native organisms and genetic exchange among populations necessary to sustain native fish and wildlife species in the Plan Area.		
Objective L3.1: Protect and improve habitat linkages that allow terrestrial covered and other native species to move between protected habitats within and adjacent to the Plan Area.	Within the reserve system, fences and other structures that serve as wildlife movement barriers will be removed, and culverts and other crossings will be improved. Thatch will be controlled in grasslands to facilitate movement by amphibians and other native wildlife. See Section 3.4.11.2.3, *General Enhancement and Management Actions, Reserve System Permeability.*	CM11-2
Goal TBEWNC2: Tidal brackish emergent wetland natural community that is managed to maintain or increase species diversity and habitat value for native species.		
Objective TBEWNC2.1: Limit perennial pepperweed to no more than 10% cover in the tidal brackish emergent wetland natural community within the reserve system.	Perennial pepperweed will be controlled within the tidal brackish emergent wetland natural community in the reserve system through the invasive plant control program.	CM11-25
Goal TFEWNC2: Biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes and functions.		
Objective TFEWNC2.1: Restore and sustain a diversity of marsh vegetation that reflects historical species compositions and high structural complexity.	Restored tidal freshwater emergent wetlands will be managed and enhanced, as needed, through nonnative plant control and supplemental native plantings, to advance this objective.	CM11-3

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Objective TFEWNC2.2: Create topographic heterogeneity in restored tidal freshwater emergent wetland to provide variation in inundation characteristics and vegetative composition.	Tidal freshwater emergent wetlands will be enhanced as needed and maintained to meet this objective. See Section 3.4.11.2.4, *Aquatic and Emergent Wetland Natural Communities, Enhancement and Management Actions.*	CM-11-26
Goal VFRNC2: Increased structural diversity including a mosaic of seral stages, age classes, plant zonation, and plant heights and layers characteristic of valley/foothill riparian natural community.		
Objective VFRNC2.1: Restore, maintain, and enhance structural heterogeneity with adequate vertical and horizontal overlap among vegetation components and over adjacent riverine channels, freshwater emergent wetlands, and grasslands.	Where natural processes such as flooding (*CM5 Seasonally Inundated Floodplain Restoration*) do not maintain structural heterogeneity, active manipulation such as planting or thinning will be implemented. See Section 3.4.11.2.5, *Riparian Natural Community, Enhancement and Management Guidelines and Techniques.*	CM11-4
Objective VFRNC2.2: Maintain 1,000 acres of early- to midsuccessional vegetation with a well-developed understory of dense shrubs on restored seasonally inundated floodplain.	Where natural processes such as flooding (*CM5 Seasonally Inundated Floodplain Restoration*) do not maintain structural heterogeneity, active manipulation such as planting or thinning will be implemented. See Section 3.4.11.2.5, *Riparian Natural Community, Enhancement and Management Guidelines and Techniques.*	CM11-4
Objective VFRNC2.3: Maintain at least 500 acres of mature riparian forest in Conservation Zones 4 or 7.	Riparian forest will be maintained in areas subject to relatively infrequent flooding. Enhancement and maintenance may include supplemental plantings of tree species typical of mature riparian forests with tall canopy. See Section 3.4.11.2.5, *Riparian Natural Community, Enhancement and Management Guidelines and Techniques.*	CM11-4
Objective VFRNC2.4: Maintain the at least 500 acres of mature riparian forest (VFRNC2.3) intermixed with a portion of the early- to midsuccessional riparian vegetation (VFRNC2.2) in large blocks with a minimum patch size of 50 acres and minimum width of 330 feet.	A mosaic of mature and early- to midsuccessional riparian vegetation will be maintained in large blocks to meet this objective. See Section 3.4.11.2.5, *Riparian Natural Community, Enhancement and Management Guidelines and Techniques.*	CM11-4
Goal VFRNC3: Maintenance or increase of native biodiversity that is characteristic of the valley/foothill riparian natural community.		
Objective VFRNC3.1: Maintain or increase abundance and distribution of valley/foothill riparian natural community vegetation alliances that are rare or uncommon as recognized by California Department of Fish and Game (2010), such as *Cephalanthus occidentalis* (button willow thickets) alliance and *Sambucus nigra* (blue elderberry stands) alliance.	Rare or uncommon riparian vegetation alliances will be maintained in the reserve system, as described in this objective. Areas supporting these alliances may be increased through invasive plant control and supplemental plantings. See Section 3.4.11.2.5, *Riparian Natural Community, Enhancement and Management Guidelines and Techniques.*	CM11-4

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Goal ASWNC2: Alkali seasonal wetlands that are managed and enhanced to sustain populations of native alkali seasonal wetland species.		
Objective ASWNC2.1: Provide appropriate seasonal flooding characteristics for supporting and sustaining alkali seasonal wetland species.	Techniques may include invasive plant control, removal of adverse supplemental water sources (e.g., agricultural or urban runoff) into reserves, and removal of hydrologic barriers to seasonal flooding. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Hydrologic Function of Vernal Pools, Seasonal Wetlands, and Stock Ponds.*	CM11-5
Objective ASWNC2.2: In grasslands surrounding alkali seasonal wetlands within restored and protected alkali seasonal wetland complex, increase the extent, distribution, and density of native perennial grasses intermingled with other native species, including annual grasses, geophytes, and other forbs.	Grazing, prescribed burns, supplemental plantings, and other techniques will be implemented to promote native perennial grasses and other native plant species. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Actions.*	CM11-6
Objective ASWNC2.3: In grasslands surrounding alkali seasonal wetlands within restored and protected alkali seasonal wetland complex, increase burrow availability for burrow-dependent species.	Control of burrowing mammals will be reduced or eliminated within alkali seasonal wetland complex in the reserve system. Grasslands will be managed through grazing, prescribed burns, and other measures to optimize conditions for burrowing mammals. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Ground-Dwelling Mammals.*	CM11-7
Objective ASWNC2.4: In grasslands surrounding alkali seasonal wetlands within restored and protected alkali seasonal wetland complex, increase prey abundance and accessibility, especially small mammals and insects, for grassland-foraging species.	Use of rodenticides and other pesticides will be reduced or eliminated within the reserve system. Grasslands will be managed through grazing, prescribed burns, and other measures to optimize conditions for burrowing mammals. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Ground-Dwelling Mammals.*	CM11-8
Goal VPNC2: Vernal pool complexes that are managed and enhanced to sustain populations of native vernal pool species.		
Objective VPNC2.1: Maintain or enhance vernal pool complexes to provide the appropriate inundation (ponding) characteristics for supporting and sustaining vernal pool species.	Techniques may include invasive plant control, removal of adverse supplemental water sources into reserves (e.g., agricultural or urban runoff), and topographic modifications. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Hydrologic Function of Vernal Pools, Seasonal Wetlands, and Stock Ponds.*	CM11-9

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Objective VPNC2.2: Maintain and enhance pollination service in the vernal pool complex, especially by native invertebrates including native solitary bees.	Vernal pool complexes will be managed to sustain appropriate habitat characteristics for solitary bees and other native pollinators of vernal pool plants. Monitoring, pilot experiments, and adaptive management will be implemented to achieve this objective. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Vernal Pool Pollinators.*	CM11-10
Objective VPNC2.3: In grasslands surrounding vernal pools within restored and protected vernal pool complex, increase the extent, distribution, and density of native perennial grasses intermingled with other native species, including annual grasses, geophytes, and other forbs.	Grazing, prescribed burns, supplemental plantings, and other techniques will be implemented to promote native perennial grasses and other native plant species. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Actions.*	CM11-6
Objective VPNC2.4: In grasslands surrounding vernal pools within restored and protected vernal pool complex, increase burrow availability for burrow-dependent species.	Control of burrowing mammals will be reduced or eliminated within the reserve system. Grasslands will be managed through grazing, prescribed burns, and other measures to optimize conditions for burrowing mammals. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Ground-Dwelling Mammals.*	CM11-7
Objective VPNC2.5: In grasslands surrounding vernal pools within restored and protected vernal pool complex, increase prey abundance and accessibility, especially small mammals and insects, for grassland-foraging species.	Use of rodenticides and other pesticides will be reduced or eliminated within the reserve system. Grasslands will be managed through grazing, prescribed burns, and other measures to optimize conditions for burrowing mammals. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Ground-Dwelling Mammals.*	CM11-8
Goal MWNC1: Managed wetland that is managed and enhanced to provide suitable habitat conditions for covered species and native biodiversity.		
Objective MWNC1.1: Protect and enhance 8,100 acres of managed wetland, at least 1,500 acres of which are in the Grizzly Island Marsh Complex.	The 1,500 acres to be protected in the Grizzly Island Marsh Complex will be managed and enhanced specifically for salt marsh harvest mouse, as described in Section 3.4.11.2.8, *Managed Wetlands*. The remaining 6,600 acres will be managed for biodiversity of native species, including waterfowl, as described in Section 3.4.11.2.8.	CM11-11

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Goal GNC2: Biologically diverse grasslands that are managed to enhance native species and sustained by natural ecological processes.		
Objective GNC2.1: Restore and sustain a mosaic of grassland vegetation alliances, reflecting localized water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.	Grazing management, prescribed burns, reseeding, and other grassland management techniques will be implemented to achieve this objective. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques*.	CM11-12
Objective GNC2.2: Increase the extent, distribution, and density of native perennial grasses intermingled with other native species, including annual grasses, geophytes, and other forbs.	Grazing, prescribed burns, supplemental plantings, and other techniques will be implemented to promote native perennial grasses and other native plant species. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Actions.*	CM11-6
Objective GNC2.3: Increase burrow availability for burrow-dependent species.	Control of burrowing mammals will be reduced or eliminated within grasslands in the reserve system. Grasslands will be managed through grazing, prescribed burns, and other measures to optimize conditions for burrowing mammals and prey accessibility. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Ground-Dwelling Mammals.*	CM11-7
Objective GNC2.4: Increase prey abundance and accessibility, especially of small mammals and insects, for grassland-foraging species.	Use of rodenticides and other pesticides will be reduced or eliminated within the reserve system. Grasslands will be managed through grazing, prescribed burns, and other measures to optimize conditions for burrowing mammals and prey accessibility. See Section 3.4.11.2.6, *Grasslands and Associated Seasonal Wetland Natural Communities, Enhancement and Management Guidelines and Techniques, Ground-Dwelling Mammals.*	CM11-8
Objective GNC2.5: Maintain and enhance aquatic features in grasslands to provide suitable inundation depth and duration and suitable composition of vegetative cover to support breeding for covered amphibian and aquatic reptile species.	Aquatic features in protected grasslands will be maintained and enhanced consistent with this objective.	CM11-24
Goal CLNC1: Cultivated lands that provide habitat connectivity and support habitat for covered and other native wildlife species.		
Objective CLNC1.1: Protect 48,625 acres of cultivated lands that provide suitable habitat for covered and other native wildlife species.	Cultivated lands will be maintained to provide suitable crop types for covered species.	Compliance monitoring

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Objective CLNC1.3: Maintain and protect the small patches of important wildlife habitats associated with cultivated lands that occur in cultivated lands within the reserve system, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant groves, riparian corridors, water conveyance channels, grasslands, ponds, and wetlands.	Wildlife habitat on protected cultivated lands will be maintained consistent with this objective.	Compliance monitoring
Goal RBR1: Suitable habitat available for the future growth and expansion of riparian brush rabbit populations.		
Objective RBR1.2: Of the 1,000 acres of early- to midsuccessional riparian habitat maintained under VFRNC2.2, maintain at least 800 acres within the range of the riparian brush rabbit (Conservation Zone 7), in areas that are adjacent to or that facilitate connectivity with occupied or potentially occupied habitat.	At least 800 acres of early- to midsuccessional riparian habitat will be maintained within the range of riparian brush rabbit. See Section 3.4.11.2.5, *Riparian Natural Community Enhancement and Management Actions.*	CM11-14
Objective RBR1.3: Of the 5,000 acres of valley/foothill riparian natural community restored under Objective VFRNC1.1, restore/create and maintain 300 acres of early- to midsuccessional riparian habitat that meets the ecological requirements of the riparian brush rabbit and that is within or adjacent to or that facilitates connectivity with existing occupied or potentially occupied habitat.	If flooding and other natural processes (*CM5 Seasonally Inundated Floodplain Restoration*) are not sufficient to sustain suitable habitat characteristics, riparian brush rabbit habitat will be manipulated through plantings and other techniques to achieve this objective. See Section 3.4.11.2.5, *Riparian Natural Community Enhancement and Management Actions.*	CM11-13
Objective RBR1.4: Create and maintain high-water refugia in the 300 acres of restored riparian brush rabbit habitat and the 200 acres of protected riparian brush rabbit habitat, through the retention, construction and/or restoration of high-ground habitat on mounds, berms, or levees, so that refugia are no further apart than 20 meters.	Created refugia in riparian brush rabbit habitat will be maintained to ensure that their functionality is sustained. See Section 3.4.11.2.5, *Riparian Natural Community Enhancement and Management Actions.*	CM11-13
Objective RBR1.5: In protected riparian areas that are occupied by riparian brush rabbit, monitor for and control nonnative predators that are known to prey on riparian brush rabbit.	Occupied riparian brush rabbit habitat will be monitored for predators, and predators will be trapped if monitoring shows potential adverse predation effects on the species. See Section 3.4.11.2.5, *Riparian Natural Community, Enhancement and Management Guidelines and Techniques, Invasive Animal Control.*	CM11-14

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Goal RW1: A reserve system that includes suitable habitat available for the future growth and expansion of riparian woodrat populations.		
Objective RW1.1: Of the 5,000 acres of valley/foothill riparian natural community restored under Objective VFRNC1.1, restore/create and maintain 300 acres riparian habitat in Conservation Zone 7 that meets the ecological requirements of the riparian woodrat (e.g., dense willow understory and oak overstory) and that is adjacent to or facilitates connectivity with existing occupied or potentially occupied habitat.	If flooding and other natural processes (*CM5 Seasonally Inundated Floodplain Restoration*) are not sufficient to sustain suitable habitat characteristics, riparian woodrat habitat will be manipulated through plantings and other techniques to achieve this objective. See Section 3.4.11.2.5, *Riparian Natural Community Enhancement and Management Actions.*	CM11-15
Objective RW1.2: Provide and maintain high-water refugia in the 300 acres of riparian woodrat habitat restored under Objective RW1.1 through the retention, construction, and/or restoration of high-ground habitat on mounds, berms, or levees, so that refugia are no further apart than 20 meters.	Created refugia in riparian woodrat habitat will be maintained to ensure that their functionality is sustained. See Section 3.4.11.2.5, *Riparian Natural Community Enhancement and Management Actions.*	CM11-15
Goal SMHM1: Suitable habitat and conditions to sustain a population of salt marsh harvest mouse in the reserve system.		
Objective SMHM1.1: Within the at least 1,500 acres of middle and high marsh restored under Objective TBEWNC1.2, provide viable habitat areas for salt marsh harvest mouse, as defined in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*. Meet population capture efficiency targets described in that plan.	See Section 3.4.11.2.4, *Aquatic and Emergent Wetland Natural Communities.*	CM11-16, CM11-17
Objective SMHM1.2: Within the 1,500 acres of managed wetland protected and enhanced in the Grizzly Island Marsh Complex under Objective MWNC1.1, provide "Viable Habitat Areas" for salt marsh harvest mouse, as defined in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*, and increase population levels above the current baseline.	See Section 3.4.11.2.8, *Managed Wetlands.*	CM11-16, CM11-17

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Goal CBR1: A reserve system that includes suitable habitat for the future growth and expansion of California black rail populations.		
Objective CBR1.1: At the ecotone that will be created between restored tidal freshwater emergent wetlands and transitional uplands (Objectives L1.3 and TFEW1.1), provide for at least 1,700 acres of California black rail habitat consisting of shallowly inundated emergent vegetation at the upper edge of the marsh (within 50 meters of upland refugia habitat) with adjacent riparian or other shrubs that will provide upland refugia, and other moist soil perennial vegetation.	Tidal freshwater emergent wetlands will be enhanced as needed and maintained to meet this objective. See Section 3.4.11.2.4, *Aquatic and Emergent Wetland Natural Communities, Enhancement and Management Actions.*	CM11-26
Goal SH1: Large, interconnected patches or contiguous expanses of protected Swainson's hawk foraging habitat.		
Objective SH1.2: Within the 48,625 acres of protected cultivated lands, protect at least 43,325 acres of Swainson's hawk foraging habitat with at least 50% in very high-value habitat production in Conservation Zones 1, 2, 3, 4, 7, 8, 9, and 11.	See Section 3.4.11.2.7, *Cultivated Lands.*	Compliance monitoring
Goal SH2: Cultivated lands that provide conditions suitable for supporting Swainson's hawk.		
Objective SH2.1: Increase distribution and abundance of potential Swainson's hawk nest trees in the Plan Area by planting and maintaining native trees along roadsides and field borders within protected cultivated lands at a rate of one tree per 10 acres.	See Section 3.4.11.2.7, *Cultivated Lands.*	Compliance monitoring
Objective SH2.2: Support the establishment and sustainability of Swainson's hawk prey populations by establishing 20- to 30-foot-wide hedgerows along field borders and roadsides within protected cultivated lands at a minimum rate of 400 linear feet per 100 acres.	See Section 3.4.11.2.7, *Cultivated Lands.*	Compliance monitoring
Goal TRBL1: Improved nesting, nesting-adjacent foraging, and wintering habitat for tricolored blackbirds in the Plan Area.		
Objective TRBL1.1: Protect and manage 50 acres of occupied or recently occupied (within the last 15 years) tricolored blackbird nesting habitat located within 5 miles of high-value foraging habitat in Conservation Zones 1, 2, 8, or 11. Nesting habitat will be managed to provide young, lush stands of bulrush/cattail emergent vegetation and prevent vegetation senescence.	Nesting habitat protected for tricolored blackbirds will be managed through mechanical clearing, burning, or other mechanisms as needed to achieve this objective. See 3.4.11.2.4, *Aquatic and Emergent Wetland Natural Communities.*	CM11-18
Objective TRBL1.2: Within the 48,625 acres of cultivated lands protected under Objective CLNC1.1, protect at least 26,300 acres of moderate-, high-, or very high-value cultivated lands as nonbreeding foraging habitat, at least 50% of which is of high or very high value.	Cultivated lands protected for tricolored blackbirds will be managed to ensure quality characteristics necessary to achieve this objective. See Section 3.4.11.2.7, *Cultivated Lands*, and Section 3.4.11.2.8, *Managed Wetlands*.	Compliance monitoring

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Objective TRBL1.3: Within the 48,625 acres of protected cultivated lands, protect at least 11,050 acres of high- to very high-value breeding-foraging habitat within 5 miles of occupied or recently occupied (within the last 15 years) tricolored blackbird nesting habitat in Conservation Zones 1, 2, 3, 4, 7, 8, or 11. At least 1,000 acres will be within 5 miles of the 50 acres of nesting habitat protected under Objective TRBL1.1.	Cultivated lands protected for tricolored blackbirds will be managed to ensure quality characteristics necessary to achieve this objective. See Section 3.4.11.2.7, *Cultivated Lands*, and Section 3.4.11.2.8, *Managed Wetlands*.	Compliance monitoring
Goal CGB1: A reserve system that includes Carquinez goldenbush occurrences and sustains suitable habitat for this species.		
Objective CGB1.2: Maintain and enhance occupied Carquinez goldenbush habitat to slow erosion and reverse degradation from livestock grazing.	Erosion in Carquinez goldenbush habitat will be slowed and reversed by excluding grazing, encouraging native vegetation, and, when necessary, using interim soil control measures to hold soil in place until vegetation can naturally colonize.	CM11-19
Goal DBC1: Expand the distribution and increase the abundance of delta button celery populations.		
Objective DBC1.1: Protect and enhance two occurrences of delta button celery. If occurrences are not found in the Plan Area, establish self-sustaining occurrences of delta button celery for a total of two occurrences[39] within the restored floodplain habitat on the mainstem of the San Joaquin River in Conservation Zone 7 between Mossdale and Vernalis.	Created occurrences of delta button celery will be enhanced by methods such as seed broadcasting and outplanting nursery-grown plants and managed to minimize the encroachment of invasive plants (native or nonnative), until the occurrence is determined by a professional biologist to be self-sustaining.	CM11-20
Goal DMW/ML1: A reserve system that supports Mason's lilaeopsis and delta mudwort.		
Objective DMW/ML1.1: No net loss of Mason's lilaeopsis and delta mudwort occurrences within restoration sites, or within the area of affected tidal range of restoration projects.	Natural recruitment of Mason's lilaeopsis and delta mudwort is expected to occur within tidal restoration sites; these occurrences will be enhanced and managed as necessary to ensure no net loss of occurrences.	CM11-21
Goal DTP/SMA1: A reserve system that supports the Delta tule pea and Suisun Marsh aster.		
Objective DTP/SMA1.1: No net loss of Delta tule pea and Suisun Marsh aster occurrences within restoration sites.	Natural recruitment of Delta tule pea and Suisun Marsh aster is expected to occur within tidal restoration sites; these occurrences will be enhanced and managed as necessary to ensure no net loss of occurrences.	CM11-22

[39] This objective allows protection of one occurrence and establishment of one occurrence in the reserve system, or establishment of two occurrences in the reserve system.

Biological Goal or Objective	How CM11 Advances a Biological Objective	Monitoring Action(s)
Goal ST1: Expanded distribution and increased abundance of slough thistle populations.		
Objective ST1.1: Protect and enhance two occurrences of slough thistle. If occurrences are not found in the Plan Area, establish self-sustaining occurrences of slough thistle for a total of two occurrences[40] within the 10,000 acres of restored floodplain on the mainstem of the San Joaquin River in Conservation Zone 7 between Mossdale and Vernalis.	Created occurrences of slough thistle will be enhanced by methods such as seed broadcasting and outplanting nursery-grown plants, and managed to minimize the encroachment of invasive plants (native or nonnative), until the occurrences are determined by a professional biologist to be self-sustaining.	CM11-23
Goal SBB/SuT1: Protected and expanded Suisun thistle and soft bird's-beak populations.		
Objective SBB/SuT1.2: Complete seed banking of all existing Suisun Marsh populations and the representative genetic diversity using accepted seed banking protocols.	See Section 3.4.11.2.4, *Aquatic and Emergent Wetland Natural Communities*.	Compliance monitoring
Objective SBB/SuT1.3: Establish a cultivated population of Suisun thistle from wild seed using accepted seed collection protocols.	See Section 3.4.11.2.4, *Aquatic and Emergent Wetland Natural Communities*.	Compliance monitoring
Objective SBB/SuT1.4: Establish two occurrences of Suisun thistle in Conservation Zone 11.	See Section 3.4.11.2.4, *Aquatic and Emergent Wetland Natural Communities*.	Compliance monitoring
[a] This objective allows protection of one occurrence and establishment of one occurrence in the reserve system, or establishment of two occurrences in the reserve system.		

3.4.12 Conservation Measure 12 Methylmercury Management

Under *CM12 Methylmercury Management*, the Implementation Office will minimize conditions that promote production of methylmercury in restored areas and its subsequent introduction to the foodweb, and to covered species in particular. This conservation measure will promote the following actions.

- Define design elements that minimize conditions conducive to generation of methylmercury in restored areas.
- Define adaptive management strategies that can be implemented to monitor and minimize actual postrestoration creation and mobilization of methylmercury.

The design elements will be integrated into site-specific restoration designs based on site conditions, community type (tidal marsh, nontidal marsh, floodplain), and potential concentrations of mercury in prerestoration sediments. The adaptive management strategies can be applied where site conditions indicate a high probability of methylmercury generation and effects on covered species.

[40] This objective allows protection of one occurrence and establishment of one occurrence in the reserve system, or establishment of two occurrences in the reserve system.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM12. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM12 on covered species will be avoided or minimized.

The techniques proposed in this conservation measure are expected to reduce methylmercury production in Delta wetland ecosystems, convert existing methylmercury to less-toxic inorganic mercury, or reduce the potential for methylmercury to enter the foodweb. Each of these outcomes will benefit all wetland communities and the covered species dependent on those communities. These effects of CM12 are evaluated in Appendix 5.D, *Contaminants*.

3.4.12.1 Problem Statement

For descriptions of the current condition of methylmercury in the Plan Area, see Appendix 5.D, *Contaminants*; Chapter 2, *Existing Ecological Conditions*; and Section 3.3, *Biological Goals and Objectives*. Section 3.3 also describes the need for methylmercury management as a component of the conservation strategies for each of the tidal natural communities and associated covered species.

Mercury is present in sediments and soils throughout the Delta, having been deposited by tributaries and rivers that drain areas of former mining operations in the mountains. The highest concentrations have been reported in Cache Creek and Yolo Bypass and the Mokelumne-Cosumnes River system (Wood et al. 2010). Mercury is also potentially present in sediments of all ROAs throughout the Delta at varying concentrations.

Mercury in an inorganic or elemental form tends to adhere to soils and has limited bioavailability. Mercury may be converted by bacteria to a different form, called methylmercury, which is much more bioavailable and toxic than inorganic forms, and has a strong tendency to bioaccumulate in organisms. The toxicity and tissue concentrations of methylmercury are amplified as it biomagnifies through the foodchain. As a consequence, the filet mercury concentrations of most sportfish in the Delta exceed fish advisory guidelines.

Mercury is converted to methylmercury in a process called methylation by sulfur-reducing bacteria that occur in anaerobic (oxygen-depleted) conditions, such as are often found in wetland soils. Current research has shown that the conversion rate is highest in sediments subjected to periodic wet and drying-out periods, including marshes and floodplains. The multiple influences of environmental parameters on mercury methylation are complex (Windham-Meyers et al. 2010). In general, the highest methylation rates are associated with high tidal marshes with intermittent wetting and drying periods and anoxic conditions that support methylation (Alpers et al. 2008). Therefore, potential effects from mercury in the Plan Area are highly dependent on many factors that must be considered on a site-specific basis, including the following.

- In-place sediment (or flooded soil) concentrations of mercury, methylmercury, sulfur, and organic compounds.
- The methylation rates of the surface sediments in restored environments.
- Other environmental conditions including pH, salinity, and redox.

Restoration actions proposed in *CM4 Tidal Natural Communities Restoration* will increase the acreage of intermittently wetted areas by converting cultivated lands and other upland areas to tidal, open water, and floodplain habitats, potentially increasing methylmercury production in the Plan Area. Some of this increased production is likely to be taken up by organisms, and to biomagnify through the foodchain. The risks that mercury and methylmercury pose to covered species are discussed in Appendix 5.D, *Contaminants*.

3.4.12.2 Implementation

CM12 will be developed and implemented in coordination with the *Sacramento-San Joaquin Delta Methylmercury Total Maximum Daily Load* (Methylmercury TMDL) (Central Valley Regional Water Quality Control Board 2011a) and *Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary* (Mercury Basin Plan Amendments)(Central Valley Regional Water Quality Control Board 2010 and 2011b). The Mercury Monitoring and Evaluation Section of DWR is currently working on DWR's compliance with the Methylmercury TMDL and Mercury Basin Plan Amendments. The Mercury Monitoring and Evaluation Section will work with the Implementation Office to attain compliance for covered activities.

The Phase I and Phase II Methylmercury TMDL programs are responsible for developing measures to control methylmercury generation and loading into the Delta in accordance with Methylmercury TMDL goals. Phase I emphasizes studies and pilot projects to develop and evaluate management practices to control methylmercury. Phase I (effective October 2011) will be underway for the next 7 years, with an additional 2 years to evaluate Phase I results and plan for Phase II. Phase II involves implementation of mercury control measures. The Mercury Monitoring and Evaluation Section is required as part of Phase I to submit final reports that present the results and descriptions of methylmercury control options, their preferred methylmercury controls, and proposed methylmercury management plan(s) (including implementation schedules) for achieving methylmercury allocations.

3.4.12.2.1 Project-Specific Mercury Management Plans

For each restoration project under *CM4 Tidal Natural Communities Restoration*, a project-specific methylmercury management plan will be developed and will incorporate all of the methylmercury management measures discussed below or will include an explanation of why a particular measure should not or cannot be incorporated. Each project-specific plan will include the following components.

- A brief review of available information on levels of mercury expected in site sediments/soils based on proximity to sources and existing analytical data.
- A determination if sampling for characterization of mercury concentrations and/or postrestoration monitoring is warranted.
- A plan for conducting the sampling, if characterization sampling is recommended.

In each of the project-specific methylmercury management plans developed under CM12, relevant findings and mercury control measures identified as part of TMDL Phase I control studies will be considered and integrated into restoration design and management plans. The Implementation Office, in conjunction with the Methylmercury TMDL program, will provide for a programmatic quality assurance/quality control (QA/QC) program that will specify sampling procedures, analytical methods, data review requirements, a QA/QC manager, and data management and reporting procedures. Each project-specific plan will be required to comply with these procedures to ensure consistency and a high level of data quality.

Because methylmercury is an area of active research in the Delta, each new project-specific methylmercury management plan will be updated based on the latest information about the role of mercury in Delta ecosystems or methods for its characterization or management. Results from monitoring of methylmercury in previous restoration projects will also be incorporated into subsequent project-specific methylmercury management plan. This program will be developed and implemented within the context of Methylmercury TMDL and Mercury Basin Plan Amendment requirements. CM12 will also be implemented to meet any requirements of the U.S. Environmental Protection Agency (EPA) or the California Department of Toxic Substances Control actions.

3.4.12.2.2 Timing and Phasing

The timing and phasing of implementing CM12 will be contingent upon the timing and phasing of individual restoration projects developed under the BDCP.

3.4.12.2.3 Minimization and Mitigation Measures

The purpose of CM12, the Methylmercury TMDL, and the Mercury Basin Plan Amendment is to coordinate research and inform future actions concerning mercury methylation and mitigation measures. In particular, the control studies conducted as part of the Methylmercury TMDL will include a description of mercury management practices identified in Phase I, an evaluation of the effectiveness, costs, potential environmental effects, and overall feasibility of the control actions. At this time, there is no proven method to mitigate methylation and mobilization of mercury into the aquatic system resulting from inundation of restoration areas. The mitigation measures described below are meant to provide a list of current research that has indicated potential to mitigate mercury methylation. This list will be updated as additional information is produced by the Phase I Methylmercury TMDL control studies and other related research.

Each project-specific methylmercury management plan will describe, at a minimum, the application or infeasibility of each of the mitigation measures described in detail in the following paragraphs. Thus, when considering implementing any mercury mitigation measure, the potential for nonbeneficial effects and interference with the overall objectives of the restoration project must be fully considered for each of the mitigation measures for each site individually. Wetland systems represent complex interactions among a multitude of physical and biological conditions that are in constant flux. CM12 is intended to evolve as it is informed by new research results over time that will inform selection and implementation of mitigation measures.

Characterize Soil Mercury

Mercury concentrations and distribution in soil will be characterized to inform restoration design, postrestoration monitoring, and adaptive management strategies. The amount of mercury that could be converted to methylmercury is directly related to the initial concentrations of mercury in restoration site sediments. Mercury is generally not homogenously distributed in alluvial sediments. Factors determining the distribution of mercury in an area include distance from source areas (tributaries carrying mercury from upland mining areas such as Cache Creek), sediment grain size (mercury preferentially adheres to fine-grained sediments in depositional areas), and distribution of channel versus overbank alluvial deposits. Sampling designs will account for these variables to assess mercury distribution throughout a restoration site. Outcomes of the characterization could include prerestoration site preparation and remediation, selection and design of appropriate mitigation measures, and design of postrestoration monitoring requirements.

Further mitigation measures and postconstruction monitoring will be mandatory if monitoring data show levels of methylmercury exceeding 0.06 nanogram per liter (unfiltered water sample), as developed by the Methylmercury TMDL.

Sequester Methylmercury Using Low-Intensity Chemical Dosing

Low-intensity chemical dosing (LICD) was developed as part of the U.S. Geological Survey (USGS) Subsidence Reversal and Carbon Capture Farming Program at a pilot restoration project on Twitchell Island. LICD has potential to provide the following benefits.

- Increased accretion in restored areas to counteract historical land subsidence in the Delta islands.
- Sequestration of carbon dioxide in wetland vegetation, mainly cattails (*Typha* spp.) and tules (*Scirpus californicus*).
- Sequestration of dissolved organic carbon in LICD floc.
- Sequestration of mercury in LICD floc.

The description of LICD presented here is primarily based on information provided by the EPA (Vendlinski pers. comm.).

Approach

The LICD process is based on the tendency of methylmercury to be chemically associated with dissolved organic carbon. The LICD process involves treating water with metal-based coagulants, such as iron sulfate or polyaluminum chloride, which bind with dissolved organic carbon and associated methylmercury, to form a floc that precipitates out of solution and is deposited. These coagulants are routinely used to remove dissolved organic carbon from drinking water. The LICD pilot program involves treating drainage waters from subsided peat islands with coagulants, then passing the coagulated water through wetland cells where the floc can settle out prior to the export of water to adjacent Delta channels.

The floc and the natural wetland vegetative matter rapidly accrete to raise the surface of the wetland, while also sequestering methylmercury and carbon. Laboratory studies indicate that up to 90% of the elemental mercury and 70% of the methylmercury can be removed from the water column using LICD process (Henneberry et al. 2011). Preliminary studies indicate that the floc formed by this process is stable under reducing conditions, and may even have capacity to sorb additional mercury in the system (Henneberry et al. in press). This initial research suggests that the methylmercury would not be remobilized after treatment.

In deeply subsided areas of the Delta, restoration to a more natural hydrology, and particularly a tidal regime, would require substantially increasing the ground surface elevation. Otherwise, the low-elevation, subsided areas would be subject to deep (up to 20 feet), permanent standing water when flooded. Field studies at Twitchell Island showed that cattails and tules accreted enough vegetative matter to increase land surface elevations by 2 to 4.5 centimeters per year, which is approximately 40 times the natural, historical accretion rate (Miller et al. 2011).

Uncertainties

As currently applied in pilot testing, LICD requires a treatment cell for sedimentation and retention of the floc. This design could preclude tidal systems, which require the natural ebb and flow of water. However, in the subsided islands of the Delta, a managed wetland with rapidly accreting organic material may be considered as in interim step to increase the elevation and thereby allow a tidal regime. This approach could supplement or replace mechanically filling the area with imported sediment to the required grade.

Additional field testing to evaluate the full efficacy of implementing the LICD process to address mercury methylation for ROAs will be necessary. Of particular interest are the effects of sequestering mercury in treatment cells, how that might affect the ecosystem and food chain within that area, and if the mercury could be remobilized. Because the process takes a load of mercury from an area of water and deposits it into the smaller area of the treatment cell, there is concern regarding accumulation of mercury in the accreting material. Researchers believe that because the dissolved organic carbon and methylmercury are precipitated together into the floc, the ratio of organic matter to mercury would not be changed, and thus on a per carbon basis the concentration of the methylmercury would also be unchanged. Furthermore, because of the added deposition of vegetative matter from wetland vegetation, the overall concentration of methylmercury could actually be reduced (Fleck pers. comm.). Additional studies are required to evaluate the concentrations of methylmercury in the treatment cell and to determine if it is permanently sequestered or if it could be remobilized. This work will be supported as a research action, and the results will be used to inform possible integration of LICD into restoration projects conducted under *CM4 Tidal Natural Communities Restoration*.

Minimize Microbial Methylation

Conversion of mercury to methylmercury depends on microbial activity in an anoxic environment. By reducing the amount of organic material at a restoration site, aerobic degradation is limited and anoxic conditions are less likely to result. Thus, conditions are not conducive for sulfate-reducing bacteria and associated methylation.

Recent research in the Yolo Bypass has demonstrated that methylmercury levels could be reduced by up to an order of magnitude by using livestock grazing to reduce loads of organic matter prior to flooding (Heim et al. in press). It should be noted that this is not appropriate for all, or probably many, restoration areas, but is an area of research that addresses mercury methylation, and should at least be considered. The mechanism involves the removal of organics through livestock grazing, resulting in less likelihood of anoxic conditions conducive to mercury methylation. Wetlands are complex systems that have evolved under anaerobic conditions and have developed communities of organizations that thrive under these conditions. For each area where removal of organic matter is considered, site-specific conditions and restoration objectives will be carefully evaluated to determine if the measure is appropriate and how it should be implemented.

Other possible restoration design approaches that would minimize mercury methylation include avoidance of drying-out periods (not applicable to tidal restoration projects) and measures that increase water column oxygenation. Restoration sites that include shallow ponded areas with extensive open expanses to promote frequent wind-driven oxygenation (e.g., high wind fetch) would minimize methylation. Removal of submerged macrophytes would also promote mixing and aeration throughout the water column. Ponds deep enough to discourage overgrowth by rooted macrophytes yet shallow enough to promote wind mixing and to allow significant light exposure to the mixed water column, which also promotes photodegradation (see below), would likely minimize mercury methylation.

Design to Enhance Photodegradation

Photodegradation has been identified as an important factor that removes methylmercury from the Delta ecosystem by converting methylmercury to the biologically unavailable, inorganic (nonmethylated) form of mercury. Photodegradation of methylmercury occurs in the photic zone of the water column (the depth of water within which natural light penetrates). At the 1% light level, the mean depth for the photic zone in the Delta was calculated to be 2.6 meters, with measured depths ranging from 1.9 meters to 3.6 meters (Gill 2008; Byington 2007). Gill and Byington also conclude that photodegradation may be most active within the top half-meter of the water column in the Delta. Gill (2008) identified photodegradation of methylmercury as potentially the most effective mercury detoxification mechanism in the Delta. In the methylmercury budgets developed by Wood et al. (2010), Foe et al. (2008), Byington (2007), and Stephenson et al. (2007), photodegradation rates of methylmercury exceed methylmercury production rates from sediment.

Once photodegraded, mercury will either be volatilized to the air (Amyot et al. 1994), hydrologically transported, or stored in sediments where it could become available for methylation once again. Once methylated, mercury would again be biologically available.

To maximize photodegradation rates, restoration sites would be maintained for as long as feasible at depths that do not exceed the photic zone.

Remediate Sulfur-Rich Sediments with Iron

Mercury is methylated by sulfate-reducing bacteria that live in anoxic conditions found in tidal marsh restoration areas. Adding iron can reduce the activity of sulfide, thereby reducing mercury methylation. Ferrous iron in sediment pore water can decrease the concentration of dissolved sulfide through the formation of iron sulfide and other minerals. Because iron sulfide is the strongest ligand for oxidized mercury under anoxic conditions, the decrease in sulfide activity should result in a decrease in the concentration of soluble inorganic mercury that is available for methylation and, ultimately, for bioaccumulation. Research in laboratories has demonstrated that the addition of ferrous iron to pure cultures of sulfate-reducing bacteria in an anoxic system decreased net mercury methylation by approximately 75% (Ulrich 2011). Iron remediation to reduce methylation will have to be evaluated on a site-by-site basis. The evaluation will consider species-specific and community effects, fate and transport of the chemicals prior to implementation, and the cost/benefit of the remediation.

Cap Mercury-Laden Sediments

Some restoration areas may require application of fill to raise grades to design elevations. At sites where this measure is implemented, mercury-containing sediments will be covered and will not be in contact with the water column. This will limit methylmercury flux into the water column and exposure to biota. Depending on the depth of the added sediment layer, bioturbation, which mixes surface and near surface sediments, could bring the mercury back up near the sediment/water interface, limiting the effectiveness of this approach. Baseline characterization of mercury in sediments and postrestoration monitoring within the framework of an adaptive management program will be integrated into this measure.

3.4.12.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will be performed as required in specific project plans and permitting documents for each restoration action where methylation of mercury is identified as a concern. Compliance monitoring will document completion and implementation of site-specific methylmercury management plans for restoration sites as well as compliance with expected Delta Methylmercury TMDL conditions, as identified in Table 3.4.12-1. Monitoring needs associated with implementation of avoidance and minimization measures may be required for each component project; see *CM22 Avoidance and Minimization Measures* and Appendix 3.C, *Avoidance and Minimization Measures*, for details of how these measures would be implemented and what types of monitoring are required.

Table 3.4.12-1. Effectiveness Monitoring Relevant to CM12

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM12-1	Methylmercury	Methylmercury allocations per the Delta Mercury Control Program	Adhere to the numeric targets selected for the load allocation of methylmercury per Resolution No. R5-2010-0043 of the Delta Mercury Control Program.[a]	Monitor methylmercury discharge from wetlands and other aquatic habitats restored as part of BDCP for the permit term.

[a] Per Resolution No. R5-2010-0043, current allocations of methylmercury for restored wetlands vary depending on Delta subarea, from 0.061 gram per year in the Marsh Creek subarea to 2010 grams per year in the Central Delta subarea.

Monitoring will account for the complexities of the system to ensure that measures implemented at the project scale through CM12 do not conflict with goals for restoration site ecological function. As previously discussed, wetlands are complex systems that often develop as carbon-rich environments with anoxic sediments under reducing conditions; these conditions also promote methylation of mercury. Mitigation measures that alter these biogeochemical factors could also affect the site ecological functions. For instance, research described in Appendix 5.D, *Contaminants*, indicates that characterizing methylmercury concentrations in an aquatic system must account for cycling through sediment, the water column, and biota. Monitoring programs will take the complex biogeochemistry of mercury and methylmercury into account.

Table 3.4.12-2 lists key uncertainties and research actions relevant to CM12.

Table 3.4.12-2. Key Uncertainties and Potential Research Actions Relevant to CM12

Key Uncertainty	Potential Research Actions
How effectively does CM12 minimize production and mobilization of methylmercury from lands in the reserve system and the foodweb?	• Evaluate this question at selected restoration sites. • Evaluate wetland management strategies intended to minimize methylation. • Evaluate the ecological fate of wetland-generated methylmercury. • Evaluate the biological thresholds for mercury exposure for covered species to guide methylmercury objectives and Delta wetland management priorities. • Evaluate Plan Area–wide effectiveness of CM12 site screening
Do measures implemented under CM12 to minimize microbial methylation of mercury interfere with the potential of a restoration project to meet its intended purpose?	• Comparatively evaluate conservation sites in different types of wetland natural communities.

3.4.12.4 Consistency with the Biological Goals and Objectives

CM12 will advance the biological goals and objectives as identified in Table 3.4.12-3. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.12-3. Biological Goals and Objectives Addressed by CM12

Biological Goal or Objective	How CM12 Advances a Biological Objective
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.	
Objective L2.4: Support improved ecosystem function in aquatic natural communities by implementing actions to improve water quality, including reducing dissolved oxygen impairments in the Stockton Deep Water Ship Channel, reducing pollutant loading by urban stormwater, and minimizing mobilization of methylmercury from lands in the reserve system.	Screening restoration sites to reduce risk of selecting sites with high mercury levels and use of techniques that reduce methylmercury production from restored sites will reduce the risk of methylmercury entering sediments, water column, or foodweb.
Goal SAST1: Improved habitat and restored linkages to enhance survival, reproduction, and distribution of Sacramento splittail in the Plan Area.	
Objective SAST1.1: Improve splittail abundance.[a]	Screening restoration sites to reduce risk of selecting sites with high mercury levels and use of techniques that reduce methylmercury production from restored sites are expected to contribute to habitat suitability of restored wetlands and floodplains for rearing and spawning, and to reduce the overall exposure of splittail eggs, juveniles, and adults to methylmercury, contributing to improved fish survival and health.

Biological Goal or Objective	How CM12 Advances a Biological Objective
Goal GRST3: Increased spatial distribution of young-of-the-year (YOY) and juvenile white sturgeon in the Bay-Delta compared to existing condition SWP/CVP regulatory requirements.	
Objective GRST3.1: Improve water quality and physical habitat.[a]	Juvenile and subadult sturgeon spend considerable time in the Delta and would be more susceptible to methylmercury bioaccumulation compared to less long-lived fishes. Screening restoration sites to reduce risk of selecting sites with high mercury levels and use of techniques that reduce methylmercury production from restored sites are expected to reduce the risk and magnitude of methylmercury bioaccumulation, contributing to improved sturgeon survival and health.
Goal WTST3: Increased spatial distribution of young-of-the-year (YOY) and juvenile white sturgeon in the Bay-Delta compared to existing condition SWP/CVP regulatory requirements.	
Objective WTST3.1: Improve water quality and physical habitat.[a]	Juvenile and subadult sturgeon spend considerable time in the Delta and would be more susceptible to methylmercury bioaccumulation compared to less long-lived fishes. Screening restoration sites to reduce risk of selecting sites with high mercury levels and use of techniques that reduce methylmercury production from restored sites are expected to reduce the risk and magnitude of methylmercury bioaccumulation, contributing to improved sturgeon survival and health.
[a] Summarized objective statement; full text presented in Table 3.3-1.	

3.4.13 Conservation Measure 13 Invasive Aquatic Vegetation Control

Under *CM13 Invasive Aquatic Vegetation Control*, the Implementation Office will take actions to prevent the introduction and control the spread of invasive aquatic vegetation (IAV) in aquatic restoration areas. This will support attainment of biological goals addressing the need for a mosaic of natural communities with ecological processes and conditions that sustain those communities. It will also support biological goals addressing maintenance of the tidal perennial aquatic natural community, minimizing predation on covered fish species, and supporting appropriate habitat and adequate food resources for covered fish species. Support for the biological goals and objectives is further detailed below in Section 3.4.13.4, *Consistency with the Biological Goals and Objectives.*

IAV includes both SAV and FAV[41]. IAV impairs covered fish habitat via several mechanisms (discussed in 3.4.13.1, *Problem Statement*).

- Alters habitat by reducing water flow, thereby decreasing turbidity.
- Provides suitable habitat for predatory fish that prey on covered fish species.
- In conjunction with predatory centrachid fishes, physically impairs access and displaces native fish from shallow-water habitats.
- Alters physical and chemical habitat attributes such as light penetration, DO, pH, and nutrient concentrations.

[41] Invasive wetland plants, such as giant reed (*Arundo donax*) and red sesbania (*Sesbania punicea*), that alter riparian natural community conditions in ways that also may negatively affect covered fish species, are addressed under *CM11 Natural Communities Enhancement and Management.*

- Displaces native plants that would otherwise create physical structure and a biological environment that supports native and nonnative fish species (e.g., aquatic habitat dominated by native plants instead of IAV would enhance the diversity of native invertebrates that provide a forage base for native and nonnative fish).

CM13 provides for the control of Brazilian waterweed (*Egeria densa*), water hyacinth (*Eichhornia crassipes*), and other-IAV throughout the Plan Area, with implementation focusing first on areas where IAV has the greatest potential to impair habitat for covered species, including in ROAs. *Egeria* is now the most extensive and problematic IAV species in the delta, but the historical record shows a substantial risk that other IAV species may be introduced or that existing IAV species may become more prominent. To address this, the BDCP will implement an early detection and rapid response program to detect, evaluate, and eradicate or control early invasions of other IAV species. In addition, CM20 *Recreational Users Invasive Species Program* discusses how watercraft inspections and public education and outreach will aim to prevent the introduction of new IAV and reduce the spread of existing IAV via recreational watercraft, trailers, and other recreational equipment.

Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM13 on covered species will be avoided or minimized. Refer to Appendix 5.F, *Biological Stressors on Covered Fish* (Section 5.F.3.4, *Invasive Aquatic Vegetation*), for a discussion of the effects of CM13 on covered species, other aquatic life, and natural communities.

3.4.13.1 Problem Statement

IAV is a widespread problem in the Delta and has multiple adverse effects on the ecosystem. *Egeria* is currently the dominant IAV species, and water hyacinth has been a major issue in the recent past; however, other IAV species also may pose a threat to water quality, and native fish sustainability. For further descriptions of the ecological issues surrounding and current condition of IAV in the Plan Area, see Appendix 5.F, *Biological Stressors on Covered Fish* (Section 5.F.3.4, *Invasive Aquatic Vegetation*).

Restoration of aquatic habitats at some sites, as proposed under *CM4 Tidal Natural Communities Restoration*, will create conditions suitable for IAV (i.e., shallow, slow-moving water). All tidal marsh channels in the Delta already contain IAV. Most IAV spread readily from fragments that can colonize and grow rapidly in shallow water. Creating suitable conditions that promote the increase and spread of IAV is a major concern as it is likely that existing IAV will spread to these new restoration areas, especially IAV species that are abundant throughout the Delta and within and adjacent to ROAs, such as *Egeria* (Figures 3.4-23 through 3.4-27).

IAV causes the following problems that affect water quality, ecosystem function, and aquatic life at all trophic levels.

- Alters habitat by reducing water flow velocity, thereby decreasing turbidity.
  - Dense stands of SAV and mats of FAV reduce local flow velocities and result in a localized reduction in turbidity levels (Brown and Michniuk 2007; Hestir et al. 2010).
  - High turbidity, which is a natural condition in the Delta, is hypothesized to facilitate predator avoidance by delta smelt and longfin smelt (Interagency Ecological Program 2008a; Anderson 2008). Conversely, reduced turbidity allows increased hunting efficiency by nonnative predatory fish that prey on covered fish species (Nobriga et al. 2005; Gregory

and Levings 1998; Huenemann et al. 2012). Thus, IAV control has the potential to increase localized turbidity and reduce predation pressure on covered fish species that use the affected areas.

- Reduced turbidity reduces the foraging ability of larval delta smelt, although it is uncertain whether this depends on concentration of suspended sediment or suspended algae (Baskerville-Bridges et al. 2004). This may also be true for longfin smelt (Rosenfield 2010). Restoration of natural turbidity levels in restored areas by controlling IAV may increase the feeding success of individuals within areas with higher comparative turbidity.

- Provides suitable habitat for predatory fish that prey on covered fish.

Invasive SAV is spread across large portions of the Delta in or adjacent to significant migration corridors and pelagic and subtidal open-water habitat for covered species (Figure 3.4-28), where it provides suitable habitat for nonnative predatory fish (Brown 2003; Nobriga et al. 2005). Juvenile and adult striped bass and largemouth bass forage at the edges of IAV stands where current breaks occur and smaller fishes congregate. In doing so, they may incidentally take covered fish species (Stevens 1966; Temple et al. 1998; Nobriga and Feyrer 2007, 2008); although trawl surveys used to target delta smelt and longfin smelt are typically done in offshore habitats away from nearshore vegetated areas, because delta smelt and longfin smelt are not usually found in these habitats (e.g., Nobriga and Cadrett 2001; Feyrer et al. 2007; Rosenfield and Baxter 2007). Largemouth bass, a very effective nearshore predator, has increased in abundance and size in the Delta and is strongly associated with dense IAV stands (Nobriga and Feyrer 2007; Conrad et al. 2010). Thus, controlling IAV is expected to help reduce suitable habitat for nonnative predatory fish, which is expected to have a subsequent reduction on predation mortality of juvenile salmon, steelhead, and splittail. However, there are no experimental or observational data from the Delta comparing predation on covered fish before and after IAV treatment.

- Physically impairs access and displaces native fish from shallow-water habitats.

Dense patches of IAV physically impair access to habitat by native fish, including covered fish species (National Marine Fisheries Service 2007; Interagency Ecological Program 2008a), by creating an impenetrable wall of dense vegetation in the water column. Control of IAV may provide increased access to rearing habitat for juvenile salmon (all races, but primarily fall-run and winter-run Chinook salmon), steelhead (to some extent), and splittail (Anderson 2008).

- Alters physical and chemical habitat attributes such as light penetration, DO, pH, and nutrient concentrations.
    - Shading by IAV (both SAV and FAV) may limit light availability for phytoplankton growth although to what extent this mechanism may be taking place has not been studied in the Delta. Other mechanisms such as nutrients, hydraulic residence time, and consumptive clams have been shown to be important. Thus, IAV control may contribute to increased phytoplankton productivity, which would locally support an increase in food availability for the prey of covered fish species to the extent that they are found within the specific habitat, or that food is exported from that habitat to the greater Delta.
    - Dense SAV beds can deplete DO to levels not conducive to fish survival (Toft 2000).

- Displaces native plants that would otherwise create physical structure and a biological environment may support a more diverse assemblage of native invertebrates that in turn are preferred as food sources by covered and other native and nonnative fish species (Toft et al. 2003).

Dense IAV stands have low plant diversity—*Egeria* is by far the dominant species of invasive SAV (Santos et al. 2009). Control of IAV may allow more diverse communities of native aquatic plants to develop. Research on water hyacinth in the Delta found that native FAV species may support a higher proportion of native invertebrates that are favored prey for native and nonnative fish species (Toft et al. 2003). Thus, control of IAV may encourage native aquatic plant growth that supports a diverse invertebrate community dominated by native species, potentially affecting food supply and quality for organisms higher up the foodweb, such as covered fish species.

3.4.13.1.1 Invasive Aquatic Vegetation in the Delta

IAV has colonized large areas of the Delta, displacing native aquatic plants (Brown 2003; California Department of Fish and Game 2008b; Ustin 2008). Two species of IAV, *Egeria* and water hyacinth, have been most problematic and have been the focus of extensive research and control efforts. Each of these species is described below.

Egeria

Egeria is a perennial aquatic plant that grows rooted in sediment in shallow, freshwater areas of the Delta, and forms very dense beds; it can also be found as free-floating fragments. *Egeria* produces numerous frequently-branched stems up to 15 feet long that form very dense stands. The climate and temperature conditions in the Delta are ideal for year-round growth of *Egeria* (Pennington and Sytsma 2009). Reproduction in the Delta is solely by vegetative fragmentation; only male plants are present in the United States, so no seed is produced. Under optimum growing conditions, the biomass of *Egeria* can double in 12 days (Pistori et al. 2004), making this species one of the fastest-growing aquatic plants. *Egeria* grows very rapidly under favorable conditions such as in the shallow-water areas of the Delta. Of 55,000 acres of the Delta surveyed in 2007, SAV dominated by *Egeria* was estimated to cover between 5,500 and 10,000 acres (10 to 18%) (Ustin 2008). Soon after, total coverage by submersed plants was much higher—61% in summer 2007 and 37% in summer 2008 (Santos et al. 2011); most of this was *Egeria*.

Egeria forms single-species stands and is by far the dominant species in mixed-SAV stands (Santos et al. 2011) These stands frequently contain smaller proportions of three other nonnative SAV species that are invasive or have the potential to become invasive: curlyleaf pondweed (*Potamogeton crispus*), Eurasian watermilfoil (*Myriophyllum spicatum*), and Carolina fanwort (*Cabomba caroliniana*) (Ustin 2008; Santos et al. 2011). Native SAV species, such as hornwort (*Ceratophyllum demersum*), may occur in dense SAV, but typically in very small amounts (Santos et al. 2011).

Water Hyacinth

Water hyacinth is a perennial aquatic floating plant that inhabits calm Delta channels, sloughs, backwaters, and other areas with low flow velocities. Water hyacinth produces thick, extensive mats on the water surface and can root in muddy soils near the edge of water bodies. Reproduction occurs by both vegetative fragmentation and seed production (Godfrey 2000). Water hyacinth proliferates during the warmer summer months and dies back during the winter. Introduced into the Delta over 100 years ago, severe infestations were present by the 1980s, when it became the dominant component of FAV in many areas of the Delta. As with SAV, FAV may contain a mixture of other nonnative and potentially invasive plants, such as water primrose (*Ludwigia* spp.) as well as native species such as water pennywort (*Hydrocotyle ranunculoides*).

Other IAV Species

Some IAV species that threaten the Delta ecosystem have recently appeared in the Delta or are present in tributary watersheds of the Delta but have not yet reached Delta waters. One IAV species of high concern is hydrilla (*Hydrilla verticillata*), a nonnative SAV species that is aggressively invasive. Limited infestations of hydrilla have been found in scattered locations across the state, including Clear Lake in Lake County. Due to its invasion history in other states and potential threat to California ecosystems, the California Department of Food and Agriculture (CDFA) was mandated by the California Legislature in the late 1970s to conduct early detection surveys for hydrilla statewide and eradicate it wherever found (Akers 2010). CDFA actively performs early detection surveys in the Delta to ensure hydrilla is found immediately should it ever reach the Delta.

A very recent invader to the Delta, South American spongeplant (*Limnobium laevigata*) is also of high concern. First recorded in California in 1996, this species was detected in the Delta in 2007 and again in 2009 and 2010 (California Department of Food and Agriculture 2011). It is considered to be a potentially greater threat to California ecosystems than water hyacinth (Anderson and Akers 2011) as it has a high growth rate, appears to withstand frost, spreads rapidly, and has smaller individual plants than water hyacinth, allowing it to be more easily transported by water currents and birds. Additionally, it produces abundant small seeds that can remain dormant in sediment for many years. Necessary management actions include vigilance and early eradication before the plant becomes established (Akers 2010; Anderson and Akers 2011). This species is considered sufficiently threatening that initial responsibility for its control was given to CDFA's Hydrilla Program, which is aggressively targeting new infestations for eradication efforts (Akers 2010). South American spongeplant is now widely considered to present a serious threat to the Delta's ecosystems and navigation. Assembly Bill (AB) 1540, enrolled August 27, 2012, amended Section 64 of the Harbors and Navigation Code to add South American spongeplant to the list of aquatic weeds to be controlled under the California Department of Boating and Waterways (DBW) Aquatic Weed Control Program, which currently controls *Egeria* and water hyacinth in the Delta, its tributaries, and Suisan Marsh. AB 1540 provides for the early control and possible eradication of South American spongeplant in the Delta watershed, which will prevent spongeplant from proliferating and spreading throughout the Delta like *Egeria* and water hyacinth, and reduce long-term control costs.

3.4.13.1.2 State Control Programs

Under the Aquatic Weed Control Program, DBW is the lead state agency responsible for the control of *Egeria* and water hyacinth, and more recently South American spongeplant, in the Delta, its tributaries, and Suisan Marsh. The Water Hyacinth Control Program (WHCP) was initiated in 1983 per Senate Bill 1344, enrolled in 1982, which designated DBW as the lead agency in cooperating with other agencies to control water hyacinth in the Delta. DBW has been effective in reducing water hyacinth in Delta waterways by using primarily chemical and limited mechanical treatment methods. AB 2193, enrolled in 1996, designated DBW as the lead agency in cooperating with other agencies in controlling *Egeria*, in addition to water hyacinth, in the Delta, its tributaries, and Suisun Marsh. DBW implemented the Egeria Densa Control Program (EDCP) in 2001. Efforts of DBW under the EDCP were initially focused in a number of locations where *Egeria* impeded navigation. Finding that mechanical control was ineffective—or, worse, contributed to the spread of *Egeria* by fragmenting the plants—the EDCP tested a range of chemical control techniques. DBW also conducted an extensive suite of toxicology and water quality tests and sampling that were required by the terms of the program's National Pollution Discharge Elimination System (NPDES) permit and under BiOps for program activities issued by USFWS and NMFS (California Department of Boating and Waterways 2008). In 2006, DBW concluded that, while its current scale of control efforts was locally effective at specific sites, it was not effective at stopping the expansion of *Egeria* in the Delta. Effective control was hampered by permit restrictions that did not allow treatment early in the growing season when it would be most effective. DBW proposed expanding the treatment area to sites across most of the legal Delta between 2006 and 2010 and concentrating on Franks Tract between 2006 and 2008 (California Department of Boating and Waterways 2006). In 2006, permit restrictions were relaxed and early-season control treatments were applied, and in 2007 and 2008, treatments were applied on substantially larger areas at Franks Tract, resulting in highly successful reduction of *Egeria* by 2007 (Santos et al. 2009). CM13 builds upon these successful large-scale treatments in the Delta.

3.4.13.2 Implementation

3.4.13.2.1 Control Actions

The Implementation Office will apply existing control methods tested and developed by the DBW EDCP and WHCP to control *Egeria*, water hyacinth, and other IAV throughout the Delta. The primary control methods employed will be the application of herbicides specifically targeting intended species and site conditions. In addition, limited mechanical removal to control water hyacinth will be conducted. Other methods of removal could be implemented as dictated by site-specific conditions, current research, and intended outcome.

Initial implementation actions are expected to begin in year 2. In addition, ongoing research will investigate potential biological control methods for *Egeria* and water hyacinth. This could minimize or avoid the need for use of herbicides. Recognizing the potential threat of other IAV species, the Implementation Office will implement an early detection and rapid response program to detect, evaluate, and treat early invasions of other IAV species.

The Implementation Office will partner with existing programs operating in the Delta (including DBW, U.S. Department of Agriculture–Agriculture Research Service [USDA-ARS], University of California Cooperative Extension Weed Research and Information Center, CDFA, local Weed Management Areas, Resource Conservation Districts, and the California Invasive Plant Council [Cal-IPC]) to perform risk assessment and subsequent prioritization of treatment areas to strategically and effectively reduce expansion of the multiple species of IAV in the Delta. This risk assessment will dictate where initial control efforts will occur to maximize the effectiveness of CM13.

3.4.13.2.2 Siting and Design Considerations for Tidal Natural Communities Restoration

The Implementation Office will ensure that tidal natural communities restoration sites are designed to minimize the risk of IAV establishment and propagation. The salinity within brackish tidal marsh areas is high enough to prevent major infestation of *Egeria* and water hyacinth. Design measures that would exclude major IAV infestations in freshwater tidal marsh areas include manipulating water flow velocity, water depth, and providing a geomorphic setting in which small tidal channels can change course via lateral channel migration. If IAV does invade and colonize restoration sites, additional control measures, as described above, may be necessary to protect restored aquatic habitat and maintain benefits for covered fish and other native aquatic organisms. In addition, the Implementation Office will work with DBW to prioritize control of established *Egeria* and water hyacinth source populations that are hydrodynamically connected to restoration sites in a way that could facilitate the spread of propagules from the source population to these sites.

Little direct research has been conducted into how to design restoration sites in the Delta to reduce the risk of invasion and colonization by IAV; however, recent research projects are providing useful insights into how flow velocity and salinity can be manipulated to reduce invasion risk. Flow velocity has a major influence on distribution, establishment, and growth of IAV in the Delta. IAV grows in low flow-velocity sites—channel margins, shallow basins, and slow-moving channels—and is absent from high flow-velocity areas. High water velocity inhibits invasive SAV growth by physically washing plants out of the sediment, and perhaps also by scouring out the fine sediments in which invasive SAV roots. A recent study found that annual maximum water velocity was the most important factor in determining the presence of SAV and, specifically, that values above 0.49 meter per second appeared to limit *Egeria* presence (Hestir et al. 2010). Similarly, FAV is dispersed by surface currents driven by tidal currents and prevailing winds.

Under *CM4 Tidal Natural Communities Restoration*, marsh channels and levee breaches will be designed to maintain flow velocities that minimize conditions favorable to IAV establishment to the extent that it does not lower production of food from the site. In addition, restoration will be designed, within restoration site constraints, to produce sinuous, high-density, dendritic networks of tidal channels that promote effective tidal exchange. Effective tidal exchange may help to achieve flow velocities that inhibit colonization by IAV, but systems that include dendritic channels have been invaded within the Delta by IAV. Channel orientation and shape will be designed to work with the prevailing wind direction to reduce or eliminate the risk that IAV fragments could disperse into the restoration sites.

Recent surveys have found extensive stands of two native species, sago pondweed (*Stuckenia pectinata*) and fineleaf pondweed (*S. filiformis*), in the shallow subtidal zone in Suisun Bay and the West Delta (Boyer 2012). Current research is investigating abiotic factors that affect the growth and distribution of native pondweeds. Still in the early stages, the research suggests the potential for manipulating salinity regimes to enhance conditions for native SAV while reducing suitability for IAV that is obligate to freshwater (Boyer 2010; Boyer 2012; Rubissow Okamoto 2012). Salinity manipulation could be achieved by designing channel shape and connectivity to influence flow regime in ROAs that contain brackish marshes.

Should IAV colonize and impair the functioning of a restoration area, control may be required depending on whether the area is then colonized by nonnative centrarchid fishes. An example of a design feature to facilitate IAV control is incorporating sites where temporary barriers could be installed to isolate portions of restoration area channels for a duration sufficient to allow the long contact time required by Fluridone (6 to 8 weeks), currently, the most effective herbicide used on *Egeria* in the Delta (California Department of Boating and Waterways 2006).

3.4.13.2.3 Methods and Techniques

The following general methods and techniques will be used in implementing CM13. All are required for a successful invasive plant control program.

- Application of IAV control methods, primarily chemical treatment, but also mechanical or biological control where appropriate.
- Threat assessment.
- Early detection and rapid response.
- Education and outreach (*CM20 Recreational Users Invasive Species Program*).

Additional components of the IAV control program—monitoring of treatment efficacy and research and development of new control methods—are discussed in Section 3.4.13.3, *Adaptive Management and Monitoring*.

Eradication or Control?

Eradication is defined as the complete removal of a species from the ecosystem. Eradication is an appropriate goal for the early invasive stages of species determined to pose a high risk, such as hydrilla in California and perhaps South American spongeplant in the Delta. Control is defined as the minimization or localized removal of a species from the ecosystem. Control is an appropriate goal for widespread and well-established invasive plant species, such as *Egeria* and water hyacinth in the Delta. To be optimally effective, control must be implemented in an adaptive management context.

The primary goal of CM13 is aggressive control, not eradication, of IAV in the Plan Area, because eradication of the major widespread IAV species in the Delta is not currently considered feasible. CM13 is intended to substantially reduce the IAV area and biomass to the level where it no longer causes substantial, ecosystem-scale adverse effects on water quality, aquatic habitats, covered fish, and other native fish and wildlife. However, eradication may be implemented where appropriate. The decision process will be informed by implementation of a risk assessment protocol and would be based on a site-by-site evaluation of density, proximity, and extent, among other factors, by biologists familiar with the Delta ecosystem, local hydrological regime, and the ecology of the species. Eradication would be considered appropriate if, for example, hydrilla were detected. Eradication may also be found appropriate for the early invasive phase of other IAV species, for example, South American spongeplant.

Control Methods

Chemical Control

Chemical control—application of herbicide—is the most feasible and effective control method. Herbicides can be used to rapidly control IAV over large areas (hundreds or thousands of acres at a time) and for extensive infestations. The major concern with the use of herbicides over large areas is the potential for toxic effects on other aquatic plants and animals and on riparian plants adjacent to treated water bodies.

As the lead agency for IAV control in the Delta, DBW has been using herbicide treatments to control *Egeria* since 2001 and water hyacinth since 1983, and has researched several different herbicides, adjuvants, and application protocols. All chemicals used were approved and labeled for aquatic use by the EPA. The herbicides studied and used were 2,4-D, glyphosate, diquat, and fluridone, and the adjuvant Agri-dex. In addition, experiments were conducted with the copper-containing herbicide Komeen, but it was not used in the control programs. DBW was required to review and summarize the results of toxicology studies on phytoplankton and zooplankton for each herbicide proposed for use in the program to meet the requirements of the CEQA, the NMFS BiOp, and its NPDES permit (see *Permit Conditions and Requirements: Avoidance and Minimization Measures*, below). In addition, DBW undertook and funded research on potential toxic effects of herbicide treatment. During and after herbicide treatments, DBW conducted extensive water quality testing to monitor herbicide concentrations at and downstream of the treatment sites for residue and toxicity. DBW also was required to comply with all restrictions on timing, application methods, and concentrations required to avoid or minimize potential adverse effects on aquatic life, including phytoplankton and zooplankton. Research and monitoring results are summarized in the second addendum to the program's environmental impact report (EIR) (California Department of Boating and Waterways 2006).

Based on DBW's research and field testing and observations, Fluridone is currently considered the most effective treatment for *Egeria* in the Delta. Fluridone is a systemic herbicide that produces its toxic effect in plants by inhibiting synthesis of carotenes. It is slow-acting, requiring a residence time of 6 to 8 weeks to be effective. Where flow rates do not allow long enough contact, multiple applications are made. The concentration range of Fluridone used in the EDCP is 10 to 20 parts per billion, which is at the low end of the labeled application rates.

Mechanical Control

Mechanical treatment of IAV involves removal from the water by hand or machine and disposal on land. Both hand and machine removal can be relatively successful at small scales. For example, physical removal has been successful in reducing or eliminating South American spongeplant in the early stages of infestation (Anderson and Akers 2011). Removal of small infestations of water hyacinth in the Delta has been achieved by "herding," in which small rafts of water hyacinth are pushed into a flowing channel to be washed downstream into saline water where they die (California Department of Boating and Waterways 2006).

Removal and disposal of large amounts of IAV become very problematic, because transportation is costly and suitable terrestrial disposal sites nearby are difficult to find. For *Egeria* and most other IAV species, mechanical removal fragments the plants, and the small fragments disperse and readily multiply as new plants, often worsening the infestation.

Biological Control

Biological control involves releasing organisms, typically invertebrates or pathogens that are specific to the target invasive species, into the environment where they will establish and prey upon the target species with the aim of reducing the population. Generally, the biological control agent does not eradicate the target species, but reaches an equilibrium where the target species persists at a low population level.

Biological control has been successful against water hyacinth, particularly in the southeast United States (Center et al. 2002). The CDFA released weevils (*Neochetina eichhorniae* and *N. bruchi*) and a moth (*Sameodes albiguttalis*) that eat water hyacinth at selected sites in the Delta. Only *N. eichhorniae* established but survived at densities too low to affect water hyacinth, in part, because of cool winter temperatures (California Department of Boating and Waterways 2003). Pathogens may have infected the weevils, but additional studies are needed to investigate this possibility. DBW recently began releasing the water hyacinth water hopper (*Megamelus scutellaris*) at three sites in the Delta (California Department of Food and Agriculture 2011).

A fungus, *Fusarium* sp., isolated from *Egeria* in its native range has shown promise in laboratory experiments but has not yet been tested under field conditions. USDA-ARS is currently evaluating the potential of leaf–mining flies (*Hydrellia* spp.) as a biological control agent for *Egeria* in the Delta (Cabrero Walsh et al. in press). One species of *Hydrellia* has shown some potential against hydrilla under laboratory and controlled field conditions.

One of the risks associated with biological control is that the organism may attack closely related native species. The water hyacinth–eating weevils prey on all members of the pickerelweed family (Pontederiaceae). Only one species of the family in California is native, the grassleaf mudplantain (*Heteranthera dubia*), which does not occur in the Delta—the closest known occurrence is in Colusa County (Calflora 2012).

Before release of a potential biocontrol organism in California, extensive evaluation is undertaken by the CDFA's Biological Control Program, which is a component of the Plant Health and Pest Prevention Service's Pest Prevention Program. The evaluation process involve determining the host-specificity to assess risk to nontarget species; domestic quarantine if approved for import into California under state and federal regulation; small-scale field testing to determine effectiveness against the target species; and additional evaluation of risks to nontarget species and the environment. Once released, long-term monitoring and evaluation continue to assess efficacy and risk to nontarget organisms.

Scale of Control Treatment

To control *Egeria*, the Implementation Office will fund treatment of between approximately 1,700 acres per year (low estimate) and 3,300 acres per year (high estimate). (See Chapter 8, Section 8.3.13, *CM13 Invasive Aquatic Vegetation Control*, for a discussion of these estimates). These figures are similar to the amount of *Egeria* treated by the DBW in 2007 and 2008 at Franks Tract. Comparison of the proposed treatment acreage with the estimated total acreage of *Egeria* across the Delta and results of DBW's large-scale *Egeria* control efforts at Franks Tract provide useful insight into the feasibility of this scale of treatment and the projected outcome in terms of the overall reduction in *Egeria* extent throughout the Delta.

In 2006, DBW estimated that *Egeria* occupied 11,500 to 14,000 acres in the Delta and was spreading at a rate of 10 to 20% per year (California Department of Boating and Waterways 2006). More recent measurements (2007), based on aerial imagery analysis, estimate *Egeria* occupied approximately 10,000 acres (Ustin 2008).The DBW (2006) and Ustin (2008) estimates of overall rate of increase were similar.

Prior to 2007, the EDCP treated 500 acres or less of *Egeria* with herbicide annually, and the acreage of *Egeria* continued to increase. However, in 2007 and 2008, the treatment of over 3,000 acres per year in Franks Tract produced significant results. *Egeria* cover was reduced by 1,500 acres (47%) in 2007 (Ustin 2008; Santos et al. 2009), and *Egeria* biovolume was significantly reduced (Ruch and California Department of Boating and Waterways 2006). Additional treatment in 2008 yielded a further 50% reduction (Santos et al. 2009). Similar results were achieved at Fourteenmile Slough, a smaller site (Santos et al. 2009). These results demonstrate that successful treatment of the order of a thousand acres annually can be achieved in the Delta.

Under CM13, the low estimate (1,700 acres per year) for proposed treatment is equivalent to approximately 12 to 15% of the total estimated area of *Egeria* in the Delta, and the high estimate (3,300 acres per year) is equivalent to approximately 24 to 29%. Projected changes in total acreage of *Egeria* Delta-wide (Figure 3.4-29) for the low and high treatment amounts assume a 10 and 20% annual increase in *Egeria* extent. The high rate (20%) of *Egeria* increase is likely a somewhat unrealistic figure, because a steady rate of increase is unsustainable; as *Egeria* expanded it would begin to fill all suitable habitat. Although no estimates of the total amount of suitable habitat for *Egeria* across the Delta are available, there are indications that the rate of increase might be slowing as suitable habitat is colonized (Hestir 2010 in Baxter et al. 2010). The projections show that with the low treatment amount and steady 20% annual increase in *Egeria*, control would not be effective; however, with the low treatment amount and a 10% annual increase in *Egeria*, control would be effective within fewer than 20 years. With the high treatment amount, effective control would occur very rapidly. Small or sparsely infested areas may also be targeted for control, if they are located where they could provide a source of propagules with potential to invade restoration areas. As part of CM13, evaluation and monitoring of potential IAV source populations is proposed in coordination with existing control efforts in the Delta, and threshold values would be defined to trigger control actions. These threshold triggers would be based on a site-by-site evaluation of density, proximity, and extent, among other factors, by biologists familiar with the Delta ecosystem, local hydrological regime, and the ecology of the species. The evaluation would use a protocol such as Weed Heuristics: Invasive Population Prioritization for Eradication Tool (WHIPPET) (Skurka Darin et al. 2011).

Based on the control efficiencies shown in Figure 3.4-29, the following inferences seem to be supported.

- If *Egeria* is controlled with an initial high investment in treatment, it is feasible to bring *Egeria* under control within 5 to 11 years, a relatively short time period compared to the 50-year BDCP term.
- Thereafter, control would only be needed on a local basis to control any new *Egeria* infestations.
- Thus, the long-term cost of *Egeria* control would likely be lower for an aggressive initial treatment than with a consistent but lower level of control that might never achieve full control.
- The strategy of complete *Egeria* control is only achievable if control occurs throughout the Delta.
- A strategy that only targets *Egeria* infestations within the ROAs would have to continue throughout the plan term due to the high risk of re-infestation.

Thus, the control program would likely have highest ecological-effectiveness and highest cost-effectiveness, if it is designed to achieve full *Egeria* control throughout the Delta in the shortest possible timeframe.

DBW's program of chemical treatment of water hyacinth has been considered successful—this IAV species is considered to be currently under control in the Delta—so efforts in the future will likely be limited to eradicating new infestations before they spread.

To treat new and emerging IAV species, the Implementation Office will respond at the appropriate scale and intensity in coordination with existing programs and cooperators, such as CDFA and USDA-ARS.

Permit Conditions and Requirements: Avoidance and Minimization Measures

Currently, DBW is the only entity authorized to use herbicide to treat *Egeria* and water hyacinth, and more recently South American spongeplant, in the Delta, its tributaries, and Suisun Marsh. DBW was required to obtain three permits for each program (WHCP and EDCP).

- Two BiOps were required under the federal Endangered Species Act (ESA)[42].
  - A USFWS BiOp was required for Sacramento splittail, giant garter snake, valley elderberry longhorn beetle, and delta smelt.
  - An NMFS BiOp was required for winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon.
- The Central Valley Regional Water Quality Control Board (Central Valley Water Board) required an NPDES permit.

The BiOps identified possible direct and indirect adverse effects that the WHCP and EDCP might have on federally listed species and specified requirements for avoidance and minimization of effects on federally listed species.

NPDES permits are required for all aquatic pesticide applications in California. The NPDES permit goals were to minimize the extent of potential impacts on water quality in the Delta and to create a water monitoring and reporting program. The Central Valley Water Board imposed the following monitoring protocols on the EDCP and WHCP.

- Document compliance with the permit requirements.
- Support the development, implementation, and effectiveness of best management practices (BMPs).
- Demonstrate the full recovery of water quality and protection of beneficial uses of the receiving waters after treatment applications.
- Monitor all pesticides and application methods used.

To illustrate the permit requirements, Table 3.4.13-1 lists the permits obtained for the EDCP for the initial 5 years (2001 to 2005). The permits were obtained for the EDCP proposed treatment acreages of 1,531 acres in 2001 and 2002 and 1,631 acres in 2003, 2004, and 2005—a total of 8,105 acres. DBW's overall approach was similar to that proposed in CM13: treatment of "target" areas (for DBW these consisted of sites where *Egeria* interfered with navigation) and "nursery" sites (i.e., source populations, primarily shallow-water areas that provide ideal habitat for *Egeria*) (California Department of Boating and Waterways 2001).

[42] The federal nexus for this activity is the USDA-ARS, which is responsible for conducting research and providing technical input into the control of nuisance weeds and agricultural pests.

Table 3.4.13-1. List of Permits Required for the Egeria Densa Control Program (2001–2005)

Agency	Permit Type	Permit
U.S. Fish and Wildlife Service	BiOp	• 2001–2003 1-1-00-F-0234, as amended • 2004–2005 1-1-04-F-0148
NOAA Fisheries	BiOp	• 2001 SWR-99-SA-0053 letter • 2002 SWR-99-SA-104 • 2003–2005 SWR-02-SA-8279, as amended
Central Valley Regional Water Quality Control Board	National Pollutant Discharge Elimination System (NPDES) Permits	• 2001–2002 CA0084735 (Individual) • 2002–2003 CA990003 (General) • 2004–2005 CA990005 (General)

These permits placed restrictions on where and when herbicide treatment could occur, established the allowable chemical concentrations in treated areas and adjacent waters, and required extensive water quality monitoring and toxicity research. In addition to the conditions and restrictions in the above permits, the EIRs and addenda for the EDCP (California Department of Boating and Waterways 2001, 2006) and the programmatic EIR for the WHCP (California Department of Boating and Waterways 2009a) contain avoidance and mitigation measures designed to reduce adverse effects on sensitive species, natural communities, and water quality.

The herbicides used, primarily Sonar formulations (active ingredient fluridone) for *Egeria* control and primarily Weedar 64 (active ingredient 2,4-D) and also Rodeo (active ingredient glyphosate) for water hyacinth control, are registered by the EPA and by the California Department of Pesticide Regulation for use in California. Registration of an herbicide involves many years of research and is considered the functional equivalent of an EIR for the purpose of CEQA.

The herbicide programs are obliged to follow the California Department of Pesticide Regulation procedures for pesticide application and to comply with all requirements of the Division 6 Pesticides and Pest Control Operations of the federal Food and Agriculture Code covering labeling, handling, transportation, mixing, and rinsing containers. Additional requirements include a memorandum of understanding between DBW and regional water agencies outlining application restrictions relating to drinking water intakes and filing a Notice of Intent with the County Agricultural Commissioner of each county where herbicide use occurs.

All of the applicable conditions adopted by DBW and imposed by USFWS, NMFS, and NPDES as part of its IAV control programs are also incorporated into CM13, except for the toxicity research, which is completed. Examples of minimization and avoidance measures and monitoring and reporting requirements under the three permits are provided in Table 3.4.13-2, including those incorporated into the BDCP.

Table 3.4.13-2. Examples of the Types of Minimization and Avoidance Measures and Monitoring and Reporting Requirements Under Environmental Permits Required for the California Department of Boating and Waterway's Herbicide Programs in the Delta

Type of Measure/ Condition	In the BDCP?	Agency	Examples of Measures/Conditions
Coordination and Planning	N/A	NMFS	A NMFS representative sits on the Egeria Densa Task Force involved with planning and prioritization of sites.
Avoidance—site and timing restrictions	Yes	NMFS and USFWS	• Timing restrictions based on outmigration of juvenile salmonids at specific sites (e.g., no treatment before June 1 at sites with juvenile outmigration, no treatment from October 16 to March 31) • Survey for elderberry shrubs and treat at low tide if any elderberry shrubs are within 100 feet of the water's edge • Application window restrictions on timing between repeat applications for water hyacinth
Plans and Protocols	Yes	NPDES	• An aquatic pesticide application plan including BMPs. • A pesticide application log including specific information on each application • *The Water Hyacinth Control Program Protocol and Procedures Manual* and appendices that include requirements covering herbicide handling, treatment planning protocol, day of treatment protocols, and BMPs, plus the permit conditions of the two biological opinions and the NPDES permit (California Department of Boating and Waterways 2009b)
Fish Monitoring	Yes	NMFS	• Collection of dead fish resulting from treatment • Protocol for collecting information on each fish salvaged and environmental and water quality conditions • Fish passage protocol to ensure that operations have no impacts on fish
Treatment Monitoring	Yes	NMFS, NPDES	Monitoring and monthly reporting of the following. • Pre- and posttreatment measurements of chemical residue, pH, turbidity levels, water temperature, and DO at selected sites • Water temperature and DO changes resulting from EDCP activities • Amounts, types, and dates of herbicide application at each site • Visual assessment of pre- and posttreatment conditions of treated sites to determine efficacy of treatment and any effects of chemical drift • Operational status of equipment and vessels
Surveillance and Treatment Efficacy Monitoring	Yes		Development of effective and efficient methods for mapping and monitoring *Egeria* and water hyacinth presence pre- and posttreatment, including: • Aerial mapping analyses, • Hyperspectral analyses of aerial imagery, and • Hydroacoustic analyses

Type of Measure/ Condition	In the BDCP?	Agency	Examples of Measures/Conditions
Environmental Monitoring	Yes	NMFS, NPDES	• A water monitoring program requiring that a minimum of 10% of all treatment sites be sampled for each water type to collect and analyze Delta water quality data, and results of chemical residue and toxicity tests • An environmental monitoring plan • An approved monitoring protocol and sampling plan • A quality assurance project plan for chemical residue and toxicity monitoring, describing procedures and protocols for data collection and analysis • An annual report describing permit compliance and program findings and conclusions • An annual data validation package to confirm the quality of environmental monitoring data
Water Quality Targets and Limits	Yes	NPDES	• Specific turbidity standards • pH limits • Residue concentrations
Dissolved Oxygen	Yes	NMFS, USFWS	• No treatment if DO levels are between 4 to 6 parts per million in low-flow areas or below 5 parts per million in high-flow areas • Development of protocol for monitoring DO • Review committee to examine monitoring results
Toxicity Research	No	NMFS, USFWS	Toxicity studies conducted by California Department of Fish and Wildlife Aquatic Toxicology Laboratory on impacts of aquatic herbicides on target organisms and special status species; key findings are summarized by DBW (2006) • Toxicity studies on two garter snake species as surrogates for giant garter snake (Hosea et al. 2004) • Toxicity testing on Sacramento splittail for exposure to various aquatic herbicides (California Department of Fish and Game 2003a) • Chronic toxicities of herbicides on neonate Cladoceran and larval fathead minnow (Riley and Finlayson 2004a) • Acute toxicities of herbicides on larval delta smelt and Sacramento splittail (Riley and Finlayson 2004b) • Ceriodaphnia Dubia *(Water Flea) Static Definitive Chronic Toxicity Test Data (7-day) for Exposure to Various Aquatic Herbicides* (California Department of Fish and Game 2003b)
Environmental Training	Yes	NMFS, USFWS	Environmental awareness training for all field crew members • Species identification and impact avoidance guidelines • Protocol for identification and protection of elderberry shrubs • Protocol for identification and protection of delta smelt, Chinook salmon, steelhead, green sturgeon, and associated protected habitats • Protocol for take of protected species • Use and calibration of equipment

N/A = not applicable; NMFS = National Marine Fisheries Service; USFWS = U.S. Fish and Wildlife Service; NPDES = National Pollution Discharge Elimination System; BMP = best management practice; DO = dissolved oxygen; EDCP = Egeria Densa Control Program

Prevention, Threat Assessment, Early Detection, and Rapid Response

Long-term success of an invasive plant control program depends not only on application of control methods, but also on early detection of potentially invasive plants, assessment of the level of risk they pose, and the capability to respond rapidly to the threat in time to enable efficient and environmentally sound decisions (National Invasive Species Council 2003; California Department of Food and Agriculture and California Invasive Weed Awareness Coalition 2005).

Recognizing that the introduction and spread of potential IAV is a continuing process, the Implementation Office will consider using assessment tools such as WHIPPET (Skurka Darin et al. 2011) to assist in screening and prioritizing specific IAV species and invaded sites for control.

Prevention is a vital component of invasive species control programs, because efforts expended as soon as a potential IAV species is detected can prevent incurring the much greater costs of controlling the species once it has established and spread. South American spongeplant is an excellent example: small infestations are relatively easy to eradicate, but if the plant is allowed to establish and set seed, the seeds can survive in sediment and the population becomes very difficult to eradicate. In addition, the abundantly produced tiny seedlings move easily to establish new infestations (Akers 2010).

The Implementation Office will establish an early detection and rapid response program to monitor and detect potential IAV that can be targeted before becoming problematic. A good example of such a program is CDFA's Hydrilla Eradication Program. The program conducts an annual survey of the Delta to detect hydrilla before it can establish a foothold. CDFA works in cooperation with county agricultural commissioners and a variety of federal, state, and county agencies including DBW, DWR, and Reclamation. Other early detection programs in the Delta include those of CDFA's Integrated Pest Control Branch and the Bay Area Early Detection Network (Williams et al. 2009). The Implementation Office will also support public education and outreach efforts to provide information on IAV species, how they are spread, and the problems they create (see *CM20 Recreational Users Invasive Species Program*).

3.4.13.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*. Compliance monitoring for CM13 will consist of documenting in a GIS database the location, extent, and type of control measures implemented; documenting funding provided for control measures in annual progress reports, and maintaining plans of proposed and executed control actions.

Effectiveness monitoring will be conducted to evaluate progress toward meeting the objectives discussed in Section 3.4.13.4, *Consistency with the Biological Goals and Objectives.* If necessary, the implementation actions described above will be adjusted via adaptive management, as described in Section 3.6, to meet these objectives.

Effectiveness monitoring will be conducted at two scales: Delta-wide and at individual restoration sites and adjacent areas. Delta-wide monitoring will be conducted in collaboration with the existing monitoring programs of DBW and USDA-ARS and will include annual risk assessment and subsequent prioritization of treatment areas throughout the Delta in partnership with DBW and other cooperators to reduce expansion of the multiple species of IAV in the Delta. Individual restoration sites will be monitored for IAV consistent with the site-specific restoration plan to determine whether success criteria have been met. See Section 3.4.3.4.2, *Site-Specific Restoration Plans*, for a description of the elements to be incorporated into site-specific restoration plans. If success criteria are not met within the specified schedule, control measures will be implemented as described in the restoration plan. Table 3.4.13-3 lists key uncertainties and research action relevant to CM13, for incorporation into site-specific restoration plans, as appropriate.

Table 3.4.13-3. Key Uncertainties and Potential Research Actions Relevant to CM13

Key Uncertainty	Potential Research Actions
What are the most effective designs of tidal restoration sites to achieve tidal flow velocities that preclude rooting by IAV?	• Conduct empirical and lab studies to determine flow constraints on rooting of IAV species of concern. • Conduct model studies to assess velocity field for alternative restoration site design. • Conduct field tests in restoration site projects.
How are restored natural communities being affected by IAV and have there been changes in existing areas?	• Evaluate the effect of tidal natural communities restoration on the establishment of IAV in subtidal aquatic habitats. • Evaluate whether there have been changes in IAV that could be related to Plan operations (e.g., changes in Delta hydrodynamics).
Is it feasible to create conditions that favor the growth of native pondweeds (*Stuckenia* spp.) rather than IAV?	• Evaluate environmental conditions that support native pondweed stands, focusing on abiotic factors, particularly salinity, that determine growth and distribution of native pondweeds. • Evaluate how future salinity changes affect growth and distribution of pondweeds and *Egeria*. • Determine what differences in environmental conditions and abiotic factors favor *Stuckenia* over *Egeria*. • Evaluate to what extent restoration sites can be designed to encourage colonization and growth of native pondweeds while discouraging *Egeria*. • Determine the potential for native pondweed stands to contribute to restoration of native communities and ecosystem functions in the Delta. • Determine if the epifaunal invertebrate assemblages supported by native pondweed stands provide substantial foraging and cover benefits in comparison with *Egeria*.
IAV = invasive aquatic vegetation; SAV = submerged aquatic vegetation	

Monitoring Methods

Effective methods to detect, map, and monitor IAV on the landscape scale in the Delta have been developed and tested over the past few years, including hyperspectral aerial imagery and automated image analysis and classification tools (Underwood et al. 2006; Ustin 2008; Santos et al. 2009). The methods have proven capable of discriminating and mapping the extent of target IAV. They involve testing different types of aerial imagery and classification tools, combined with use of boat surveys and GPS units to collect and record data. Because the spectral signature and analysis algorithms are typically specific to each species of IAV targeted, developing methods to detect and quantify new IAV species would require additional ground-truthing.

On a smaller scale (i.e., for each restoration area), annual surveys will be conducted to assess and map IAV infestations using standard protocols (e.g., CDFA's *California Weed Mapping Handbook* [DePietro et al. 2002], North America Weed Management Association's *North America Invasive Plant*

Mapping Standards [North America Weed Management Association 2002]). Survey methods, results, and recommendations will be documented in annual reports. Based on a review of performance and effectiveness monitoring results, the Implementation Office will adjust funding levels, areas and focus of operations, or other related aspects to improve the performance and/or biological effectiveness of the IAV control measures through the adaptive management process. Such changes will be addressed in annual work plans.

The Implementation Office will also coordinate with the DBW, USDA-ARS, and CDFA programs, whose ongoing efforts will direct what elements the BDCP may want to support. Generally, the BDCP will focus on detection and treatment of IAV infestations within the Plan Area, with priority given to infestations that have high potential to affect existing or planned restoration sites. Research activities addressing key uncertainties will also receive priority.

Research Actions

The Implementation Office will support existing research and promote new research projects on IAV species, especially those emerging as a threat, to test and develop effective control methods. Knowledge of biological and ecological characteristics of the invasive plant (e.g., growth patterns, reproductive system, dispersal mechanisms) is important in designing effective control program, as is knowledge of the physical environment at treatment sites (e.g., flow regime, flow velocity, salinity). Choice of treatment type will be based on Delta-specific research, as much as possible—as has been the case with the EDCP and WHCP—but research from other delta systems and results from successful control programs in similar systems would also be informative. In addition to DBW's extensive research and monitoring program, recent and ongoing research in the Delta includes extensive surveys of the extent of SAV, development of mapping techniques for IAV, research into the ecology and physiology of water hyacinth and *Egeria*, investigation of biological control agents for water hyacinth and *Egeria*, and research on the environmental effects and biological relationships of IAV species.

CM13 contains a number of key uncertainties that affect its potential to achieve relevant biological goals and objectives (Section 3.4.13.4, *Consistency with the Biological Goals and Objectives*). In the near-term, the Implementation Office will support research actions designed to resolve these key uncertainties. The research actions listed in Table 3.4.13-3 are examples; in practice, the Implementation Office will issue requests for proposals from qualified researchers to address the stated key uncertainties. Proposals will be evaluated by a technical work group of the Adaptive Management Team, and appropriate action taken via the decision process described in Chapter 7, *Implementation Structure*.

3.4.13.4 Consistency with the Biological Goals and Objectives

CM13 will advance the biological goals and objectives as identified in Table 3.4.13-4. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.13-4. Biological Goals and Objectives Addressed by CM13

Biological Goal or Objective	How CM13 Advances a Biological Objective
Goal L1: A reserve system with representative natural and seminatural landscapes consisting of a mosaic of natural communities that is adaptable to changing conditions to sustain populations of covered species and maintain or increase native biodiversity.	
Objective L1.4: Include a variety of environmental gradients (e.g., hydrology, elevation, soils, slope, and aspect) within and across a diversity of protected and restored natural communities.	IAV control will reduce the prevalence of dense IAV stands that alter environmental conditions and displace native species; this will help to reestablish representative environmental conditions with regard to natural community structure and support reestablishment of representative environmental gradients.
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.	
Objective L2.6: Increase native species diversity and relative cover of native plant species, and reduce the introduction and proliferation of nonnative species.	IAV control targets invasive plants for removal, thereby allowing establishment of native aquatic plants. Since the IAV supports the introduced warm-water predator and nonpredator fish community, its control is also expected to reduce the dominance of invasive centrarchid predator fishes, allowing increased numbers and diversity of native fishes and allied aquatic organisms.
Objective L2.9: Increase the abundance and productivity of plankton and invertebrate species that provide food for covered fish species in the Delta waterways.	Control of IAV reduces its potential to compete with native aquatic plants such as pondweeds (*Stuckenia* spp.), which support a diverse invertebrate epifauna.
Goal L4: Increased habitat suitability for covered fish species in the Plan Area.	
Objective L4.1: Manage the distribution and abundance of nonnative predators in the Delta to reduce predation on covered fishes.	IAV provides cover for centrarchid nonnative predatory fishes, and its control will reduce habitat suitability for those fish. This is likely to reduce predation on covered fish by nonnative predatory fishes.
Goal TPANC2: Tidal perennial aquatic natural community that supports viable populations of native fish.	
Objective TPANC2.1: Control invasive aquatic vegetation that adversely affects native fish habitat.	CM13 is focused on IAV control and is expected to attain this objective.
Goal DTSM2: Increased quality and availability of habitat for all life stages of delta smelt and increased availability of high-quality food for delta smelt.	
Objective DTSM2.1: Increase the extent of delta smelt habitat.[a]	To the extent that removal of IAV increases low-gradient, sandy shoal habitat, delta smelt spawning habitat will be increased.
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.	
Objective GRST1.1: Improve juvenile and adult survival.[a]	Control of IAV may result in the restoration of suitable rearing habitat for sturgeon as well as contribute toward increasing the extent of habitat suitable for some prey resources important to sturgeon, which may increase juvenile and adult survival.
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.	
Objective WTST1.1: Improve juvenile and adult survival.[a]	Control of IAV may result in the restoration of suitable rearing habitat for sturgeon as well as contribute toward increasing the extent of habitat suitable for some prey resources important to sturgeon, which may increase juvenile and adult survival.

IAV = invasive aquatic vegetation.
[a] Summarized objective statement; full text presented in Table 3.3-1.

3.4.14 Conservation Measure 14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels

Under *CM14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels*, the Implementation Office will ensure that the Stockton Deep Water Ship Channel (DWSC) DWR Aeration Facility (Aeration Facility), which is currently operational, will continue to operate as needed during the BDCP permit term in order to maintain the concentrations of DO above target levels during the entire BDCP permit term. The Implementation Office will develop annual work plans in coordination with fish and wildlife agencies, the Central Valley Water Board, and the current Aeration Facility operating entities that specify the extent of DO improvements to be implemented and will monitor the effectiveness of measures intended to improve DO levels. The Implementation Office will make funding available for the continued long-term operation and maintenance of the Aeration Facility by year 1. The Implementation Office will also coordinate with the Central Valley Water Board to determine water quality standards to be met both as requirements of the San Joaquin River DO TMDL (U.S. Environmental Protection Agency 2007) and as part of BDCP biological goals and objectives, as well as operational triggers related to when to initiate operations and what the duration of operations will be once implemented.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM14. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that potential adverse effects of CM14 on covered species will be avoided or minimized. Refer to Appendix 5.C, *Flow, Passage, Salinity, and Turbidity* (Section 5.C.5.3.11), for an evaluation of the effects of CM14 on covered fish species.

3.4.14.1 Purpose

The primary purpose of CM14 is to meet or contribute toward achieving biological goals and objectives of the BDCP related to passage and distribution of covered fish species, as well as maintenance of natural ecological processes. This conservation measure is intended to improve water quality conditions by alleviating the low DO levels in the Stockton DWSC. The conservation measure will ensure that, in the affected portion of the Stockton DWSC, DO levels do not decrease to levels that may adversely affect covered fish species or result in passage delays for covered fish species.

3.4.14.2 Problem Statement

For descriptions of the ecological values and current condition of DO in the Stockton DWSC, see Chapter 2, *Existing Ecological Conditions,* and Section 3.3, *Biological Goals and Objectives*. Section 3.3 also describes the need for addressing low DO concentrations as a component of the conservation strategies for aquatic communities and associated covered species, based on the existing conditions and ecological values of these resources.

The discussion below describes conditions that will be improved through implementation of CM14.

As much as 60% of the natural historical inflow to Central Valley watersheds and the Delta have been diverted for human uses. Depleted flows have contributed to higher water temperatures, lower DO levels, and decreased recruitment of gravel and large woody debris. Other factors that have also contributed to low DO include dredging to deepen and widen shipping channels as well as excessive algal and nutrient loading resulting from land use upstream. Periods of low DO concentrations have historically been observed in the San Joaquin River's Stockton DWSC, which is located downstream from Stockton, California (Figure 3.4-30). The majority of these low DO concentrations have been observed in the summer and fall months in a 7.5-mile-long reach upstream of Turner Cut. These periods of low DO are most prolonged and acute from June through October, but they have also been observed in other months (ICF International 2010a). For example, over a 5-year period starting in August 2000, a DO meter recorded channel DO levels at Rough and Ready Island (Dock 20 of the Port of Stockton, West Complex). During this monitoring period, the 5 mg/L DO criterion for the protection of aquatic life in the San Joaquin River between Channel Point and Turner and Columbia Cuts was violated on 297 days. These violations occurred during the September through May migratory period for salmonids in the San Joaquin River (National Marine Fisheries Service 2006). Low DO levels have the potential to delay the migration of both juvenile and adult fish, and may result in greater stress on covered fish species.

Adult fish, including covered fish species migrating upstream in the fall and early winter, encounter lowered DO in the DWSC due to low flows and excessive algal and nutrient loads coming downstream from the upper San Joaquin River watershed. Currently, migration routes for adult and juvenile covered fish are limited in this section of the San Joaquin River. Fish can migrate through the DWSC, Old River, or Middle River. The DWSC is the most direct route to spawning habitat upstream of Stockton and rearing habitat downstream within the Delta. Besides being the most direct route, the DWSC likely provides fewer potential hazards for migrating covered fish species, such as reduced exposure to predators and reduced potential for entrainment compared with migration through the Old and Middle Rivers.

Levels of DO below 5 mg/L have been reported to delay or block migratory movements by fall-run Chinook salmon (Hallock et al. 1970). Low DO levels can cause physiological stress and mortality of fish, including Chinook salmon and steelhead (Jassby and Van Nieuwenhuyse 2005) and other aquatic organisms (Central Valley Regional Water Quality Control Board 2007). Once spring-run Chinook salmon are reestablished in the San Joaquin River under the San Joaquin River Settlement Agreement, similar effects could be expected if low DO conditions in the DWSC were to occur during the adult migration period for spring-run Chinook salmon (approximately March through September). In addition, juvenile white sturgeon, which rear in the San Joaquin River, exhibit reduced foraging and growth rates at DO levels below 58% saturation (5.8 mg/L at 15°C) (Cech and Crocker 2002).

Ultimately, the low DO levels occur when the rate of oxygen depletion in the DWSC exceeds the rate of oxygen recharge or production. Oxygen recharge and production rates decrease primarily due to two causes.

As the river water flows downstream from the San Joaquin River channel to the DWSC, the channel depth increases from approximately 9 feet to over 35 feet, which in turn results in a reduction in velocity and thus a reduction in water column mixing as the water depth increases and the water velocity decreases. This reduces the efficiency of oxygen recharge from atmospheric diffusion.

Oxygen is produced within the water column via photosynthesis, primarily by phytoplankton but also by SAV. The rate of this oxygen production decreases when light levels decrease. Because the water is turbid and the DWSC is deep, a large proportion of the water column is below the photosynthetic compensation depth (the depth at which an organism's oxygen production by photosynthesis balances oxygen consumption by respiration). Thus, photosynthetic rates, per unit water volume per unit time, are lower.

Conversely, the rate of oxygen consumption in the DWSC is maintained or elevated, relative to upstream waters, for several reasons.

- Phytoplankton at depths below the phytosynthetic compensation depth cause net DO depletion because their respiration rate exceeds their photosynthesis rate.
- Nonphotosynthetic organisms respire in the water column. These include fish, invertebrates such as zooplankton, and microorganisms such as bacteria that metabolize ammonia in the water column.
- Nonbiological chemical reactions consume oxygen in oxidation-reduction reactions.

Also, slow water velocities and reduced water column mixing result in stronger contrasts between high and low DO due to diurnal variations in photosynthesis (photosynthesis only occurs during the daylight hours, so DO levels drop through the night).

The low DO concentrations recorded in the DWSC violate the Central Valley Basin Plan water quality objectives for DO, causing a seasonal barrier to salmonid migration through the DWSC (Hallock et al. 1970) and possibly other covered fish species. In January 1998, the State Water Resources Control Board adopted the Clean Water Act Section 303(d) list that identified this DO impairment, and the Central Valley Water Board initiated development of a TMDL to identify factors contributing to the DO impairment and assign responsibility for correcting the low DO concentration (Central Valley Regional Water Quality Control Board 2005; ICF International 2010a).

Since the approval of the DO TMDL Basin Plan Amendment in 2005, two actions have been implemented to alleviate low DO conditions in the DWSC. First, beginning in 2007 the City of Stockton added engineered wetlands and two nitrifying biotowers to the Stockton Regional Wastewater Control Facility to reduce ammonia discharges to the San Joaquin River. This action decreased the ammonia levels in facility effluent from approximately 30 to 35 mg/L to approximately 2 mg/L, thereby reducing biochemical oxygen demand in the DWSC. The ammonia was the biggest oxygen demand in the winter months and because nitrification treatments were initiated, DO concentrations in the DWSC have improve markedly during the winter months. However, other factors continue to contribute to DO depressions, including reduced river velocity through the Stockton DWSC as a result of increased channel capacity, and upstream contributions of organic materials (e.g., algal loads, nutrients, agricultural discharges).

DO concentrations between May and October would continue to be depressed without additional measures and, prior to the Stockton Regional Wastewater Control Facility improvements, would often drop to less than 4 mg/L between June and September (Jones & Stokes 2002). In response to this problem, DWR constructed the Aeration Facility to determine its applicability for improving DO conditions in the DWSC (ICF International 2010a). Constructed between 2006 and 2007 at the west (downstream) end of Rough and Ready Island at the Port of Stockton Dock 20, the Aeration Facility has been maintained and operated for testing purposes by DWR. The Aeration Facility underwent an individual Section 7 consultation in 2007 (Jones & Stokes 2007). In 2008, demonstration testing began in June and ended in late September. In 2009, testing was not possible until September because of state bond funding issues. Operations testing of flood-tide aeration and nighttime aeration was conducted in September 2009. Additional operations testing and DWSC monitoring were conducted during summer 2010. The demonstration phase ended in December 2010, and DWR, the Central Valley Water Board, and several DO TMDL stakeholders are in the process of securing a short-term (3 to 5 years) agreement for funding of operations and maintenance responsibilities.

The demonstration phase was successful at increasing DO levels by approximately 1 mg/L within the DWSC under most circumstances. This has been enough to meet the objectives of the DO TMDL for the most part, primarily because the major source of biological oxygen demand (BOD) has been eliminated since 2007 with the completion of the City of Stockton's Regional Wastewater Control Facility's nitrification facility (ICF International 2010a). In general, the Aeration Facility can be used in many circumstances to meet the objectives of the DO TMDL; however, several factors strongly influence DO levels in the DWSC (e.g., natural DO concentrations, surface reaeration, BOD concentrations, algal photosynthesis, river flow, and tidal cycle). The Aeration Facility is not able to meet the objectives of the DO TMDL under all circumstances due to the strong influence of these various factors (ICF International 2010a, 2010b). In general, the Aeration Facility capacity of 7,500 pounds per day of oxygen should be sufficient to maintain the DWSC DO above the DO TMDL objectives (5 mg/L during December through August, and 6 mg/L during September through November) most of the time, and the periods and severity of DO deficits (below DWSC DO TMDL objectives) will likely be less frequent and smaller in magnitude (ICF International 2010a).

In general, the Aeration Facility would operate continuously for up to 4 days to increase DO levels within the DWSC and achieve the DO objective of the TMDL and the BDCP biological goal and objectives. Based on monitoring, continuous operations beyond 4 days (adding up to 7,500 pounds per day of oxygen) do not result in a greater increase in DO levels in the DWSC (in terms of concentrations or distance from the diffuser)(ICF International 2010a). Thus continuous operation of the Aeration Facility for up to 4 days appears to provide the greatest benefit in terms of increasing DO concentrations within the DWSC.

3.4.14.3 Implementation

3.4.14.3.1 Operational Actions

Under this conservation measure, the Implementation Office will ensure continued funding for and operation of the Aeration Facility, and the continued implementation of measures to improve the facility's effectiveness in meeting BDCP biological goals and objectives, as well as the objectives of the DO TMDL.

The Aeration Facility will be operated to ensure that the Stockton DWSC will not present a passage delay for covered fish species due to low DO levels. The Implementation Office will work with the fish and wildlife agencies and the Central Valley Water Board to develop an annual work plan for the Aeration Facility that will define the thresholds for when the Aeration Facility will operate and the duration of operation. The Implementation Office will also coordinate with the Central Valley Water Board to ensure that the requirements of both BDCP biological goals and objectives and the DO TMDL are compatible and effectively met.

The methods for determining responsibility for the DO deficit within the DWSC and assigning proportional responsibilities for funding the operation the Aeration Facility (or other implementation measures) that could increase the DWSC DO concentrations to meet the objectives of the DO TMDL have not been adopted; thus the long-term funding for operations and maintenance beyond testing has not been secured and currently the Central Valley Water Board has not mandated such funding. Under CM14, the Implementation Office will share in funding the long-term operation and maintenance costs associated with the operation of the Aeration Facility. The Implementation Office also will consider funding for modifications to the Aeration Facility and/or construction of additional aeration facilities to increase DO levels in the Stockton DWSC and will potentially implement additional recommendations, which could improve the effectiveness of CM14 beyond the test results and thus provide greater benefit to covered fish species.

3.4.14.3.2 Siting and Design Considerations

The Aeration Facility consists of two vertical turbine pumps. The pumps convey river water via discharge piping to two U-Tube contactor wells located west of Dock 20 on the adjacent island. Oxygen is injected at the top of each well. The wells are constructed to a depth of approximately 200 feet below grade. Each well is totally contained, including a bottom seal. Oxygenated water flows down the well in a concentric feed pipe and back up the well annular section. Oxygenated water exiting the U-Tube wells is routed through approximately 1,000 feet of piping back to the DWSC, under Dock 20, and 1,000 feet upstream from the pump intakes where a liquid diffuser mounted along the inboard row of piers, away from shipping traffic, discharges the oxygenated water back to the river (Figure 3.4-31). The Aeration Facility has been successful in field tests by DWR (ICF International 2010a). Results suggest that the Aeration Facility is effective at raising DO levels by approximately 1 mg/L in much of the channel; however, some recommendations have been put forth (ICF International 2010a) based on the successful operational testing of the Aeration Facility from 2008 to 2010. There are three general recommendations for the future long-term operations of the Aeration Facility.

The Aeration Facility could be a major component of the TMDL implementation plan for achieving the Central Valley Basin Plan DO objective in the DWSC when the river flow and inflow DO and BOD concentrations would have resulted in low DO conditions. TMDL accounting procedures for identifying the likely causes for low DO conditions in the DWSC could be developed but would have to be accepted by the Central Valley Water Board and by affected stakeholders.

A long-term monitoring strategy should be developed as part of the TMDL implementation plan to identify periods when the Aeration Facility should be operated and to confirm that the added DO was sufficient to achieve the DO TMDL objective. The monitoring strategy should include all data needed for the TMDL accounting procedures.

Several modifications to the Aeration Facility should be further evaluated, as necessary, to increase the capacity to deliver added DO to the DWSC or to improve the distribution of added DO upstream of the diffuser to meet the objectives of the DO TMDL or the BDCP biological goal and objectives. For example, the discharge from the two U-Tube wells could be separated, with a second discharge line and diffuser extended 0.5 mile upstream to distribute more of the added DO upstream of the existing diffuser.

3.4.14.4 Adaptive Management and Monitoring

Implementation of CM14 will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting funding and operation of the Aeration Facility.

Effectiveness monitoring will be conducted to evaluate progress toward advancing the biological objectives discussed below in Section 3.4.14.5, *Consistency with the Biological Goals and Objectives*, as well as the objectives of the DO TMDL. Monitoring will consist of reviewing DO levels at various distances from the diffuser(s). If the objectives are not being sufficiently met, the results will help to determine if modifications to the Aeration Facility could be implemented to increase DO concentrations and achieve the intended objectives. The Implementation Office will work with the fish and wildlife agencies and the Central Valley Water Board to develop an annual work plan and will use effectiveness monitoring results to determine whether Aeration Facility operations result in measurable reductions in passage delays for covered fish species and achieve the objectives of the DO TMDL.

To ensure that the Aeration Facility operations result in measurable benefits to covered fish species by reducing passage delays caused by low DO levels, DO levels will be monitored in the Stockton DWSC from Rough and Ready Island downstream to Turner Cut. Monitoring will be relatively consistent with previous monitoring efforts implemented to determine the effectiveness of the Aeration Facility. Long-term monitoring will consist of continuous monitoring at five established water quality monitoring stations, including Turning Basin and R3 through R6 monitoring stations (Figure 3.4-30), to evaluate the DO levels in the Stockton DWSC and in San Joaquin River upstream of the DWSC and San Joaquin River confluence. Monitoring is not expected to be necessary downstream of the R6 monitoring station, because data from the R7 monitoring station indicate low DO problems did not occur at this site. The measured parameters will include DO and possibly water temperature, pH, and oxygen-depleting substances (e.g., 5-day biochemical oxygen demand, volatile suspended solids, chlorophyll *a*).

Should monitoring or new information indicate that modifications to the Aeration Facility, or the design, installation, and operation of one or more additional aerators in the DWSC, are warranted to further improve DO conditions, funding such efforts as part of CM14 would be considered within the context of adaptive management. Relevant factors in this decision would be the extent to which such efforts would contribute to achieving the BDCP biological goal and objectives and the availability of funds allocated for this conservation measure. Consideration would include, but not be limited to, the locations where low DO conditions persist in the DWSC, the extent to which low DO conditions contribute to passage delays through the DWSC, and the extent to which additional aerators would alleviate the low DO conditions and reduce passage delays.

Based on a review of performance and effectiveness monitoring results, the Implementation Office or Adaptive Management Team may recommend adjustments to funding levels, Aeration Facility operations, or other related aspects to improve the performance and/or biological effectiveness of the Aeration Facility through the adaptive management process (Section 3.6). Such changes, if approved by the Authorized Entities Group and the Permit Oversight Group, will be addressed in annual work plans.

The Implementation Office will also coordinate with the TMDL stakeholder effort, whose ongoing efforts will direct what elements the BDCP may want to contribute to (i.e., what is not required under the TMDL but is required to achieve the BDCP biological goals and objectives). For example, the Central Valley Water Board is currently discussing whether the current TMDL standard of 6 mg/L from September 1 through November 30 each year is appropriate, or whether a water quality objective of 5 mg/L year-round is more appropriate. Because these decisions will affect the BDCP, the Implementation Office will participate in these conversations. Additionally, the Implementation Office will also coordinate with the Central Valley Water Board to discuss operations and triggers for initiating and halting operations the Aeration Facility to meet water quality objectives.

Table 3.4.14-1 provides potential monitoring actions, metrics, success criteria, and timing and duration for monitoring relevant to CM14. These monitoring elements may be modified, as necessary, to best assess the effectiveness of CM14, based on the best available information at the time of implementation.

Table 3.4.14-1. Effectiveness Monitoring Relevant to CM14

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM14-1	Site-level assessment of water quality	DO concentrations	Achievement of DO concentrations consistent with the DWSC DO TMDL of 6 mg/L from September 1 through November 30 and 5 mg/L at all other times on a year-round basis, particularly from May through October when DO levels have historically fallen below the target levels.	Year-round monitoring of DO concentrations, for the BDCP permit term

3.4.14.5 Consistency with Biological Goals and Objectives

CM14 will advance the biological goals and objectives as identified in Table 3.4.14-2. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above (i.e., monitoring of DO levels within the DWSC), the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Effectiveness monitoring will be implemented to ensure DO levels within the DWSC meet the criteria outlined within the DO TMDL are being achieved. If effectiveness monitoring shows that these criteria are being met, it is assumed that this CM is contributing to the following BGOs.

Table 3.4.14-2. Biological Goals and Objectives Addressed by CM14 and Related Monitoring Actions

Biological Goal or Objective	How CM14 Advances Biological Objective	Monitoring Action
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.		
Objective L2.4: Support improved ecosystem function in aquatic natural communities by implementing actions to improve water quality, including reducing dissolved oxygen impairments in the Stockton Deep Water Ship Channel, reducing pollutant loading by urban stormwater, and minimizing mobilization of methylmercury from lands in the reserve system.	Ensure DO levels within the Stockton DWSC are adequate to allow anadromous fish passage.	CM14-1

Biological Goal or Objective	How CM14 Advances Biological Objective	Monitoring Action
Goal SRCS1: Increased spring-run Chinook salmon abundance.		
Objective SRCS1.1: Improve through-Delta survival.[a]	Spring-run Chinook salmon have been extirpated from the San Joaquin River, but a reintroduction effort is underway as part of the San Joaquin River Restoration Program, which expects to release up to 54,400 juvenile spring-run Chinook salmon juveniles reared at the Feather River Fish Hatchery. Over the BDCP permit term a sustainable population of spring-run Chinook salmon may become established in the San Joaquin River; however, providing DO levels within the Stockton DWSC that are conducive to migrating juvenile salmonids may reduce the stress experienced when DO levels are low and thereby contribute to increased migration success and survival.	CM14-1
Goal SRCS2: Substantial reduction of passage delays (to contribute to increased migration and spawning success and thus abundance) at anthropogenic impediments for adult spring-run Chinook salmon migrating through the Delta.		
Objective SRCS2.1: Limit adult passage delays in the Yolo Bypass and at other human-made barriers and impediments in the Plan Area.[a]	As mentioned above, spring-run Chinook salmon have been extirpated from the San Joaquin River, but a reintroduction effort is underway as part of the San Joaquin River Restoration Program. Operation of the Aeration Facility is intended to help reduce passage delays of adult spring-run Chinook salmon that may result from low DO levels.	CM14-1
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.		
Objective FRCS1.1: Improve through-Delta survival.[a]	Providing DO levels in the Stockton DWSC that are conducive to migrating juveniles may reduce the stress experienced when DO levels are low and thereby contribute to increased migration success and survival.	CM14-1
Goal FRCS2: Substantial reduction in passage delays (to contribute to increased migration and spawning success and thus abundance) at anthropogenic impediments for adult fall-run/late fall–run Chinook salmon migrating through the Delta.		
Objective FRCS2.1: Limit adult passage delays in the Yolo Bypass and at other human-made barriers and impediments in the Plan Area.[a]	Operation of Aeration Facility is intended to help reduce passage delays of adult fall-run/late fall–run Chinook salmon that may result from low DO levels.	CM14-1
Goal STHD1: Increased steelhead abundance.		
Objective STHD1.1: Improve through-Delta survival.[a]	Providing DO levels in the Stockton DWSC that are conducive to migrating juveniles may reduce the stress experienced when DO levels are low and thereby contribute to increased migration success and survival.	CM14-1

Biological Goal or Objective	How CM14 Advances Biological Objective	Monitoring Action
Goal STHD2: Substantial reduction in passage delays (to contribute to increased migration and spawning success and thus abundance) at anthropogenic impediments for adult steelhead migrating through the Delta.		
Objective STHD2.1: Limit adult passage delays in the Yolo Bypass and at other human-made barriers and impediments in the Plan Area.[a]	Operation of the Aeration Facility is intended to help reduce passage delays of adult steelhead associated with low DO levels.	CM14-1
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.		
Objective GRST1.1: Improve juvenile and adult survival.[a]	Providing DO levels in the Stockton DWSC that are conducive to juvenile and adult sturgeon (i.e., >5 milligrams per liter) may reduce the stress experienced when DO levels are low and thereby contribute to increased sturgeon migration success and survival.	CM14-1
Goal GRST3: Increased spatial distribution of young-of-the-year (YOY) and juvenile green sturgeon in the Delta compared to existing conditions.		
Objective GRST3.1: Improve water quality and physical habitat.[a]	Operation of the Aeration Facility will contribute to DO conditions more suitable for sturgeon, which may result in increased spatial distribution of sturgeon in the Plan Area.	CM14-1
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.		
Objective WTST1.1: Improve juvenile and adult survival.[a]	See Objective GRST1.1 above.	CM14-1
Goal WTST3: Increased spatial distribution of young-of-the-year (YOY) and juvenile white sturgeon in the Bay-Delta compared to existing condition SWP/CVP regulatory requirements.		
Objective WTST3.1: Improve water quality and physical habitat.[a]	See Objective GRST3.1 above.	CM14-1
DO = dissolved oxygen; DWSC = deep water ship channel; YOY = young of year. [a] Summarized objective statement; full text presented in Table 3.3-1.		

CM14 will also provide benefits beyond those specified as biological goals and objectives. Increasing DO concentrations in the Stockton DWSC in accordance with DO TMDL objectives will achieve the following benefits.

- Reduced delay and inhibition of upstream and downstream migration of fall-run Chinook salmon, steelhead, white sturgeon, lamprey, and, once they are reestablished in the San Joaquin River, spring-run Chinook salmon and green sturgeon.
- Reduced physical stress and mortality of fall-run Chinook salmon, steelhead, white sturgeon, and lamprey, and, once they are reestablished in the San Joaquin River, spring-run Chinook salmon and green sturgeon.

3.4.15 Conservation Measure 15 Localized Reduction of Predatory Fishes

The primary purpose of CM15 is to contribute to biological goals and objectives related to abundance and passage of covered salmonids (Section 3.4.15.4, *Consistency with the Biological Goals* *and Objectives*) by locally reducing nonnative predatory fishes. This localized reduction is intended to increase the survival of migrating salmonids (Lindley and Mohr 2003; Perry et al. 2010; Cavallo et al. 2012; Singer et al. 2012). Under CM15, the Implementation Office will reduce populations of nonnative predatory fishes at specific locations and eliminate or modify holding habitat for nonnative predators (predators) at selected locations of high predation risk (i.e., predation "hotspots"). This conservation measure seeks to benefit covered salmonids by reducing mortality rates of juvenile migratory life stages that are particularly vulnerable to predatory fishes. Predators are a natural part of the Delta ecosystem. Therefore, CM15 is not intended to entirely remove predators at any location, or substantially alter the abundance of predators at the scale of the Delta system. This conservation measure will also not remove piscivorous birds, which appear to mainly prey opportunistically on hatchery salmon (Evans et al. 2011). Because of uncertainties regarding treatment methods and efficacy, implementation of CM15 will involve discrete pilot projects and research actions coupled with an adaptive management and monitoring program (Section 3.6, *Adaptive Management and Monitoring Program*) to evaluate effectiveness.

Removal of holding habitat for predatory fishes may also occur as a consequence of *CM6 Channel Margin Enhancement, CM7 Riparian Natural Community Restoration,* and *CM13 Invasive Aquatic Vegetation Control.*

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM15. See Chapter 8, *Implementation Costs and Funding Sources*, for a discussion of costs associated with implementation of CM15. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that adverse effects of CM15 on covered species will be avoided or minimized. Expected biological effects of implementing this conservation measure are summarized in Section 3.4.15.4, *Consistency with the Biological Goals and Objectives*, with further discussion in Appendix 5.F, *Biological Stressors on Covered Fish.*

3.4.15.1 Problem Statement

The purpose of a fish predator reduction program is to reduce the abundance of predators, thereby reducing the mortality rates of protected or desirable species (in this case, covered salmonids) and increasing their abundance. To achieve this goal, predator control programs aim to limit the overall opportunity for fish predators to consume covered salmonids, typically by decreasing predator numbers, modifying habitat features that provide an advantage to predators over prey, reducing encounter frequency between predators and prey, or reducing capture success of predators. Beamesderfer (2000) proposed the following decision-making process to determine where intervention measures may prove effective and appropriate.

- Are one or more species significantly reducing the abundance of covered fish species, either directly by predation or indirectly by competition for a limited resource?
- Is it feasible to affect potential predators or competitors enough to provide benefits to the covered species?
- Do biological benefits outweigh costs and social/political considerations?

For covered salmonids, a high degree of uncertainty currently surrounds each of these questions. Currently understanding is limited regarding the importance of predation as a limit on the production of covered salmonid populations and the mechanisms for competitive exclusion of covered salmonids in the Delta. This uncertainty limits the ability to predict whether reducing predator numbers will help the BDCP meet its biological goals and objectives. Furthermore, some actions may not be acceptable for social, legal, or policy reasons.

Given these uncertainties and constraints, CM15 will initially be implemented as an experimental pilot program and a series of connected research actions. Actions will be designed both to reduce uncertainties about the efficacy of this conservation measure and to increase its likelihood of desirable outcomes. The most plausible and feasible initial actions would be localized reduction of selected predatory fish species in known predation hotspots and modification of habitat features that tend to increase predation risk. The goal would be to reduce loss of covered salmonids, principally juvenile salmonids passing through the Delta.

The following sections review underlying ecological theory of the role of biological interactions in aquatic ecosystems, the role of habitat change on species assemblages, predation in the Delta, and predation hotspots.

3.4.15.1.1 Predation in Aquatic Ecosystems

Aquatic communities are shaped by both abiotic factors (e.g., flow, temperature, salinity, nutrients, physical variability) and biotic interactions (e.g., competition, predation, disease). The relative importance of biotic factors is often linked to variation in abiotic factors (Power et al. 1988; Holomuzki et al. 2010). Predation is a natural process, but its extent and effects can change when established predator-prey relationships are disrupted by environmental changes or species introductions (Baxter et al. 2010). Aquatic ecosystems can be substantially altered by introduced predators (e.g., Brown and Moyle 1991; Goldschmidt et al. 1993) or changes in established predator-prey relationships (e.g., Carpenter et al. 2001; Frank et al. 2005; Estes et al. 2011).

The pelagic organism decline conceptual model hypothesized that predation effects in the Delta have increased as a result of increased populations of pelagic and inshore predatory fishes (piscivores) (Sommer et al. 2007b; Baxter et al. 2010). Top-down forcing by predation has been suggested as one factor that, synergistically with other sources of mortality, could be limiting the production of covered fish (Sommer et al. 2007b; Baxter et al. 2010). Top-down forcing by predation can have wide-reaching effects that cascade through the ecosystem, in sometimes unpredictable patterns (Vander Zanden et al. 2006; Estes et al. 2011). Furthermore, foodweb dynamics are often complex, with indirect interactions that can mask or amplify top-down effects. For example, with competition between two prey species that share a common predator, predation rates on one prey species can be increased due to the presence of the alternative prey. In the Delta, invertebrates and nonnative prey fishes (e.g., silverside, threadfin shad) must maintain nonnative predator populations (e.g., striped bass, largemouth bass), because the relative abundance of native fishes is so much lower than the nonnatives (Matern et al. 2002; Feyrer and Healey 2003; Nobriga et al. 2005; Brown and Michniuk 2007; Grimaldo et al. 2012). This dominance of the ecosystem by nonnative species might result in depensatory predation on native fish as hypothesized by Nobriga and Feyrer (2007). Similarly, ocean-based prey, such as anchovies and caridean shrimp (Thomas 1967), subsidize the adult population of anadromous striped bass during bay and ocean residence (Loboschefsky et al. 2012). Fish generally eat what can fit in their mouths, so diet shifts as fish grow from small juveniles consuming zooplankton and fish larvae, to large juveniles and adults consuming ever larger fish. In fact, young age classes of piscivorous fishes may exert considerable predation pressure due to their comparatively high numbers (Kitchell et al. 1997; Loboschefsky et al. 2012). Cannibalism was historically common in striped bass and can maintain predator populations even as prey populations decline (e.g., Nile perch [Kitchell et al. 1997]). Finally, there is intraguild predation (Polis et al. 1989) by other small fish. Silversides have been hypothesized to be a significant predator of delta smelt eggs and larvae (Bennett 2005).

The relative strength of biotic interactions and abiotic conditions in structuring aquatic communities can vary depending on the spatial and temporal dynamics of disturbance regimes. Benign or predictable physical environments are thought to be more conducive to development of stronger biotic interactions (Peckarsky 1983; Poff and Ward 1989). One hypothesis of the pelagic organism decline is that reduced variability in environmental conditions of the estuary may have exacerbated predation effects, although there is no clear evidence that such changes have been abrupt enough to account for the decline of pelagic species such as delta smelt, longfin smelt, and striped bass (Baxter et al. 2010). Temporal shifts can occur in the relative importance of biotic and abiotic mechanisms, so that “top-down” and “bottom-up” forces work in concert but at disparate and time-varying rates (Power et al. 1988; Alpine and Cloern 1992).

Natural, co-evolved piscivore-prey systems typically have an abiotic production phase and a biotic reduction phase each year (e.g., Rodriguez and Lewis 1994; 1997). Changing the magnitude and duration of these cycles greatly alters their outcomes (Meffe 1984). Generally, the relative stability of the physical environment affects the length of time each phase dominates and thus the importance of each.

Historically, in the Bay-Delta estuary, the period of winter-spring high flow was the abiotic production phase, when most species reproduced. The biotic reduction phase probably encompassed the low-flow periods in summer and fall. This pattern has been observed on floodplain systems such as the Yolo Bypass and Cosumnes River (Feyrer et al. 2006; Moyle et al. 2007). Multi-year wet cycles probably increased (and still do) the overall “abiotic-ness” of the estuary, allowing populations of all species to increase. Drought cycles likely increased the estuary’s “biotic-ness” (Livingston et al. 1997), with low reproductive output and increased effect of predation on population abundances. Flow management in the San Francisco Estuary and its watershed has reduced flow variation (Moyle et al. 2010) and probably affected magnitude and duration of abiotic and biotic phases (Nobriga et al. 2005).

Knowledge of the strength of ecosystem interactions is necessary when attempting to manage the abundance of a particular ecosystem constituent (Essington and Hansson 2004). The consequences of a single-species focus may be counterintuitive and potentially counterproductive (Wiese et al. 2008; Pine et al. 2009). For example, on the Columbia River a predatory bird control program has been implemented to protect migrating juvenile salmon (Wiese et al. 2008). However, modeling suggested that one consequence of removing or displacing piscivorous waterbirds (which feed on juvenile northern pikeminnow when salmon are not present) could be increased pikeminnow abundance, which could theoretically increase predation losses of juvenile salmonids (Wiese et al. 2008). Other examples of unpredictable outcomes include lamprey control and trout stocking in the Great Lakes (Kitchell et al. 1994), experimental manipulations in northern glacial lakes (Kitchell et al. 1994; Estes et al. 2011), bass management in southeastern U.S. farm ponds (Pine et al. 2009), and trophic cascades in many terrestrial and aquatic systems (reviewed by Vander Zanden et al. 2006; Pine et al. 2009; Estes et al. 2011).

3.4.15.1.2 Predation in the Bay-Delta

Predators

Fish are generally opportunistic foragers that consume whatever they can fit into their mouths. Thus, fish eggs can be eaten by essentially any fish species (and many invertebrates) in the Delta; fish larvae can be eaten by a large majority of the same taxa—even the covered fish species are known to prey opportunistically on fish larvae (Lott 1998); and small juvenile fish may still have a large number of potentially predatory fish taxa they need to avoid. However, predation rates typically decline as fish grow larger, reflecting the narrower range of species and life stages that can effectively capture them. For fairly large juvenile fishes like salmonid smolts, only a handful of species inhabiting the Delta can routinely prey on them, primarily striped bass, largemouth bass and close relatives, Sacramento pikeminnow, and possibly adults of quasi-piscivorous species like white or green sturgeon, steelhead, and channel catfish. Different life stages can have different diets, which affects both available energy for growth and potential effects on prey species (Loboschefsky et al. 2012). For example, adult striped bass in the Bay-Delta feed primarily upon fish, while younger striped bass rely more on lower-energy invertebrate prey (Stevens 1966; Feyrer et al. 2003; Nobriga and Feyrer 2007); diets vary widely based on prey availability (Nobriga and Feyrer 2008). Though high turbidity environments can be an exception (Turesson and Bronmkark 2007), the prey choices of predators are typically density-dependent. Thus, predators tend to eat what is relatively abundant in the areas in which they are foraging.

Known predators of covered fish species in the Delta include the nonnative striped bass and largemouth bass, and the native Sacramento pikeminnow (Nobriga and Feyrer 2007). Other predators include native fish such as white sturgeon (although native fish are not likely a significant component of their diet), nonnative fishes such as catfishes and other centrarchids (i.e., bass, crappie, and sunfish), and piscivorous birds. Smaller fish such as silversides can be important predators on larvae.

A recent bioenergetics study of striped bass by Loboschefsky et al. (2012) suggests that estuary predation rates by age-2 striped bass increased during the period 1995 through 2003 coincident with higher population numbers. Their analysis found that subadults (age 1 and age 2) of striped bass are more abundant than adults (age 3+), making them the most abundant pelagic predator in the estuary ecosystem (Loboschefsky et al. 2012). As a result, prey consumption by subadults was similar to prey consumption by adults. Furthermore, the effects of subadults on estuarine prey may be substantial since subadults are not limited to pelagic habitats and can be abundant in inshore areas (Nobriga and Feyrer 2007), whereas adults can emigrate and forage in the Pacific Ocean. Thus, subadult striped bass are likely a more important predator of some of the covered species than adult striped bass.

Avian predators are widely distributed throughout the Delta and its upstream watersheds. Piscivorous birds in the Bay-Delta (all native) include gulls, cormorants, terns, diving ducks, herons, egrets, osprey and kingfishers. However, this pilot program will not be taking actions to manipulate or affect piscivorous birds.

Predation on Covered Fish Species

In the Delta, predation occurs on covered species as eggs (delta smelt, longfin smelt) larvae (delta smelt, longfin smelt, splittail), juveniles (delta smelt, longfin smelt, salmon, steelhead, splittail, sturgeon) and adults (delta smelt, longfin smelt, splittail. Each of these species groups is described below.

Salmon are likely to encounter striped bass and Sacramento pikeminnow throughout juvenile emigration down the Central Valley rivers and in the Delta. Salmonid juveniles may be vulnerable to largemouth bass while forging in nearshore habitats around areas of SAV. Striped bass and largemouth bass were observed to consume salmonids, but in a recent evaluation less than 1% of those predators were observed with salmon in their stomachs (Nobriga and Feyrer 2007; Nobriga and Feyrer 2008). Sacramento pikeminnow predation on salmonids has been documented upstream (Vogel et al. 1998) but not in the Delta (Nobriga et al. 2006), even though large pikeminnow have been captured in the lower Sacramento River (Nobriga et al. 2006).

Delta smelt and longfin smelt are largely pelagic. This reduces the likelihood that they will encounter nearshore predators like largemouth bass, but they can overlap extensively with striped bass. In the 1960s, delta smelt were documented in 0 to 12% of striped bass (over 12,000 stomachs examined) (Stevens 1966; Thomas 1967). At that time, delta smelt made up a small proportion (1 to 8% by volume) of the diet in subadults (age 1 and age 2), and trace amounts in young-of-the-year and adult (age 3+) striped bass. Delta smelt also comprised a large fraction of striped bass diets in the Sacramento River near Isleton in one short-term study (Stevens 1963). In 2001 and 2003 surveys, no delta smelt were found in striped bass stomachs (Nobriga and Feyrer 2008). The only published study to report striped bass predation on longfin smelt was Thomas (1967), who reported that "Sacramento smelt" comprised up to 14% of striped bass diets by volume in Suisun Bay during the winter.

Splittail are likely to be vulnerable to all three large predators (striped bass, largemouth bass and Sacramento pikeminnow) as they are widespread throughout the Delta and also use nearshore habitats to forage. In the Delta, young splittail are most abundant in extremely shallow areas of low-density SAV, whereas largemouth bass are most abundant in denser SAV (Brown 2003; Nobriga et al. 2005). One study documented striped bass and largemouth bass consumption of splittail, but splittail were observed in small fractions of the less than 1% of striped bass stomachs and 2% of largemouth bass diets (Nobriga and Feyrer 2007).

Green and white sturgeon may experience predation, although the extent to which this occurs within the Delta is unknown. The eggs and early larval stages of green and white sturgeon appear to be the most vulnerable to predation by other fish species, but the magnitude and significance of this predation is not known. It has also been reported that larval and juvenile green sturgeon are subject to predation by both native and introduced fish species. Smallmouth bass (*Micropterus dolomieui*) have been recorded on the Rogue River as preying on juvenile green sturgeon, and prickly sculpin (*Cottus asper*) have been shown to be an effective predator on the larvae of sympatric white sturgeon (Gadomski and Parsley 2005). The development of scutes is thought to protect larvae sturgeon from predation (Parsley et al. 2002).

Predation on Pacific lamprey and river lamprey is not well-documented within the Delta, and the extent to which it occurs is unknown. Lamprey migrate through the Delta at sizes small enough to be consumed by predators and have been found in a striped bass stomach (Nobriga pers. comm.). Egg and larval lamprey life stages appear to be the most vulnerable, although juvenile and possibly even adult life stages are potential prey for a variety of aquatic and terrestrial species. Fish predators of lamprey include channel catfish (*Ictalurus punctatus*), white sturgeon, pikeminnow, sculpins, and logperch (Close et al. 1995). Predation of lamprey within the Delta has not been identified as an issue of concern at this time.

Encounter and Consumption

The likelihood of a predation event is a function of three factors: rates of encounter between predator and prey; a decision by the predator to attack the prey; and capture or feeding efficiency of the predator(s). Encounter frequencies between predators and covered fish are related to their overlap in habitat use spatially and temporally, the vulnerability of prey, which is typically linked to environmental conditions like river flows and turbidity (Cavallo et al. 2012), and their abundance relative to alternative prey (Link 2004).

Consumption rates of predators (by age-class or population level) can be estimated using bioenergetics models, which use an energy budget approach for growth of individual fish (Loboschefsky et al. 2012). Total consumption rates relate to predator number, predator size, water temperature, prey density, and sometimes prey vulnerability (i.e., microhabitat use of predator and prey and whether the prey has a refuge at low density).

Predation Hotspots

The following sites throughout the Delta are currently considered hotspots of predator aggregation or activity (Figure 3.4-32).

- **Clifton Court Forebay.** Native fish entrained in Clifton Court Forebay experience high prescreen losses (75 to 100%), presumably due to predation (Gingras 1997; Clark et al. 2009; Castillo et al. 2012). Striped bass are known to readily enter and leave through the radial gates (Gingras 1997).
- **CVP intakes.** Salmon experience approximately 15% prescreen loss at the south Delta CVP intakes, attributed to predation (Gingras 1997; Clark et al. 2009).
- **Head of Old River.** Nonphysical barriers have been tested here to prevent juvenile salmonids from entering Old River and continuing to the South Delta pumping plants. However, acoustic-tagging studies of juvenile hatchery salmon documented very high predation losses to striped bass patrolling the area and swimming along the barrier infrastructure (Bowen et al. 2009). The scour hole at the head of Old River can allow predators such as striped bass and catfish to congregate and ambush prey.
- **Georgiana Slough.** Acoustic-tagging studies indicate that survival rates of juvenile salmon released near Walnut Grove are much greater for juveniles traveling down the Sacramento River mainstem instead of down Georgiana Slough (Vogel 2008; Perry et al. 2010). It is assumed that the lower survival of juvenile salmon in Georgiana Slough is a result of greater predation because there are no other known plausible mechanisms for such large differences in survival.
- **Old and Middle Rivers.** In general, survival rates are lower for juvenile salmon migrating through the central Delta.
- **Franks Tract.** This flooded island has the highest levels of invasive Brazilian waterweed in the Delta (Underwood et al. 2006), which has facilitated intensive colonization by largemouth bass. Striped bass are also common in Franks Tract.

- **Paintersville Bridge.** Multiple timber pilings meant to protect the bridge pilings and guide navigation can alter flow fields, while the structures provide predator holding habitat (Stevens 1963).
- **Human-made submerged structures.** Structures such as abandoned boats, bank revetments, and piers can attract predators as hiding areas and alter local hydraulic patterns that disorient small fish.
- **Salvage release sites.** The fish salvaged from CVP/SWP South Delta export facilities are released daily via pipes located at only a few Delta locations. Over time, this has provided a limited number of obvious places that predators can aggregate and wait for dead, dying, and disoriented prey fishes. Refinements of release operations may provide some additional benefits to reduce predation.

In addition to these existing predation hotspots, the BDCP is expected to create new hotspots.

- **North Delta water diversion facilities.** The three intakes included in *CM1 Water Facilities and Operation* would be likely predator hotspots. Large intake structures have been associated with increased predation by creating predator ambush opportunities and flow fields that disorient juvenile fish (Vogel 2008).
- **Nonphysical fish barriers.** Nonphysical fish barriers may attract predators such as striped bass; however, it is not clear if predator densities are higher near nonphysical barriers, if certain types of nonphysical barriers may be more attractive to predators (e.g., sound, air and/or light barriers), or how effective certain types/combinations of barriers are at directing covered salmonids away from areas with a high risk of entrainment and/or predation based on site-specific conditions (Bureau of Reclamation 2009).

Other hotspots are likely present in the Delta. The actions in this conservation measure will be applied to other hotspots identified in the Plan Area, if those actions will help to fulfill the purpose of this conservation measure and to meet the applicable biological goals and objectives.

3.4.15.2 Implementation

CM15 will include the following two elements.

- Hotspot pilot program. Implement experimental treatment at priority hotspots, monitor effectiveness, assess outcomes, and revise operations with guidance from the Adaptive Management Team.
- Research actions. Via the adaptive management program, support focused studies to quantify the population-level efficacy of the pilot program and any program expansion(s) intended to increase salmonid smolt survival through the Delta.

If demonstrably effective, the hotspot pilot program will be developed in three successive stages. During the first stage, a few treatment sites will be experimentally evaluated to test the general viability of various predator reduction methods. Secondary reduction actions, such as removal of abandoned vessels, may be implemented to determine if they will be effective on a large scale. After the initial scoping stage is complete, and if shown to be effective, the second stage will consist of implementation of a pilot program with a larger range of treatment sites and refined techniques, incorporating what is learned from the first stage. The main focus at this stage is to study the efficacy of predator reduction on a larger scale to determine whether it is making a demonstrable difference and/or has any unintended ecological consequences (i.e., unexpected changes to foodweb dynamics that may have negative effects on covered fish species). The pilot program may include such activities as direct predator reduction at hotspots (e.g., Clifton Court Forebay, head of Old River scour hole, the Georgiana Slough sites, and SWP/CVP salvage release sites) and removal of old human-made structures (e.g., pier pilings, abandoned boats).

To minimize uncertainty about the appropriate management regime necessary to maintain and enhance survival of covered salmonids, effectiveness monitoring will be implemented with the pilot program. The pilot program would begin with a preliminary assessment phase to compare two approaches for reducing local predator abundances: removal of predator hotspot structures (e.g., abandoned boats, derelict pier pilings) and general predator reduction in reaches with known high predation loss.

The pilot program will be carefully monitored and refined to determine whether either of these practices is effective. If the pilot program shows that the main issues are resolvable, the third stage would consist of a defined predator reduction program (i.e., defined in terms of predator reduction techniques and the sites and/or areas of the Plan Area where techniques will be employed). Research and monitoring would continue throughout the duration of the program to address remaining uncertainties and ensure the measures are effective (i.e., that they reduce numbers and densities of predators and increase survival of covered salmonids).

The following sections provide an overview of lessons from other reduction programs, management principles and key uncertainties, and details of the hotspot pilot program.

3.4.15.2.1 Lessons from Predator Control Programs

Case studies from other aquatic systems illustrate the challenges and mixed outcomes from altering or manipulating predator-prey dynamics.

Attempts to apply predator-prey theory and models to predator management at the scale of large, complex systems can yield unpredictable outcomes, as illustrated by examples from the Great Lakes (Kitchell et al. 1994). Pelagic community structure can experience rapid, discontinuous changes in predator-prey interactions. Overfishing in the Great Lakes and invasion of sea lamprey caused the collapse of native piscivores (lake trout), leading to an explosion of planktivorous alewife in Lake Michigan and Lake Ontario and the domination of exotic rainbow smelt in Lake Superior (Kitchell et al. 1994). Attempts were then made to suppress sea lamprey with piscicide applications, followed by stocking of (predatory) nonnative salmon and native lake trout, which helped restore the native plantivorous fish populations. In Lake Michigan, the salmon and lake trout consumed alewife at a high rate, reducing their populations to 10 to 15% of their peak abundances. In Lake Superior, native lake trout became reestablished and the populations of nonnative rainbow smelt collapsed to 10% of the peak.

In Lake Victoria, introduced Nile perch may have caused the collapse and extirpation of many native fishes, including hundreds of haplochromine cichlid species (Kitchell et al. 1997; Balirwa et al. 2003). However, even this “classical” example of nonnative predator impact from tropical Africa is not without controversy; other authors think this collapse of native fishes had more to do with competition with nonnative tilapia than predation by Nile perch (Goudswaard et al. 2002). Some evidence suggested that intensive fishing could locally reduce predator numbers and allow some recovery of haplochromines (Balirwa et al. 2003). A bioenergetics model estimated the impact of

Nile perch predation and evaluated effects of intensive commercial fishing (30% removal assumed) (Kitchell et al. 1997). Gillnetting targets larger Nile perch, while beach seining targets young juveniles, which are more abundant and feed on smaller fish. Both forms of fishing would reduce total predation, but beach seining would reduce predation more than gillnetting. Adults have greater per capita consumption of haplochromines, but they also control juvenile Nile perch stocks by cannibalism. Harvesting juvenile Nile perch would deplete the population before the cohorts could grow, eliminating large numbers of future haplochromine predators.

Sustaining the potential benefits of predator reduction is challenging in open systems such as rivers. In the Colorado River Basin, six of seven reduction programs failed to improve native fish populations and a third of the reviewed programs failed to reduce predatory fish abundances (Mueller 2005). The main problem was rapid recolonization of treatment zones by new predators.

In the Lower Columbia River, a sustained predator reduction program has been implemented since 1990 to reduce the abundance of northern pikeminnow (Porter 2010; Independent Scientific Review Panel 2011). Salmonids comprise 64% of prey fish in pikeminnow downstream of Bonneville Dam (Porter 2011). Modeling simulations indicated that if predator-size northern pikeminnow were exploited at a 10 to 20% rate, the resulting restructuring of their population could reduce their predation on juvenile salmonids by 50%. The program uses a reward bounty for anglers and has tested but discontinued other methods (gillnetting, longline, purse seine, trapnet) as inefficient at the system-wide scale. From 1991 to 2011, anglers have harvested over 3.7 million pikeminnow. In 2011, approximately 15% of pikeminnow were removed at a program cost of $1 million (Porter 2011). After 20 years of modifications and fine-tuning, the program has achieved 10 to 20% exploitation rates on large northern pikeminnow, which are the most predaceous, and an estimated 40% reduction in modeled predation on outmigrating smolts compared to preprogram levels (Independent Scientific Review Panel 2011). However, no attempt has been made to relate predator reduction to adult return rates (Independent Scientific Review Panel 2011). The efficacy of the pikeminnow management program depends on the lack of compensatory response by other piscivores such as smallmouth bass and birds. Previous evaluations have not detected responses by the predatory community to sustained pikeminnow reduction, although responses to fisheries management programs may not be detected for several years.

In the Delta, Cavallo et al. (2012) conducted a pilot study on the North Fork Mokelumne River to evaluate effectiveness of localized predator reduction to improve reach-specific survival of salmon smolts (Cavallo et al. 2012). This study used a before-after/control-impact (BACI) study design. Predatory fish were removed by boat electrofishing on two occasions, 5 days apart. Acoustically tagged salmon survival increased significantly after the first predator reduction in the impact reach; however, survival estimates returned to preimpact levels after the second predator reduction. Reduction benefits were “undone” within 1 week. If site-specific predator reductions are to benefit juvenile salmon survival, sustained effort over time (with daily rather than weekly reduction efforts) may be necessary (Cavallo et al. 2012). However, such sustained efforts may be cost-prohibitive on more than a very localized scale.

3.4.15.2.2 Management Principles and Uncertainties

Because of the high degree of uncertainty regarding predation/competition dynamics for covered fish species and the feasibility and effectiveness of safely removing large fractions of existing predator populations, the proposed predator reduction program is envisioned as an experimental pilot program within an adaptive management framework.

The pilot program will focus on increasing survival of migrating juvenile salmonids. The timing, pathways, and behavior of migrating salmonid smolts suggest that focused predator removal at discrete hotspots may increase their survival (e.g., Bowen et al. 2009; Perry et al. 2010; Cavallo et al. 2012). Effective methods exist for capturing and removing large predators and for measuring outcomes, including local predator density and salmon survival (e.g., smolt survival tagging studies, BACI reach-specific salmon survival).

These predator reduction efforts may also benefit juveniles of Pacific lamprey, river lamprey, green sturgeon, and white sturgeon that are migrating at the same time as the treatment.

For delta smelt and longfin smelt, reduction of large predators is less likely to provide benefits. Smelt spawn in the Plan Area, where they have previously been shown to be vulnerable to predation (Stevens 1963; Thomas 1967). During their egg and larval stages the smelts are also vulnerable to predation from a wide array of predators including small fishes such as silversides (Bennett 2005). Thus, larger fish such as adult striped bass are not the most significant predator, because they eat larger prey (Nobriga and Feyrer 2008). Moreover, reductions in large predator populations are likely to increase small predator populations, if predators have a strong influence on prey fish population dynamics (Essington and Hansson 2004). This has likely already been observed in the San Francisco Estuary's striped bass population. Kimmerer et al. (2000, 2001) suggested the adult striped bass population had resilience to persistent low recruitment of ago-0 fish stemming from compensatory density dependence in the juvenile stage. This is consistent with Loboschefsky et al. (2012), who reported increased abundance and prey consumption of age-2 striped bass during a period of declining adult consumption and ago-0 abundance in the 1990s and early 2000s. Furthermore, wide-scale reduction in an apex predator could trigger unintended trophic cascades. High uncertainty exists regarding whether the dynamic biotic interaction is top-down control, apparent competition, indirect effects, or other complex interactions (Vander Zanden et al. 2006). For example, wide-scale reductions in striped bass could result in competitive release and a compensatory response by silverside or other intraguild competitors.

In summary, predator reduction for delta smelt and longfin smelt faces two risks. First, it has to occur at a scale much larger than the hotspot approach proposed for salmonid smolts; the cost may be high and the probability of benefit may be low, if the program fails to identify the most significant predator species/life stage(s) and/or fails to remove enough predators. Second, unintended negative consequences could result, if too many of the wrong predator or competitor species are reduced—or even if the right predator population is reduced. Therefore, the BDCP pilot program will not undertake reduction efforts focused on benefiting delta smelt or longfin smelt.

Key uncertainties for developing and evaluating a predator reduction program include the following.

- Under what circumstances and to what degree does predation limit the productivity of covered fish species?
- Which predator species and life stages have the greatest potential impact on covered fish species?
- What habitat factors facilitate predation in the Delta, and how can those impacts be mitigated?
- How should hotspots for localized predator reduction and/or habitat treatment be prioritized?

- What are the best predator reduction techniques? Which methods are feasible, cost effective, and best minimize potential impacts on covered species?
- What are the effects of localized predator reduction measures on predator fish and covered fish species (e.g., increased survival)?
- How can predation rates on covered fish species be quantified?

These uncertainties are considered and addressed in the design of the pilot program and the research priorities, as detailed in the following sections.

3.4.15.2.3 Hotspot Pilot Program

The hotspot pilot program will consist of discrete pilot projects and research actions coupled with an adaptive management and monitoring program to evaluate effectiveness. To minimize uncertainty about the efficacy of management regimes necessary to maintain and enhance survival of covered fishes, pilot experiments will be conducted to test the effects of predator reduction and structural habitat modifications or removal. The experiments will be designed to test a range of reasonable management alternatives at appropriate local spatial scales (Perry et al. 2010) and river flows (Kjelson and Brandes 1989; Cavallo et al. 2012). All experiments and research work under the pilot program will be subject to review and approval by the Adaptive Management Team.

Guidelines and Techniques

A plan will be developed for each pilot project. Treatment methods will be dictated by site-specific conditions and intended strategy. Elements of each pilot project plan will include the following.

- Goals and objectives of treatment and monitoring.
- Baseline conditions.
- Treatment actions and schedules: reduction method, spatial extent, frequency and duration of treatment.
- Experimental design: reduction and treatment sites, metrics of effectiveness, and analysis approach.
- Applicable permit terms and conditions.
- Monitoring requirements and schedules.
- Adaptive management approach.

The pilot program will use the following approaches to reduce encounter frequency between predators and native fishes.

- Reduce the local abundance of predators.
- Remove human-made predator hiding places.

Localized Reductions of Predatory Fish

The first strategy involves direct reduction of predators from areas with high predator densities (predator hotspots). Pilot projects to reduce predatory fish at hotspots will incorporate study design principles similar to those used by Cavallo et al. (2012). A test program will incorporate a BACI study approach, analyzing the survival of covered fish like salmon with and without predator reduction treatments. This approach would be implemented in river reaches with known predator hotspots, including Georgiana Slough, Old and Middle Rivers, and the lower Sacramento River near Paintersville Bridge. The study design would compare treated and untreated (control) reaches, or above and below treated areas (e.g., scour hole at the head of Old River).

Before each predator reduction treatment, tagged salmon smolts would be released in the designated treatment and control reaches to determine the baseline level of reach-specific survival and predation loss. In some locations, longer-term monitoring of expected reach-specific survival can help solidify predictions of baseline survival (e.g., Newman 2008; Perry et al. 2010; Singer et al. 2012). Flow rates during the release period would be measured in the reaches to account for the effect of stream velocity on the reach-specific survival rates of migrating juvenile salmonids. Hydroacoustic tracking and DIDSON cameras may also be employed to provide a general estimate of predator densities within the river reaches (e.g., the number of predators along the shore, within the main part of the channel, or around prominent in-channel vegetation or structures).

Once a location is selected, one of the reaches would receive predator reduction while the other one would represent the control reach. Experimental reaches would be relatively short (1 to 2 kilometers or less) to maximize the ability to effectively reduce the number of predators in the test reach. Multiple treatments of a given predator reduction strategy would be applied to the treated river reach to help develop an estimate of predator reduction effectiveness and an amount of time the treatment is effective (Cavallo et al. 2012). Following predator reduction, tagged salmon would be released daily to assess estimated predation loss, and to determine persistence of any change in local predator abundance or salmon survival rates. Tethered salmon may also be used to determine where elevated predation occurs (e.g., neashore, in the channel, near structures) in order to refine and target reduction techniques. Sustained reduction efforts would likely be necessary to maintain local reductions in predators (Cavallo et al. 2012).

To evaluate predation-related loss at the new north Delta intakes on the Sacramento River, it will be necessary to monitor the reach where the intakes will be located and potential predation loss within this reach. Studies are currently being designed to provide key baseline survival rates for emigrating covered salmonids and presence/absence data for other covered and predatory fish species within the reach containing the new intakes. These studies will be implemented to collect baseline data and then after installation of the north Delta intake facilities to document whether survival through this reach of the river changes.

Various techniques used to control fish populations are reviewed in Table 3.4.15-1; however, only physical reduction techniques will be considered for testing and implementation in the Delta. These include boat electrofishing, hook-and-line fishing, passive capture by net or trap (e.g., gillnetting, hoop net, fyke trap), and active capture by net (e.g., trawl seine, beach seine). Advantages of physical reduction include public acceptance of these known techniques, lack of impacts on water quality, low level of hazard to nontarget organisms, higher level of feasibility compared to dewatering or chemical treatment in the open Delta waterways, and lower level of risk of unintended ecological consequences. Limitations include high exploitation rates required to achieve meaningful and measurable benefits, potentially high expense and intense labor, and short-lived benefits (Finlayson et al. 2010). The predator control techniques implemented would be analyzed to identify capture efficiency of predatory fish, as well as rates of injurious by-catch of covered fish. Addressing the uncertainty associated with the implementation of reduction techniques will be evaluated and refined through the adaptive management process, as described in Section 3.6.3.

Table 3.4.15-1. Potential Methods of Localized Reduction of Predatory Fish Populations

Technique	Advantage	Limitation	Potential Application
Methods Potentially Applicable for the Delta			
Electrofishing	• Can be used in areas with dense vegetation (SAV) or submerged structures • Can preferentially target larger predatory fish (which consume more and larger prey per capita)	• Incidental injury or mortality possible for covered fish species • Labor-intensive • Expertise required • May be less effective with smaller but more numerous juvenile predators • Does not work well in brackish water • Low efficiency for mobile predators	• Apply in shallow areas with submerged structures or SAV, regions where techniques such as netting are less effective
Hook-and-line	• Can be modified to target specific species • Low mortality of by-catch • Easy to implement • Could enlist voluntary (perhaps with incentives) help of anglers • Take of predators beyond legal bag limits could be covered by scientific collecting permits, if approved by CDFW	• Time-intensive • Skill, knowledge, and proper equipment are necessary to efficiently capture fish by hook and line • Participation of anglers limited by requirement for scientific collecting permit • Take of predators may be limited by scientific collecting permit	• Deploy paid fisherman (biologists or technicians) or volunteers to angle for predators in targeted areas. • Implement in hotspots such as Clifton Court Forebay or along portion of the mainstem San Joaquin River.
Passive trapping (e.g., fyke nets, hoop net traps, baited traps)	• Effective against sunfish and other centrarchids (except largemouth bass) • Hoop nets effective on catfish • Low mortality rates of by-catch • Can be deployed in areas too deep for beach seining	• Not effective for largemouth bass • Labor-intensive to maintain • Cannot be set in shallow areas • Must be periodically moved to maintain catch efficiency	• Effective for areas with high flow
Gillnetting	• Shown to be effective against striped bass and other mobile fish species • Works well in turbid waters	• High by-catch of splittail and for some mesh sizes, adult salmonids •	• Use in areas of the Delta with turbid waters and lack of submerged vegetation or structures (e.g., the hole at Head of Old River)
Active capture (e.g., trawling or beach seines)	• Mesh size of nets could be large enough to capture larger predators while achieving relatively low rates of incidental by-catch of juvenile salmonids and adult delta and longfin smelt	• Labor-intensive • Ineffective in areas with a lot of submerged vegetation or structures • Need open beach areas to conduct beach seines • Limited to wadeable depths	• Use in areas lacking submerged structures or dense vegetation that may hinder or get entangled in the netting • Beach seining requires open beaches

Technique	Advantage	Limitation	Potential Application
Predator lottery fishing tournaments	• Can be designed to direct volunteer fishing effort to particular fish species, at specific times and locations • Low mortality of by-catch • Potential for good public relations	• Requires provision in fishing tournament regulations to allow participants to possess fish in excess of bag limits and outside of legal size limits (similar to provisions already provided for black bass tournaments in the Delta) • Requires targeting fish in identified, localized hotspots, and avoiding indiscriminately catching fish throughout the Plan Area	• Release predators with internal coded tags, and advertise the event and offer a prize for angler catching a specific tag coded fish • Implement in hotspots such as Clifton Court Forebay or along portion of the mainstem San Joaquin River
Methods Unsuitable or Infeasible for the Delta			
Dewatering or water level fluctuation	• Effective against all fish species	• Only feasible in enclosed water bodies that can be drawn down (reservoirs)	• Not suitable in the Delta
Chemical treatment of targeted waters (e.g., rotenone)	• Effective against all fish species • Rotenone degrades moderately rapidly in water • Can be used in large aquatic systems • Rapid results	• May harm covered fish species • Has temporary impacts on drinking water and recreation • Potential public health and safety concerns • Poor public perception	• Only in the summer months when few covered fish are present in the Delta • May not be suitable for use near active water intakes
Pulsed pressure wave	• Most effective against fish with swim bladders (e.g., striped bass and largemouth bass)	• May injure or kill covered species • Difficult to control area of influence	• Apply over dense SAV where largemouth bass are prevalent, during the summer months when fewer covered species are present in the Delta
Bait prey fish (hatchery salmon) with oral piscicide	• Once permitted, likely to be very cost-effective • Affects only predators consuming released baited prey fish • Can be very site- and time-specific	• Permitting use will be very difficult • Poor public perception • Potential public health and safety concerns	• Implant hatchery salmon with piscicide in soluble capsule • Release baited fish at targeted area • Recover stunned or dead predators from the targeted area
Sources: Nielsen and Johnson 1983; Feyrer and Healey 2003; Finlayson et al. 2010; U.S. Army Corps of Engineers 2012; Cavallo pers. comm.			

Predator lottery fishing tournaments, a variant of the hook-and-line fishing technique, could be useful for reducing local abundance of predators at hotspots such as Clifton Court Forebay or along mainstem San Joaquin River (Cavallo pers. comm.). These tournaments would be designed to encourage intensive angling pressure at a particular location during a particular period of time (i.e., when covered prey species are present), and targeting specific predatory fish species (i.e., striped bass, largemouth bass). Such tournaments would be cost-effective, and potential by-catch would be minimized by requiring fisherman to use only particular hook-and-line methods that are known to be effective for the target predator(s). Following a tournament, tagged fish would be released and recaptured at these localized hotspots, using methods similar to those used to evaluate prescreen loss at Clifton Court Forebay (Gingras 1997; Clark et al. 2009) or at other locations within the Delta (Cavallo et al. 2012). The results would be compared to survival studies of covered fish within localized hotspots prior to predator reduction efforts. The comparison would take into account flow rates through the area (Kjelson and Brandes 1989; Perry et al. 2010; 2012; Cavallo et al. 2012) and water temperature (Kjelson and Brandes 1989; Baker et al. 1995; Marine and Cech 2004), since these factors play a significant role in affecting predation losses as indexed by smolt survival (Cavallo et al. 2012).

Other potential methods of predator control considered but not addressed further in this analysis include biological techniques (e.g., predators, intraspecific manipulation, pathological reactions), dewatering or water fluctuation techniques (e.g., reservoir drawdown), streamflow manipulation, predator fish barriers, chemical treatment (i.e., using broadcast applications of piscicide or oral delivery of treated bait), and the use of high-intensity sound waves (e.g., explosives and pulsed pressure waves [U.S. Army Corps of Engineers 2012]). These methods are not considered further due to limited feasibility, potential permitting issues, public health and safety concerns, and/or poor public perception.

Habitat Modification to Reduce Predator Holding Areas

The pilot program also will evaluate the modification or elimination of habitat features that provide holding habitat for predatory fish and/or increase capture efficiency by predators. Examples of such habitat features include submerged human-made structures (e.g., abandoned boats, derelict structures, bridge piers), water diversion facilities (e.g., intakes, forebays [Vogel 2008]), channel features (e.g., scour hole at head of Old River [Bowen et al. 2009]), beds of invasive aquatic vegetation (Nobriga et al. 2005; to be treated under *CM13 Invasive Aquatic Vegetation Control*), and salvage release sites (California Department of Water Resources 2010b). One hypothesis is that removal of structures could have the benefit of reducing local aggregations of predators.

Reach-specific survival rates of tagged salmon smolts will be assessed using a before-and-after comparison study (Cavallo et al. 2012) to evaluate the predation-related impact of removing predator hotspot structures. Survival assessments will take into account the role of flow rates (Kjelson and Brandes 1989; Perry et al. 2010; 2012; Cavallo et al. 2012) and water temperature (Kjelson and Brandes 1989; Baker et al. 1995; Marine and Cech 2004) in comparing the before-and-after-removal survival results. Such a before-and-after comparison approach would also be implemented by targeting predators associated with the scour hole at the head of Old River, a known predator holding area. Another method for estimating the efficacy of predator control would be to sample predators at habitat locations and document predator density, then use bioenergetics models to estimate how much consumption of covered fish species may have been reduced (Cavallo pers. comm.). This method may be cost-prohibitive, however, due to the extensive data that would be required.

Another approach is to modify salvage release methods and vary or increase release locations to avoid unintentionally creating predator feeding stations at the release pipe. A pilot experiment will increase the number of release sites from four to eight, alternate the timing of releases between the eight sites to discourage predators from holding at release sites, and remove debris near salvage release sites monthly from October through June to reduce the predation loss of salvaged splittails and other fish. Increasing the number of release sites, alternating the timing of releases between the sites, and removing debris that may provide predator cover are expected to contribute to a reduction in predation of covered fish species.

3.4.15.2.4 Program Timeline

During year 1, the Implementation Office will evaluate the strategies for logistical issues, relative effectiveness, incidental impacts on covered fish, and cost-effectiveness. The initial year of assessment will be used to improve understanding of the intricacies of implementing each strategy of predator reduction specifically in the Delta ecosystem. Initially, the implementation of the pilot program may be managed by Implementation Office staff, but eventually responsibility would transfer to CDFW and NMFS field staff.

After year 1 of pilot program implementation, the Implementation Office will refine the scope and methodology of the pilot program—based on review by and coordination with the fish and wildlife agencies—and continue with implementation for an additional 5 to 7 years. Review and coordination with the fish and wildlife agencies will occur every other year thereafter for the duration of the implementation period. At the end of this pilot implementation period, program assessment will involve independent science review and publication of findings. After the reviews are considered, the Adaptive Management Team, in collaboration with the fish and wildlife agencies, will refine operations and decide whether and in what form predator reduction and further adaptive management will continue.

3.4.15.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Research actions will be performed in conjunction with the pilot projects. The focus of the research actions will be to investigate the key uncertainties associated with localized predator reduction measures. Research to examine predation and other biotic interactions at the community scale is not a priority of the BDCP research program, although such information would be useful to provide a broader context for planning and interpretation of results. Examples would include pelagic organism decline studies (Baxter et al. 2010) and bioenergetics studies at the ecosystem scale (Loboschefsky et al. 2012). The Adaptive Management Team will designate a Technical Working Group to issue requests for proposals to evaluate the key uncertainties associated with CM15. The Technical Working Group will then evaluate submitted proposals and award grant funds managed by the Implementation Office.

Examples of key uncertainties identified in Section 3.4.15.2.2, *Management Principles and Uncertainties*, and potential research actions for CM15 are provided in Table 3.4.15-2. Specific research actions, and their timeframe for implementation, will be chosen by the Adaptive Management Team.

1 **Table 3.4.15-2. Key Uncertainties and Potential Research Actions Relevant to CM15**

Key Uncertainty	Potential Research Action	Timeframe
Where is predation likely to occur in the vicinity of the new North Delta intakes?	Perform field evaluation of similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District) and identify predator habitat areas at those facilities (same as FFTT preconstruction study 5, *Predator Habitat Locations*).	1 or 2 year study; needed prior to intake facility final design
What are the best predator reduction techniques? Which are feasible, most effective, and best minimize potential impacts on covered species?	Perform literature search and potentially field evaluations at similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District). Test and evaluate various predator reduction techniques at operational south Delta facilities with regards to efficacy, logistics, feasibility, cost and benefits, and public acceptance. Determine if these techniques also take covered fishes and assess ways to reduce such by-catch, if necessary (extended version of FFTT Pre-construction study 6, Predator Reduction Methods).	2 years, to be completed prior to final design of north Delta intakes
What are predator density and distribution in the intake reach of the Sacramento river?	Use a Didson camera or other technology and/or acoustic telemetry at two to three proposed screen locations; perform velocity evaluation of eddy zones if needed. Collect baseline predator density and location data prior to facility operations; compare to density and location of predators near operational facility. Identify ways to reduce predation at the facilities (same as FFTT study 9. *Predator Density and Distribution*, both pre- and postconstruction).	Start studies as soon as possible to collect multiple datasets before construction begins. Continue with 3-year postconstruction study (provided varied river flows and sufficient predator populations)
How should hotspots for localized predator reduction and/or habitat treatment be prioritized?	Document the extent and locations of predator hotspots within the Delta, and evaluate relative intensity of predation and feasibility of treatment. Use a habitat suitability approach at known hotspots to identify specific physical features and hydrodynamic conditions that facilitate elevated predation loss. Perform tagging studies to identify areas that facilitate intense predation (e.g., Bowen et al. 2009; Vogel 2011).	1-year study, performed by year 5
Which predator species and life stages have the greatest potential impact on covered fish species?	Determine whether large predators that are comparatively easy to target for reduction are the key predators of some or many covered fishes. Conduct site-specific monitoring of predator abundance (by species and life stage) during periods when covered fish species (particularly juvenile salmonids) are present. Determine site-specific diet composition of predators (e.g., using DNA analysis of predator stomach contents).	1- to 3-year study, performed by year 5

Key Uncertainty	Potential Research Action	Timeframe
What are the effects of localized predator reduction measures on predator fish and covered fish species?	Use before and after studies to evaluate the distribution and abundance of predators and covered fish species at treatment location and nearby sites. Metrics include abundance, age classes, and distribution of predators such as striped bass, largemouth bass, and other smaller piscivorous fish. Measure rates of site recolonization by predators following reduction treatments.	2- to 3-year study, performed by year 5
Is modification of sportfishing regulations a viable and effective means of achieving localized predator reduction?	Perform literature review and interviews with qualified agency and independent scientists to summarize potential benefits, hazards, costs, and implementation issues associated with using modification of sportfishing regulations to manage predatory fish in the Delta.	Up to a 1-year study performed by year 5
Under what circumstances and to what degree does predation limit the productivity of covered fish species?	Evaluate predation effect on productivity of covered fish species using life-cycle simulation models and site-specific bioenergetics modeling (Loboschefsky et al. 2012).	1-year study, best performed after other studies providing detailing the incidence of predation
How have other BDCP conservation measures affected the distribution and intensity of predation in the Plan Area?	Restoration actions are expected to create additional habitat for some species of predators along with covered species (e.g., *CM2 Yolo Bypass Fisheries Enhancement*, *CM4 Tidal Natural Communities Restoration*, *CM5 Seasonally Inundated Floodplain Restoration*, *CM6 Channel Margin Enhancement*, and *CM7 Riparian Natural Community Restoration*). Monitoring and potential active adaptive management studies will be developed, if increased predation is suspected or demonstrated in conjunction with habitat restoration or enhancement projects.	Study timing and duration to be determined by Adaptive Management Team; studies best performed periodically during BDCP implementation as progress proceeds on these other CMs.

Compliance monitoring for the pilot program will consist of documenting the progress of the pilot program and research actions in annual adaptive management and monitoring reports. After about 5 to 7 years, the results and findings from the pilot program studies will be synthesized into a comprehensive report, which will be formally evaluated by an independent scientific review committee. The public release of the scientifically reviewed report would coincide with a symposium to formally present the findings and receive feedback. Based on feedback on the formal report and from the symposium, the Adaptive Management Team will recommend to the Permit Oversight Group and Authorized Entity Group to either continue with predator reduction strategies or halt further predator reduction actions.

Predator control plans will be working documents that will be updated and revised, as needed, to document current best practices. All predator control plans will be formally reviewed and updated by the Implementation Office at least every 5 years to ensure that the adaptive management and monitoring program (Section 3.6) and the results of the latest research are being applied to management at each predator hotspot.

It is expected that as the pilot program results are used to develop effective predator reduction actions, effectiveness and compliance monitoring will be used to track those actions. The findings will be used to modify CM15 to improve program effectiveness with minimal negative impacts. The actions may also be adjusted as described in Section 3.6, *Adaptive Management and Monitoring Program*, with the development of new restoration techniques and other pertinent information as it becomes available.

3.4.15.4 Consistency with the Biological Goals and Objectives

CM15 will advance the biological goals and objectives as identified in Table 3.4.15-3. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.15-3. Biological Goals and Objectives Addressed by CM15

Biological Goal or Objective	How CM15 Advances Biological Objective
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.	
Objective L2.8: Provide refuge habitat for migrating and resident covered fish species.	In tandem with *CM4 Tidal Natural Communities Restoration*, *CM6 Channel Margin Enhancement*, and *CM13 Invasive Aquatic Vegetation Control*, CM15 may increase the number of Delta locations that provide low predation risk.
Goal L4: Increased habitat suitability for covered fish species in the Plan Area.	
Objective L4.1: Manage the distribution and abundance of nonnative predators in the Delta to reduce predation on covered fishes.	CM15 will directly reduce the abundance of established nonnative predators in localized areas of the Delta where predation is a significant source of mortality for juvenile salmonids.
Objective L4.2: Manage the distribution of covered fish species to minimize movements into areas of high predation risk in the Delta.	Reducing predator abundance at known predation hotspots is intended to reduce the number and confine the distribution of areas of high predation risk.
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.	
Objective WRCS1.1: Improve through-Delta survival.[a]	Reducing predator abundance at known predation hotspots is intended to reduce predation of all juvenile salmonids that migrate through or rear in the Delta. This will contribute toward increasing through-Delta survival.
Goal SRCS1: Increased spring-run Chinook salmon abundance.	
Objective SRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.	
Objective FRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.
Goal STHD1: Increased steelhead abundance.	
Objective STHD1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.
[a] Summarized objective statement; full text presented in Table 3.3-1.	

3.4.16 Conservation Measure 16 Nonphysical Fish Barriers

Under *CM16 Nonphysical Fish Barriers*, the Implementation Office will use nonphysical barriers to redirect juvenile fish away from channels and river reaches in which survival is lower than in alternate routes (Figure 3.4-33). Nonphysical barriers may be installed and operated from October to June or when monitoring determines that salmonid smolts are present in the target areas. Nonphysical fish barriers have not been shown to be effective for other covered fish species; thus, this conservation measure is only expected to yield beneficial outcomes for salmonids. Refer to Section 3.4.16.2.2, *Siting and Design Considerations*, for further discussion.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM16. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM16 on covered species will be avoided or minimized. Refer to Chapter 5, Section 5.5, *Effects on Covered Fish*, for effects of CM16 on covered fish species.

The primary purpose of CM16 is to meet or contribute to achieving biological goals and objectives related to increasing the survival of juvenile salmonids. This conservation measure is intended to increase survival by discouraging fish from entering channels known to result in higher mortality than other viable migration routes.

3.4.16.1 Problem Statement

For descriptions of the ecological values and current condition of fish barriers in the Plan Area, see Chapter 2, Section 2.3.3.3.3, *Water Supply Facilities and Facility Operations,* and Section 3.3.7.3, *Chinook Salmon, Sacramento River Winter-Run ESU*. Section 3.3.7.3 (and subsequent salmonid sections) also describes the need for nonphysical fish barriers as a component of the conservation strategies for covered salmonids, based on the existing conditions and ecological values of these resources.

The discussion below describes conditions that may be improved through implementation of CM16.

Juvenile salmonids experience low survival rates while migrating through the Delta toward the ocean. Survival rates vary among routes taken through the Delta (Brandes and McLain 2001; Perry and Skalski 2008, 2009; Holbrook et al. 2009; Perry et al. 2009), potentially as a result of differential exposure to predation, entrainment mortality at state and federal water export facilities and small agricultural diversions, and other factors associated with particular routes taken through the Delta (San Joaquin River Group Authority 2006; Bureau pers. comm.; Perry et al. 2009).

Survival for routes through the interior Delta was at most 35% that of survival for fish remaining in the Sacramento River (Perry et al. 2009). Such low probability of survival when migrating through the interior Delta indicates that significant population-level impacts could result if a sizable portion of the salmon population passed through this area. Perry and Skalski (2009) found that 20 to 35% of tagged salmon used Sutter and Steamboat Sloughs during migration, while 27% to nearly 33% of the population entered the interior area. Low survival probabilities and high proportions of the population migrating through the interior Delta combine to significantly reduce salmon survival through the Delta during migration. Physical barriers have been used in the Delta, such as the Delta Cross Channel gates and the rock barrier at the Head of Old River, to prohibit the entry of fish into channels where survival rates are low. Physical barriers are effective at prohibiting entry of salmonids into channels, but they also alter flow dynamics in these channels, which may affect tidal flows, sediment loads, bathymetry, water supply reliability, potential for noxious algal blooms, toxic concentrations, and other water quality parameters. Operation of nonphysical barriers is predicted to cause smaller changes in the physical configuration of the channel, thus reducing flow-related effects, while improving survival of salmonids by deterring or discouraging them from entering channels with a higher risk of mortality.

Installation and seasonal operation of nonphysical barriers are hypothesized to improve survival of juvenile salmonids migrating downstream by guiding fish into channels in which they experience lower mortality rates (Welton et al. 2002; Bowen et al. 2009; Bowen and Bark 2010). A nonphysical barrier induces behavioral aversion using a combination of sound, lights, and bubbles (called a three-component barrier). Such nonphysical barriers have shown promising results in laboratory experiments on juvenile Chinook salmon in conditions emulating the Sacramento River/Georgiana Slough flow split (Bowen et al. 2008) and a field experiment on Atlantic salmon (*Salmo salar*) smolts in the River Frome, UK (Welton et al. 2002). Preliminary evidence suggests that a three-component barrier was effective in deterring, or discouraging acoustically tagged Chinook salmon juveniles from entering the head of Old River during a 2009 pilot study (Bowen et al. 2009). Field trials of nonphysical barriers that use only one component, such as sound or light, have demonstrated less success in deterring fish. For example, out of 25 separate single-component sound and light systems placed in 21 different locations in Europe and the United States to affect the behavior of salmonids near water intakes and canals, fewer than 50% were effective in altering fish behavior (Bureau of Reclamation 2008).

The three-component Nonphysical Barrier Test Project at the divergence of Old River from the San Joaquin River (head of Old River) in the Delta successfully deterred 81% of acoustically tagged Chinook salmon smolts from entering Old River (Bowen et al. 2009). Deterred fish are those fish that approach within 2 meters or less of the nonphysical fish barrier but do not cross the barrier, as determined by direct inspection of tracking data. However, the protection efficiency (i.e., the relative proportion of smolts successfully going down the San Joaquin River instead of Old River, without being preyed upon) did not differ between barrier-on and barrier-off conditions, because a large proportion of deterred smolts were preyed upon at a scour hole just downstream of the nonphysical barrier. Therefore, the success of CM16 may be conditional on the implementation of *CM15 Localized Reduction of Predatory Fishes* to reduce predation at "hotspots" such as scour holes. In 2010, flows at the Head of Old River–San Joaquin River divergence were substantially higher than in 2009 and resulted in a greatly reduced deterrence efficiency (23%) that was nevertheless statistically highly significant compared to deterrence rates with the barrier turned off (0.5%) (Bowen and Bark 2010). Of the smolts not preyed upon in the study area, the protection efficiency was statistically significantly greater with the barrier on (43%) than with the barrier off (26%), meaning fewer fish were preyed upon with the barrier on than with the barrier off.

DWR has undertaken a pilot study using a similar three-component nonphysical barrier at the Georgiana Slough–Sacramento River divergence to determine the effectiveness of the Bio-Acoustic Fish Fence in preventing outmigrating juvenile Chinook salmon from entering Georgiana Slough (California Department of Water Resources 2012c). Approximately 1,500 acoustically tagged juvenile late fall–run Chinook salmon produced at the Coleman National Fish Hatchery were released into the Sacramento River upstream of Georgiana Slough and their downstream migrations past the nonphysical barrier and divergence with Georgiana Slough were monitored (California Department of Water Resources 2012c). During the 2011 study period, the nonphysical barrier reduced the percentage of salmon smolts passing into Georgiana Slough from 22.1% (barrier off) to 7.4% (barrier on), a reduction of approximately two-thirds of the fish that would have been entrained. This improvement produced an overall efficiency rate of 90.8%; that is, 90.8% of fish that entered the area when the barrier was on exited by continuing down the Sacramento River. There was some indication that the behavior and movement patterns of juvenile salmon were influenced by the high river flows that occurred in spring 2011. However, at high (> 0.25 meter per second) and low (< 0.25 meter per second) across-barrier velocities, barrier-on operations resulted in statistically significant increases in overall efficiency for juvenile salmon. While the response by juvenile Chinook salmon to the nonphysical barrier at Georgiana Slough appears positive, it does not necessarily reflect the response of steelhead (California Department of Water Resources 2012c).

3.4.16.2 Implementation

3.4.16.2.1 Required Actions

The Implementation Office may install nonphysical barriers at the sites described below. These barriers will use a combination of sound, light, and bubbles, similar to the three-component nonphysical barrier used in the 2009 DWR Head of Old River Test Project (Bowen et al. 2009). Design and permitting for the initial barrier installations will take approximately 2 years, with installation and operation beginning in year 3. The cost estimate for this conservation measure (Chapter 8, *Implementation Costs and Funding Sources*) assumes that seven barriers would be constructed and operated during the permit term; however, fewer than seven barriers may be constructed if they are found to be less effective biologically and more expensive per barrier than the cost estimates. Similarly, more than seven barriers may be constructed if they are found be biologically effective and less costly per barrier than estimated.

3.4.16.2.2 Siting and Design Considerations

Siting and design considerations may include survival rates of juvenile salmonids along specific migration routes within the Plan Area; site-specific conditions such as flow, turbidity, substrate, and channel bathymetry; and predator interation with nonphysical barriers. Currently, likely sites for nonphysical barrier placement include Head of Old River (Figure 3.4-34), Delta Cross Channel, Georgiana Slough, and possibly Turner Cut and Columbia Cut. Barriers at these locations have a high potential to deter juvenile salmonids from using specific channels/migration routes that may contribute to decreased survival resulting from increased predation and/or entrainment, or to direct juvenile salmonids to areas that may increase their survival such as Yolo Bypass. The Implementation Office may consider other locations in the future, if, for example, future research demonstrates differential rates of survival in Sutter and Steamboat Sloughs or in Yolo Bypass relative to the mainstem Sacramento River. The Implementation Office will be responsible for installation, operation, maintenance, and removal of the nonphysical barriers. Nonphysical barrier placement may be accompanied by actions to reduce local predator abundance, if monitoring finds that such barriers attract predators or direct covered fish species away from potential entrainment hazards but toward predator hotspots. Barriers will be removed and stored offsite while not in operation (Holderman pers. comm.).

Site-specific conditions will drive the design of nonphysical barrier in terms of techniques to anchor and secure the structure, measures to indicate the location of the structure for the safety of waterway users (i.e., recreational boaters) and preferences for fish migration routes. As described in Chapter 8, *Implementation Costs and Funding Sources*, the capital and operational costs of nonphysical barriers increase dramatically in deep and wide sections of channels. Therefore, the expected and measured benefits of the barrier at a particular location will be evaluated against its biological benefits.

The Implementation Office will evaluate the potential for nonphysical barriers to attract predators. Initial studies carried out by the Bureau of Reclamation (2009) indicate that nonphysical barriers may attract predators such as striped bass; however, it is not clear if predator densities are higher near nonphysical barriers, if certain types of nonphysical barriers may be more attractive to predators (e.g., sound, air and/or light barriers), or how effective certain types/combinations of barriers are at directing covered salmonids away from areas with a high risk of entrainment and/or predation based on site-specific conditions. Further investigations are necessary to determine whether, and under what conditions, nonphysical barriers may be appropriate.

3.4.16.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting in a database the installation and operation of nonphysical fish barriers.

Effectiveness monitoring will consist of assessing the effectiveness of nonphysical barriers, including the pilot testing now under way in the Delta. The Implementation Office will use results of effectiveness monitoring to determine whether operations of nonphysical barriers result in measurable benefits to juvenile salmonids and to identify adjustments to funding levels, methods, or other related aspects of the program that would improve its biological effectiveness. Effectiveness monitoring actions will include tagging hatchery-reared juvenile salmonids, releasing these fish upstream of nonphysical barriers, and monitoring their migration both with and without the nonphysical fish barrier operating. Different configurations of nonphysical fish barriers (i.e., lights, sound, and/or bubbles) may be employed to determine the differences in effectiveness.

Table 3.4.16-1 provides potential monitoring actions, metrics, success criteria, and timing and duration for monitoring relevant to CM16. These monitoring elements may be modified, as necessary, to best assess the effectiveness of CM16, based on the best available information at the time of implementation.

Table 3.4.16-1. Effectiveness Monitoring Relevant to CM16

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM16-1	Site-Level Assessment	Migration	Monitor the effectiveness of nonphysical fish barriers in deterring juvenile salmonids from migrating into interior Delta and other waterways known to result in reduced survival	Annually for 5 years beginning at permit authorization, reevaluating monitoring needs after year 5

Table 3.4.16-2 lists key uncertainties and research actions relevant to CM16. If any changes to the program are warranted based on the results of research and effectiveness monitoring, they will be implemented through the adaptive management decision-making process, and through subsequent annual work plans.

Table 3.4.16-2. Key Uncertainties and Potential Research Actions Relevant to CM16

Key Uncertainty	Potential Research Actions
How effective are nonphysical barriers over the long term?	• Evaluate change in survivorship of covered species. • Evaluate effectiveness of barriers in high-flow areas. • Monitor changes in proportion of covered species distribution and abundance upstream and downstream of barrier. • Evaluate behavioral response of covered species to barriers. • Evaluate the effectiveness and permeability of nonphysical barriers with studies using tagged juvenile salmonids.
How do nonphysical barriers affect predators?	• Determine the abundance of predators within the area of the nonphysical barriers, both before and after installation, and evaluate the effect of the barriers on the survival of outmigrating juvenile salmonids. • Evaluate effectiveness of deterrents on green sturgeon, white sturgeon, and Chinook salmon. • Evaluate potential attraction of predators to fish nonphysical barriers (e.g., type and number of predators). • Evaluate the extent of predator aggregation at nonphysical barriers before and after installation. • Evaluate predator composition before and after installation of nonphysical barriers. • Evaluate predator response to operation of nonphysical barriers.

Nonphysical fish barriers are not proposed for delta smelt or longfin smelt, because the barriers have not undergone field trials for these species. Previous laboratory-based evidence suggested that a nonphysical barrier configuration effective in deterring salmon smolts was not effective in deterring delta smelt (Bowen et al. 2008). Subsequent laboratory studies have shown that significant deterrence of delta smelt by nonphysical barriers may occur, if through-barrier water velocity is sufficiently low to allow avoidance (Bowen pers. comm.). If the Adaptive Management Team finds that nonphysical barriers are demonstrated to be effective in deterring delta smelt and longfin smelt, they may recommend that the Permit Oversight Group and the Authorized Entity Group jointly approve installation of nonphysical barriers at the mouths of Old and Middle Rivers and in Three Mile Slough (if salinity manipulation is not also needed) to deter these species from moving into these channels where the risk of entrainment to the south Delta export facilities is relatively high.

3.4.16.4 Consistency with the Biological Goals and Objectives

CM16 will advance the biological goals and objectives as identified in Table 3.4.16-3. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.16-3. Biological Goals and Objectives Addressed by CM16

Biological Goal or Objective	How CM16 Advances Biological Objective	Monitoring Action
Goal L4: Increased habitat suitability for covered fish species in the Plan Area.		
Objective L4.2: Manage the distribution of covered fish species to minimize movements into areas of high predation risk in the Delta.	Nonphysical fish barriers provide a means of diverting covered fish species, primarily salmonids, from waters that pose a high risk of entrainment and/or predation.	CM16-1
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.		
Objective WRCS1.1: Improve through-Delta survival.[a]	Nonphysical fish barriers are intended to encourage juvenile salmonids to avoid migration routes in the Plan Area that are known to have a high risk of entrainment and/or predation, thereby contributing toward increased through-Delta survival.	CM16-1
Goal SRCS1: Increased spring-run Chinook salmon abundance.		
Objective SRCS1.1 (Juvenile Survival): Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM16-1
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.		
Objective FRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM16-1
Goal STHD1: Increased steelhead abundance.		
Objective STHD1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM16-1

[a] Summarized objective statement; full text presented in Table 3.3-1.

3.4.17 Conservation Measure 17 Illegal Harvest Reduction

Under *CM17 Illegal Harvest Reduction*, the Implementation Office will reduce illegal harvest of Chinook salmon, Central Valley steelhead, and sturgeon in the Delta, bays, and upstream waterways by providing funding to increase the enforcement of fishing regulations in the Delta, bays and upstream waterways with the goal of reducing illegal harvest of covered salmonids and sturgeon.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM17. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that adverse effects of CM17 on covered species will be avoided or minimized. Refer to Chapter 5, *Effects Analysis*, Section 5.5.3.1.5, *Reduced Illegal Harvest*, for a discussion of the beneficial effects of CM17 on covered fish species.

The primary purpose of CM17 is to increase the enforcement of fishing regulations in the Plan Area to reduce illegal harvest of adult salmonids and sturgeon. This action is expected to contribute to meeting biological goals and objectives relevant to abundance and distribution of adult salmonids and sturgeon in the Plan Area.

3.4.17.1 Problem Statement

Illegal harvest is thought to have substantial effects on sturgeon populations, particularly white sturgeon (Beamesderfer et al. 2007). Illegal harvest of juvenile and adult Chinook salmon and steelhead in the Delta and bays is also common (Laughlin 2007).

Section 3.3, *Biological Goals and Objectives*, describes the need for illegal harvest reduction as a component of the conservation strategies for covered species, based on the existing conditions and ecological values of the fish resources in the Plan Area.

California has a population of approximately 37 million people (U.S. Census Bureau 2012), but has fewer than 200 field wardens. This is the lowest game warden-to-population ratio of any state in the nation. The CDFW Delta-Bay Enhanced Enforcement Program (DBEEP) currently provides a squad of 10 CDFW game wardens tasked with enforcing regulations against poaching of anadromous fish species in the Delta. The program is funded by water contractors through the Delta Fish Agreement (California Department of Water Resources and California Department of Fish and Game 1986). The Implementation Office will contribute directly to this existing program to expand its size. The current 10-person DBEEP team has proven to be very effective since its inception, and is an excellent example of what a team of fish and game wardens can do when allowed to direct its efforts at a significant issue such as enforcement within the San Francisco Bay and Delta region. An increase in the number of wardens on the DBEEP team will provide a higher level of protection for all fish species and habitat in the Delta, and will allow CDFW to work more high-priority poaching issues (California Department of Fish and Game 2012a). This is expected to provide more effective enforcement against the illegal harvest of covered species.

3.4.17.2 Implementation

The Implementation Office will provide funds to CDFW to hire and equip 24 additional staff (17 additional game wardens and seven supervisory and administrative staff) in support of the existing field wardens assigned to the DBEEP. These staff increases will be supported for the duration of the BDCP permit term. It is expected that it will take 2 to 3 years to achieve the staff increases, with the full increase in enforcement efforts associated with CM17 beginning in year 3.

The additional game wardens will conduct patrols throughout the Delta wherever deemed necessary to reduce illegal harvest of adult salmonids and sturgeon. Increased enforcement as part of CM17 will be focused on the Bay-Delta area and its waterways; however, increased enforcement outside of the Plan Area may occur as part of CM17. Any reduction in illegal harvest of covered fish species, whether inside or outside the Plan Area, is expected to contribute to the achievement of the biological goals and objectives for the covered fish species, as outlined in Table 3.4.17-1. One location where increased patrols are expected to occur is the Fremont Weir, both before and following improvement to the structure planned as part of *CM2 Yolo Bypass Fisheries Enhancement*. There is increased risk of illegal harvest of adult salmonids and sturgeon when the fish become concentrated in the pool immediately downstream of the Fremont Weir. Increased enforcement will deter illegal fishing and contribute to a decrease in illegal harvest.

3.4.17.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting funding and actual costs for providing required CDFW staff in the Plan Area, and determining and reporting compliance ratios in routine enforcement activities including the number of contacts with the public and number of warnings and citations issued per year. Determination of compliance ratios will be based on the DBEEP annual reports, which summarize actions and accomplishments over the previous year.

The Implementation Office will coordinate with CDFW to adjust enforcement strategies and funding levels through the adaptive management process described in Section 3.6, based on review of DBEEP annual reports. DWR will coordinate with CDFW to ensure that information that could be important to the BDCP is included and summarized in the DBEEP annual reports upon BDCP permit authorization.

The current level of illegal harvest within the Plan Area is unknown. Poachers may shift illegal harvest efforts and strategies to avoid detection, especially more sophisticated and organized poaching rings that may be operating within the Plan Area. Organized groups of poachers targeting sturgeon are likely the greatest concern because of the high prices that white sturgeon caviar can fetch. Recreational anglers who may inadvertently catch and keep a fish because of misidentification or lack of understanding or knowledge of recreational fishing regulations are also a concern. An increase in enforcement is expected to result in a decrease in illegal harvest within the Plan Area over time and will be monitored to evaluate the effectiveness of increase enforcement; however, it will be difficult to definitively document a decrease in illegal harvest or to conclude that an increase or decrease in the number of citations issued in a given year equates to a reduction in the extent of illegal harvest occurring within the Plan Area. Thus, the principal tool for effectiveness monitoring will be tracking trends in the number and distribution of citations and arrests relative to level of effort.

Table 3.4.17-1 provides potential monitoring actions, metrics, success criteria, and timing and duration for monitoring relevant to CM17. These monitoring elements may be modified, as necessary, to best assess the effectiveness of CM17, based on the best available information at the time of implementation.

Table 3.4.17-1. Effectiveness Monitoring Relevant to CM17

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM17-1	Illegal Harvest Tracking	Increase enforcement and track trends in number, types and distribution of citations and arrests associated with illegal harvest made by warden within the Plan Area.	An increase in the abundance of covered salmonids and green and white sturgeon over time.	Year-round enforcement and annual reporting, for the duration of the BDCP permit term.

Key uncertainties include whether increased enforcement reduces illegal harvest and whether increased enforcement has beneficial effects on anadromous fish stocks. Monitoring data will be used to answer these uncertainties by evaluating the incidence of illegal take of covered species (especially Chinook salmon, steelhead, and sturgeon) and whether changes in abundance and population dynamics can be attributed to reductions in illegal harvest.

3.4.17.4 Consistency with Biological Goals and Objectives

CM17 will advance the biological goals and objectives as identified in Table 3.4.17-2. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.17-2. Biological Goals and Objectives Addressed by CM17 and Related Monitoring Actions

Biological Goal or Objective	How CM17 Advances Biological Objective	Monitoring Action
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.		
Objective WRCS1.3: Reduce illegal harvest.[a]	CM17 will directly contribute toward achieving this objective by focusing on reducing illegal harvest of covered fishes through increased enforcement in the Plan Area.	CM17-1
Goal SRCS1: Increased spring-run Chinook salmon abundance.		
Objective SRCS1.3: Reduce illegal harvest.[a]	See Objective WRCS1.3 above.	CM17-1
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.		
Objective FRCS1.3: Reduce illegal harvest.[a]	See Objective WRCS1.3 above.	CM17-1
Goal STHD1: Increased steelhead abundance.		
Objective STHD1.3: Reduce illegal harvest.[a]	See Objective WRCS1.3 above.	CM17-1
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.		
Objective GRST1.1: Improve juvenile and adult survival.[a]	CM17 will directly contribute toward achieving this objective by focusing on reducing illegal harvest of covered fishes, including green sturgeon, in the Plan Area, thereby increasing survival of adult green sturgeon.	CM17-1
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.		
Objective WTST1.1: Improve juvenile and adult survival.[a]	CM17 will directly contribute toward achieving this objective by focusing on reducing illegal harvest of covered fishes, including white sturgeon, in the Plan Area, thereby increasing survival of adult white sturgeon.	CM17-1
[a] Summarized objective statement; full text presented in Table 3.3-1.		

Enhanced enforcement on poaching will contribute toward reducing mortality and potentially increasing population sizes of green sturgeon (Beamesderfer et al. 2007; Boreman 1997; California Department of Fish and Game 2007a), white sturgeon (Bay-Delta Oversight Council 1995; Boreman 1997; Schaffter and Kohlhorst 1999; Beamesderfer et al. 2007; California Department of Fish and Game 2007b, 2008c), Chinook salmon (all races) (Bay-Delta Oversight Council 1995; Williams 2006), and steelhead (California Department of Fish and Game 2007a, 2008c, 2008d; Moyle et al. 2008).

Spring-run Chinook salmon are expected to experience the greatest benefit, because their over-summer holding and ease of locating may make them more susceptible to poaching than other runs. Additionally, CM17 could reduce mortality and potentially increase population size of splittail in light of the daily bag limits for splittail recently established by the California Fish and Game Commission.

Magnitudes of population-level benefits of CM17 are expected to vary inversely with the population size of each covered species (Bay-Delta Oversight Council 1995; Begon et al. 1996; Futuyma 1998; Moyle et al. 2008).

3.4.18 Conservation Measure 18 Conservation Hatcheries

Under *CM18 Conservation Hatcheries*, the Implementation Office will establish new and expand existing conservation propagation programs for delta and longfin smelt. The Implementation Office will support two programs.

- The development of a delta and longfin smelt conservation hatchery by USFWS to house a delta smelt refugial population and provide a continued source of delta and longfin smelt for experimentation.
- The expansion of the refugial population of delta smelt and establishment of a refugial population of longfin smelt at the University of California (UC) Davis Fish Conservation and Culture Laboratory (FCCL) in Byron.

The principal purpose of CM18 is to ensure the existence of refugial captive populations of both delta and longfin smelt, thereby helping to reduce risks of extinction for these species. The use of two refugial facilities will decrease the likelihood of catastrophic loss of captive fish to disease. The refugial populations will also constitute a source of animals for experimentation, as needed, to address key uncertainties about delta and longfin smelt biology. This approach minimizes the need to harvest wild stock for research purposes. This conservation measure will also support achievement of the biological goals and objectives, as detailed below in Section 3.4.18.4, *Consistency with the Biological Goals and Objectives.*

The refugial populations established and maintained by USFWS with funding from the BDCP could also function as a source of animals for reintroduction or supplementation of wild populations. Reintroduction or supplementation is not proposed by the BDCP. However, if deemed necessary by USFWS and CDFW, and if technically feasible, the hatcheries could be used for this purpose independent of the BDCP.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM18. Refer to Table 5.4-1 and Table 5.6-1 in Chapter 5, *Effects Analysis*, for a discussion of the effects of CM18 on covered species and natural communities. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM18 on covered species will be avoided or minimized.

3.4.18.1 Problem Statement

For descriptions of the ecological values and current condition of delta and longfin smelt in the Plan Area, see Chapter 2, *Existing Ecological Conditions,* and Section 3.3, *Biological Goals and Objectives*. The decline of delta smelt prompted listings under both the ESA and the California Endangered Species Act (CESA). USFWS currently lists delta smelt as threatened under the ESA; California Fish and Game Commission classifies delta smelt as endangered under the CESA. Similar declines in the longfin smelt population in the Bay-Delta prompted the California Fish and Game Commission in 2010 to list the species as threatened under CESA. The longfin smelt is currently a candidate species for listing under the ESA. Bay-Delta populations of both delta smelt and longfin smelt have experienced dramatic declines over the past five decades of monitoring, including further declines over the past decade or so due to a combination of factors (Sommer et al. 2007b; Baxter et al. 2008, 2010) (Figure 2.A.1-2, *Annual Abundance Indices of Delta Smelt Delta Smelt from 1959 to 2009*, and Figure 2.A.2-3, *Annual Abundance Indices of Longfin Smelt from 1967 to 2009*, in Appendix 2.A). Delta smelt continue to decline. It is possible that very low population size could result in an Allee effect[43], causing an even more rapid decline of the species due to factors unique to small populations (Baxter et al. 2008). Allee effects occur because, below a certain threshold, the individuals in a population can no longer reproduce rapidly enough to replace themselves, and the population spirals toward extirpation. Thus, if Allee effects are acting on the delta smelt population now, or do so in the future, then the risk of extirpation of delta smelt would increase. Longfin smelt abundance has followed a trend similar to delta smelt culminating in record low abundance indices several times in the past decade (Sommer et al. 2007b; Baxter et al. 2008, 2010), so there may also be a potential for Allee effects in the longfin smelt population.

Genetic analyses indicate that delta smelt constitutes a single, well-mixed population (Stanley et al. 1995; Trenham 1998; Fisch et al. 2009; Fisch 2011). Genetic variation within Bay-Delta longfin smelt has received less detailed study, but work to date (Stanley et al. 1995; Israel and May 2010) has not identified multiple populations in the region. Accordingly, it is likely that a single refugial population could be used to preserve and maintain a significant fraction of genetic diversity at the species (for delta smelt) or distinct population segment (for longfin smelt) level.

Implementation of CM18 is thus expected to reduce the risk of extinction for both species via *ex situ* conservation of refugial populations. Artificial propagation and maintenance of refugial populations of delta and longfin smelt would provide the following benefits.

- Provide a safeguard against the possible extinction of delta and/or longfin smelt by maintaining captive populations that have genetic variability reflecting that of naturally spawned populations (Lande 1988; Hedrick et al. 1995; Sveinsson and Hara 1995; Carolsfeld et al. 1997; Sorensen 1998; Hedgecock et al. 2000; Kowalski et al. 2006; Turner et al. 2007; Turner and Osborne 2008; Clarke pers. comm.; Essex Partnership 2009).
- Improve the knowledge base regarding threats to and management of delta and longfin smelt by providing an opportunity to study the effects of various stressors on these species in a controlled environment using hatchery-reared specimens instead of wild caught individuals.
- Establish a source population that, if sufficiently productive, could be used to supplement delta and longfin smelt populations naturally propagated in the wild (Lande 1988; Deblois and Leggett 1993; Sveinsson and Hara 1995; Carolsfeld et al. 1997; Sorensen 1998; Flagg et al. 2000; Richards et al. 2004; Kowalski et al. 2006; Purchase et al. 2007; Clarke pers. comm.). Such a supplementation, combined with effective habitat restoration and other measures to improve conditions in their natural environment, could contribute to achieving self-sustaining population levels in the wild. However, neither DFG nor USFWS has determined that such supplementation is necessary or appropriate, and such use is not proposed by the BDCP.

[43] Allee effects occur when reproductive output per fish declines at low population levels (Allee 1931).

3.4.18.2 Implementation

The new facility proposed by USFWS will house genetically managed refugial populations of delta and longfin smelt (Clarke 2008). The starting population for this new facility will likely consist of a combination of both wild-caught fish and hatchery broodstock supplied from the UC Davis FCCL facility (Hoover pers. comm.). At the existing USFWS delta smelt hatchery in the Livingston Stone Fish Hatchery, mortality rates of adult delta smelt are low. Transport mortality is less than 0.5% monthly, and fish are screened for pathogen risks prior to transport. Mortality during rearing ranges from 0.5 to 1% in the nonspawning months, and 3 to 5% during the spawning season due to necessary handling (Hoover pers. comm.) Mortality rates at the new facility are expected to be similar. State-of-the-art genetic management practices will be implemented to maintain close genetic variability and similarity between hatchery-produced and natural-origin fish. A minimum of 250 pairs of smelt will be housed at the new facility; this number was determined by the agencies as the minimum captive population necessary to avoid loss of genetic diversity over time (Hoover pers. comm.).

The facility will be designed to provide captive propagation of other species, if necessary, in the future. The facility will discontinue housing refugial populations of delta and longfin smelt only when these species achieve recovery, as defined by USFWS. The specifications and operations of this facility have not been developed, nor has the facility location been determined, though it is expected to be located within the Plan Area in the vicinity of Rio Vista. Additional permitting and environmental documentation will be needed to implement this conservation measure once facility designs and funding are available. Because of these challenges, it is expected that design, permitting, and construction of the facility will take approximately 6 years, with the facility becoming operational by year 7.

The FCCL is currently in need of additional space and funds to expand the refugial population of delta smelt and establish a refugial population of longfin smelt. Currently, the FCCL houses about 250 pairs of spawning delta smelt, which produce around 200,000 eggs each year. The FCCL is currently permitted to supplement its refugial population with 50 wild delta smelt per year, which are typically captured on the lower Sacramento River near Decker Island. At the FCCL, typical survival rates are about 10 to 20% from egg to adult, with most fish lost during the larval phase; adult mortality rates are typically low. The facility has started attempts to establish a longfin smelt refugial population, although dedicated funding at present is very limited. The facility is permitted to capture 50 wild longfin smelt a year, but ability to capture live, healthy, wild longfin smelt is limited. (Lindberg pers. comm.)

To expand both refugial populations and maintain them over the long term, this conservation measure assumes a maximum capture rate for delta smelt and longfin smelt of double the current maximum, to 100 each annually. Due to sampling constraints and actual need, this maximum capture rate is not expected to be needed every year.

The FCCL and the Genomic Variation Laboratory at UC Davis are and will be the primary entities developing and implementing genetic management of the delta smelt refugial population from 2009 through 2015 or longer; thereafter they may play a secondary role by keeping a back-up population(s). Design, permitting, and construction of upgrades to the existing FCCL facility are expected to take 3 years, with the upgrades becoming operational in year 4.

Genetic management practices will be implemented to maintain genetic diversity comparable to that of natural-origin fish, minimize genetic adaptation to captivity, minimize mean kinship, and equalize family contributions. The current genetic management plan for the refugial population of delta smelt at the FCCL has been shown to be successful in retaining genetic diversity of the founding wild broodstock through the F3 generation, preventing genetic divergence from the wild population by supplementing the captive population with wild fish, and maintaining an effective population size of more than 500 individuals (Fisch et al. 2009, 2010). The plan is expected to retain 90% of the founding population's genetic diversity over 100 generations (Fisch 2011); however, maintenance of genetic diversity likely would become more difficult if artificial propagation was implemented on a larger scale (Israel et al. 2011).

The Implementation Office will enter into binding memoranda of agreement or similar instruments with USFWS and UC Davis. If and when populations of these species are considered recovered by USFWS, the Implementation Office will terminate funding for the propagation of the species and either fund propagation of other covered fish species, if necessary and feasible, or discontinue funds to this conservation measure and reallocate them to augment funding other conservation measures identified in coordination with the fish and wildlife agencies through the adaptive management process (Section 3.6.3).

3.4.18.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting construction and operation of facilities at the FCCL to expand the refugial population of delta smelt and to establish a refugial population of longfin smelt.

Effectiveness monitoring will be used to verify success of the *ex situ* conservation program by showing maintenance of genetic diversity comparable to wild populations. Appropriate methods are under development currently and will be refined in collaboration with fish agency and hatchery staff.

There is one key uncertainty associated with CM18: Can refugial populations of both delta and longfin smelt be maintained with little or no supplementation from wild stocks? Answering this question will require the development of techniques for ensuring successful breeding and survivorship, so that refugial populations can be shown to increase without further supplementation from wild stocks.

Based on review of monitoring results in USFWS and UC Davis annual reports, the Implementation Office, in coordination with fish and wildlife agencies and UC Davis, will adjust funding levels, hatchery operations, or other related aspects of the conservation measure in a manner that will improve the performance and/or biological effectiveness of the program through the adaptive management process (Section 3.6.3). Such changes would be incorporated in subsequent annual work plans.

Establishing viable refugial populations of delta smelt and longfin smelt would provide insurance against the potential extinction of these species. If the native smelt populations continue the trajectory of decline seen over most of the recent years, the point could come when a conservation hatchery is the only option to preserve them. A conservation hatchery also provides a stock of fish that could be used to test the effects of various stressors on these species in a controlled environment (e.g., Baskerville-Bridges et al. 2004; Bennett 2005), while minimizing the need to harvest wild stocks on a large scale and put them at further risk. Experiments performed on delta smelt and longfin smelt at the conservation hatcheries are anticipated to be important parts of targeted research associated with the BDCP adaptive management and monitoring program.

3.4.18.4 Consistency with the Biological Goals and Objectives

CM18 will advance the biological goals and objectives as identified in Table 3.4.18-1. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties to ensure that these biological goals and objectives are met.

Table 3.4.18-1. Biological Goals and Objectives Addressed by CM18

Biological Goal or Objective	How CM18 Advances Biological Objective
Goal DTSM1 Increased end of year fecundity and improved survival of adult and juvenile delta smelt to support increased abundance and long-term population viability.	
Objective DTSM1.3: Achieve an improved Recovery Index.[a]	The creation and expansion of refugial hatchery populations of delta and longfin smelt will ensure *ex situ* conservation of these species, which will contribute to ensuring their continued existence, a prerequisite to achieving abundance and population growth goals.
Goal LFSM1: Increased fecundity and improved survival of adult and juvenile longfin smelt to support increased abundance and long-term population viability.	
Objective LFSM1.1: Achieve longfin smelt population growth.[a]	See DTSM1.3.
[a] Summarized objective statement; full text presented in Table 3.3-1.	

3.4.19 Conservation Measure 19 Urban Stormwater Treatment

Under *CM19 Urban Stormwater Treatment,* the Implementation Office will provide a mechanism for implementing stormwater treatment measures that will result in decreased discharge of contaminants to the Delta. These measures will be focused on urban areas.

The primary purpose of CM19 is to contribute to Objective L2.5, which calls for water quality conditions within the Delta that help restore native fish habitat. Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM19. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM19 on covered species will be avoided or minimized. Refer to Appendix 5.D, *Contaminants*, for effects of CM19 on covered fish species.

3.4.19.1 Problem Statement

For descriptions of the ecological challenges and current condition of stormwater runoff in the Plan Area, see Chapter 2, *Existing Ecological Conditions*, and Section 3.3, *Biological Goals and Objectives*. Section 3.3 also describes the need for stormwater runoff management as a component of the conservation strategies for natural communities and associated covered species, based on the existing conditions and ecological values of these resources.

The discussion below describes conditions that will be improved through implementation of CM19.

Stormwater runoff is a leading source of water pollution in the United States and is a large contributor to toxic loads present in the Delta (Weston et al. 2005; Amweg et al. 2006; Werner et al. 2008). As stormwater runoff flows to the Delta, it accumulates sediment, oil and grease, metals (e.g., copper and lead), pesticides, and other toxic chemicals. Unlike sewage, stormwater is often not treated before discharging to surface water. Despite stormwater regulations limiting discharge volumes and pollutant loads, many pollutants enter Delta waterways. Of particular concern for fish species is the overuse of pesticides, some of which can have deleterious effects on the aquatic food chain (Weston et al. 2005; Teh et al. 2005). Pyrethroid chemicals used as pesticides on suburban lawns are of particular concern, and are a delivered to the Delta system by runoff. These chemicals at very low concentrations can have lethal effects on low trophic levels of the food chain (plankton), and mainly sublethal effects on covered fish species (Weston and Lydy 2010). Other urban pollutant sources, which can be transported directly or indirectly by stormwater runoff to the Delta, include nutrients from failing septic systems, and viruses and bacteria from agricultural runoff.

All major urban centers in the Delta, including Sacramento, Stockton, and Tracy, and multiple smaller cities must comply with NPDES Municipal Separate Storm and Sewer System (MS4) permits. These permits require municipalities to develop and implement a stormwater management plan or program with the goal of reducing the discharge of pollutants to the maximum extent practicable under Section 402(p) of the Clean Water Act. CM19 will be implemented within the context of these comprehensive plans. Phase II of the regulations that established MS4 permits requires smaller municipalities and construction sites, referred to as Small MS4s, to comply with similar requirements.

3.4.19.2 Implementation

3.4.19.2.1 Funding and Treatment Actions

The Implementation Office will oversee a program to provide funding for grants to entities such as the Sacramento Stormwater Quality Partnership, and/or counties and cities whose stormwater contributes to Delta waterways (hereafter the *stormwater entities*) under NPDES MS4 stormwater permits, to implement actions from and in addition to their respective stormwater management plans. Proposed actions will be reviewed by technical staff in the Implementation Office or by outside experts supporting the Implementation Office. Projects will be funded if the Implementation Office determines that they are expected to benefit covered species. Interagency agreements and program development are expected to take 2 years, with the program becoming operational in year 3. Individual actions under the program are expected to take approximately 5 years each to fund, design, permit, and construct.

Examples of stormwater and treatment BMPs that could be funded by this program can be found in the following sources.

- California Stormwater Quality Association (1993) stormwater BMP handbooks.
- State stormwater BMP manuals (U.S. Environmental Protection Agency 2012).

- National Menu of Stormwater Best Management Practices (U.S. Environmental Protection Agency 2008).

The list of relevant sources will continue to change, and the Implementation Office will retain discretion to approve applications proposing use of all known and reasonable treatment methodologies. Some of the types of actions that could be funded under this conservation measure include, but are not limited to those listed below.

- Constructing retention or irrigation holding ponds for the capture and irrigation use of stormwater.
- Designing and establishing vegetated buffer strips to slow runoff velocities and capture sediments and other pollutants.
- Designing and constructing bioretention systems (grass buffer strips, sand bed, ponding area, mulch layer, planting soil, and plants) to slow runoff velocities and for removal of pollutants from stormwater.
- Constructing stormwater curb extensions adjacent to existing commercial businesses that are likely to contribute oil and grease runoff.
- Establishing stormwater media filters to remove particulates and pollutants, such as that located at the American Legion Park Pump Station in Stockton.
- Providing funds for moisture monitors to be installed during construction of sprinkler systems at commercial sites that will eliminate watering when unnecessary.
- Providing support for establishment of onsite infiltration systems in lieu of new storm drain connections for new construction, such as pervious pavement in place of asphalt and concrete in parking lots and along roadways, and downspout disconnections to redirect roof water to beds of vegetation or cisterns on existing developed properties, including residential.

The Implementation Office will enter into binding memoranda of agreement or similar instruments with stormwater entities receiving grants under this conservation measure to ensure that their project is implemented.

3.4.19.2.2 Timing and Phasing

This conservation measure would be in effect over the BDCP permit term. The Implementation Office will advertise and promote this grant program to ensure that the first awards are made by year 2, assuming qualified projects are considered. Allowing a reasonable time for project design and implementation, the first stormwater treatment measures would likely be in place by year 5.

3.4.19.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting funding made available and provided to the Sacramento Stormwater Quality Partnership and/or jurisdictions in the Delta, and how funding was used toward implementing CM19.

Effectiveness monitoring will be conducted to evaluate progress toward advancing the biological objectives discussed below in Section 3.4.19.4, *Consistency with the Biological Goals and Objectives*. Individual stormwater entities will be responsible for conducting the monitoring necessary to assess the effectiveness of BDCP-supported elements of their stormwater management plans. Normally, such monitoring will be limited to that required by the applicable NPDES MS4 stormwater permit, which is intended to verify that discharges support applicable beneficial uses of the receiving waters. The Implementation Office may require further monitoring (e.g., to test effectiveness of experimental treatment measures), if such monitoring is determined appropriate during review of the project proposal (Section 3.6). The Implementation Office will provide ongoing review of monitoring, progress, and other relevant reports from the stormwater entities and will coordinate with the stormwater entities to adjust stormwater pollution reduction strategies and annual funding levels through the adaptive management process, as appropriate, based on this review.

The Adaptive Management Team will use results of effectiveness monitoring to determine if reducing stormwater pollution loads results in measurable benefits to covered fish species or their habitat and to identify adjustments to funding levels, control methods, or other related aspects of the program that will improve the biological effectiveness of the program. Recommended changes, if approved by the Permit Oversight Group and the Authorized Entity Group, will be included in subsequent annual work plans.

The Implementation Office may discontinue effectiveness monitoring for this measure in future years, if monitoring results indicate a strong correlation between reduction in stormwater pollution loads entering the Delta and responses of covered fish species. Such a determination is subject to review by the Adaptive Management Team and would require approval by the Permit Oversight Group and the Authorized Entity Group.

Table 3.4.19-1 provides potential monitoring actions, metrics, success criteria, and timing and duration for monitoring relevant to CM19. These monitoring elements may be modified, as necessary, to best assess the effectiveness of CM19, based on the best available information at the time of implementation.

Table 3.4.19-1. Effectiveness Monitoring Relevant to CM19

ID #	Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM19-1	Conduct ongoing review of monitoring, progress, and other relevant reports from the stormwater entities.	Decreases in stormwater constituents/pollutant loads such as total suspended sediment, oil and grease, total and dissolved metals (i.e., copper and zinc), pesticides and other toxic chemicals	Reductions in stormwater constituents and pollutant loads within the Plan Area over time	Annual effectiveness monitoring and reporting, performed by the individual stormwater entities, for the duration of the BDCP permit term
CM19-2	Fund individual stormwater entities in the Plan Area to implement BMPs.	Implement BMPs for urban stormwater runoff through local jurisdictions within the Plan Area (e.g., cities and towns) to achieve compliance with NPDES MS4 and Phase II NPDES MS4 permit conditions	Reductions in pollutant loads in urban stormwater effluent generated by local jurisdictions	Individual stormwater entities will be responsible for performing annual monitoring of BMPs implemented at the local level for the duration of the BDCP permit term.

3.4.19.4 Consistency with the Biological Goals and Objectives

CM19 will advance the biological goals and objectives as identified in Table 3.4.19-2. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.19-2. Biological Goals and Objectives Addressed by CM19

Biological Goal or Objective	How CM19 Advances Biological Objective	Monitoring Action
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.		
Objective L2.4: Support improved ecosystem function in aquatic natural communities by implementing actions to improve water quality, including reducing dissolved oxygen impairments in the Stockton Deep Water Ship Channel, reducing pollutant loading by urban stormwater, and minimizing mobilization of methylmercury from lands in the reserve system.	Reduction of pollutant loads in stormwater discharges will reduce a substantial source of nonpoint source pollutant loading in Delta tributary watersheds.	CM19-1, CM19-2

Biological Goal or Objective	How CM19 Advances Biological Objective	Monitoring Action
Goal DTSM1: Increased end of year fecundity and improved survival of adult and juvenile delta smelt to support increased abundance and long-term population viability.		
Objective DTSM1.1: Increase fecundity over baseline conditions.[a]	Improving water quality is intended to contribute to improved habitat conditions and increased productivity, which may result in increased growth of individual delta smelt and/or an increased delta smelt population thereby contributing to increased fecundity.	CM19-1, CM19-2
Objective DTSM1.3: Achieve an improved Recovery Index.[a]	Improving water quality is intended to contribute to improved habitat conditions and increased productivity, which may result in increases in delta smelt populations.	CM19-1, CM19-2
Goal DTSM2: Increased quality and availability of habitat for all life stages of delta smelt and increased availability of high-quality food for delta smelt.		
Objective DTSM2.1: Increase the extent of delta smelt habitat.[a]	Improving water quality is intended to improve habitat suitability in some existing delta smelt habitat and may also render suitable some areas of currently unsuitable habitat.	CM19-1, CM19-2
Goal LFSM1: Increased fecundity and improved survival of adult and juvenile longfin smelt to support increased abundance and long-term population viability.		
Objective LFSM1.1: Achieve longfin smelt population growth.[a]	Improving water quality is intended to contribute to improved habitat conditions and increased productivity, which may result in increases in longfin smelt populations.	CM19-1, CM19-2
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.		
Objective WRCS1.1: Improve through-Delta survival.[a]	Improving water quality is intended to contribute to increased primary and secondary productivity. This would reduce stress on covered salmonids, contributing to improved through-Delta survival	CM19-1, CM19-2
Goal SRCS1: Increased spring-run Chinook salmon abundance.		
Objective SRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM19-1, CM19-2
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.		
Objective FRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM19-1, CM19-2
Goal STHD1: Increased steelhead abundance.		
Objective STHD1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.	CM19-1, CM19-2

Biological Goal or Objective	How CM19 Advances Biological Objective	Monitoring Action
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.		
Objective GRST1.1: Improve juvenile and adult survival.[a]	Poor water quality conditions were identified by the National Marine Fisheries Service (2010) as one of several threats contributing to the risk of extinction of the southern DPS of green sturgeon. Improving water quality is intended to contribute to improved habitat conditions and increased productivity, which may result in increases in juvenile and adult green sturgeon populations.	CM19-1, CM19-2
Goal GRST3: Increased spatial distribution of young-of-the-year (YOY) and juvenile green sturgeon in the Delta compared to existing conditions.		
Objective GRST3.1: Improve water quality and physical habitat.[a]	Improving water quality is intended to improve habitat suitability by reducing contaminant loading in the water column and in sediments near contaminant source discharges.	CM19-1, CM19-2
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.		
Objective WTST1.1: Improve juvenile and adult survival.[a]	See Objective GRST1.1 above.	CM19-1 and CM19-2
Goal WTST3: Increased spatial distribution of young-of-the-year (YOY) and juvenile white sturgeon in the Bay-Delta compared to existing condition SWP/CVP regulatory requirements.		
Objective WTST3.1: Improve water quality and physical habitat.[a]	See Objective GRST3.1 above.	CM19-1, CM19-2
[a] Summarized objective statement; full text presented in Table 3.3-1.		

Reducing the amount of pollution in stormwater runoff entering Delta waterways will benefit covered fishes through the following mechanisms.

- Increasing aquatic productivity, which will support food abundance for splittail, delta and longfin smelt, sturgeon, steelhead, and Chinook salmon (all races) (Essex Partnership 2009).
- Reducing loads of pesticides and herbicides, which can be toxic to the invertebrates and phytoplankton (Amweg et al. 2006; Weston et al. 2005) that form the base of the foodweb or are important prey species for covered fish species.
- Reducing sublethal effects (behavior, tissue and organ damage, reproduction, growth, and immune) of toxic contaminants (including metals and pesticides), which will improve the health of splittail, delta and longfin smelt, sturgeon, steelhead, and Chinook salmon (all races).
- Reducing pyrethroids and other chemicals from urban and stormwater, which will improve the health of covered fish species (Weston and Lydy 2010).

Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) analysis indicates that actions to reduce the amount of pollution in stormwater runoff entering Delta waterways will be of high benefit to delta smelt, white sturgeon, steelhead, and Chinook salmon (Essex Partnership 2009).

3.4.20 Conservation Measure 20 Recreational Users Invasive Species Program

Under *CM20 Recreational Users Invasive Species Program*, the Implementation Office will fund a Delta Recreational Users Invasive Species Program designed to implement actions to prevent the introduction of new aquatic invasive species and reduce the spread of existing aquatic invasive species via recreational watercraft, trailers, and other mobile recreational equipment used in aquatic environments in the Plan Area.

Implementation of the Delta Recreational Users Invasive Species Program is intended to contribute towards achieving biological goals L2 and TPANC1, which address maintenance of native biological diversity and control of invasive species. Conservation measure consistency with these goals is detailed below in Section 3.4.20.4, *Consistency with the Biological Goals and Objectives*.

Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM20. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to ensure that effects of CM20 on covered species will be avoided or minimized. Refer to Chapter 5, *Effects Analysis*, for a discussion of the effects of CM20 on natural communities and covered species.

The primary purpose of CM20 is to meet or contribute to biological goals and objectives addressing the control of invasive organisms and native plant species diversity. It will do this primarily by educating recreational users about the importance of avoiding further introductions of aquatic invasive species and by instituting recreational watercraft inspections that directly reduce the risk of invasive species introduction and proliferation.

3.4.20.1 Problem Statement

Cohen and Carlton (1998) recognized 234 introduced species in the San Francisco Bay estuary and the Delta, of which 69% are invertebrates, 14% are fish and other vertebrates, 13% are plants, and 4% are protists. A subset of these introduced species is the initial focus of this conservation measure, although the list of species addressed will evolve over time in response to new species introductions or changes in the distribution and abundance of existing invasive species.

Two nonnative invasive clams, the Asian clam (*Corbicula fluminea*) and *Potamocorbula*, provide an instructive example of the risk of invasive species introductions to the Plan Area. These clams are efficient filter feeders, competing with native species such as delta smelt for food resources (Nobriga and Herbold 2009). The introduction of these clams has substantially reduced the estuary's pelagic productivity at all trophic levels, from phytoplankton (Jassby et al. 2002 in Nobriga and Herbold 2009) to fish (Kimmerer 2002 and 2006 in Nobriga and Herbold 2009). So prodigious is the feeding capacity of *Potamocorbula* that they are able to daily filter up to a dozen times the water column present above them—in areas where the seabed is covered with these invasive clams, all the water in the area passes through a clam every 2 hours. Introductions of nonnative species such as the *Potamocorbula* have altered the entire foodweb of the Delta. The decline of all plankton-feeding pelagic fishes in the Delta is tied to this dramatic shift in the foodweb. Where most energy and carbon in the system once flowed through plankton and fishes, they now flow through nonnative clams. Nonnative clams feed on a number of the same plankton species that serve as key forage for delta smelt and other at-risk pelagic fishes, and are thus direct competitors with many native fish.

Other invasive bivalves, such as quagga mussel (*Dreissena bugensis*) and zebra mussel (*Dreissena polymorpha*) (collectively "dreissenid mussels"), could likewise impair the productivity of waters in the Plan Area, and represent one of the principal invasive species risks in the Delta. Dreissenid mussels are filter feeders capable of filtering up to 1 liter of water per day per adult mussel (Pacific States Marine Fisheries Commission 2008). Quagga mussels have been found in numerous southern California water bodies, and zebra mussels have been found in one central California water body; however, neither of these mussels has yet been found in the waters of the Plan Area.

These filter feeders threaten the stability of the foodweb and also represent a potentially major maintenance problem at water diversion facilities. However, these species require fresh water with a suitable concentration of dissolved calcium in order to survive. The potential distribution of dreissenid mussel habitat in the Plan Area has been described by Claudi and Prescott (2011), who examined water chemistry data for sites in the SWP. They found that, within the Plan Area, the Sacramento River at Hood does not provide suitable water chemistry, but that marginally suitable water chemistry occurs at most SWP facilities in the south Delta. The south Delta, therefore, can be regarded as at-risk for dreissenid mussel invasion.

Dreissenid mussels were initially introduced to North America from Europe via ballast water discharge from deep draft vessels serving ports in the Great Lakes (Zook and Phillips 2012). However, recreational watercraft are thought to be the principal vector of their introduction to western waterways such as Lake Mead and downstream waters of the Colorado River system (Zook and Phillips 2012). In response, numerous local jurisdictions in the western United States, including at least 93 jurisdictions in California (California Department of Fish and Game 2012b), have adopted regulations providing for education, inspection, or cleaning of watercraft potentially acting as dispersal vectors for the mussels. These programs are already in place at a number of lakes, streams, and reservoirs in the Central Valley, but have not yet been implemented in the Bay-Delta. CDFW and USFWS have prepared a rapid response plan for use if dreissenid mussels are detected in the Bay-Delta (Smith and McMartin 2011), but it has not been implemented. The risk of introduction of these highly invasive mussels to the Delta is high given 1) the heavy use of the Bay-Delta by recreational watercraft and 2) the presence of water conditions suitable for establishment and proliferation of dreissenid mussels. Implementation of this conservation measure will reduce this high risk of an introduction of dreissenid mussels to the Plan Area via recreational watercraft, trailers, and other equipment used in aquatic environments.

Recreational watercraft can also serve as a dispersal vector for invasive aquatic vegetation (IAV). See CM13, *Invasive Aquatic Vegetation Control*, for a description of primary IAV species of concern and how IAV has affected Delta ecosystems. Most IAV species, such as South American spongeplant (known to occur in the Delta) and hydrilla (not yet known to occur in the Delta), have the ability to reproduce vegetatively by plant fragments; these and other IAV are often fragmented by watercraft and then transported and introduced to new water bodies as boats and trailers move between watersheds (Mills and Sommer 1995). The risk of such introductions can be reduced by inspecting watercraft, trailers, and other equipment, and cleaning them of invasive plants.

3.4.20.2 Implementation

3.4.20.2.1 Prevention and Reduction Actions

The Implementation Office will provide funding to implement the Delta Recreational Users Invasive Species Program. The Implementation Office will implement actions to help prevent the introduction of new aquatic invasive species and reduce the spread of existing aquatic invasive species via recreational watercraft, trailers, and other equipment in the Plan Area. The program will consist of two primary elements, described in more detail below: education and outreach, and watercraft inspection.

Program actions are likely to be implemented on the ground by multiple agencies, including the Implementation Office, CDFW, Reclamation, local water districts, counties, and others. Implementing agencies will be determined by the Implementation Office based on a variety of factors including likely effectiveness, enforcement ability, and cost effectiveness. As with all conservation measures, however, ultimate responsibility for successful implementation rests with the Implementation Office.

Similar programs have been instituted in many local jurisdictions in California. For example, in Lake County, all vessels large enough to be moved by trailer must be inspected annually and reinspected every time they have been used on waters outside the county; vessels must display a sticker showing that they have been inspected (Lake County Invasive Mussel Prevention Program 2011). Lake County's program applies to all lakes in the county, and also includes a boater education program supported by a website (www.nomussels.com) and signage at boat ramps. At Lake Berryessa, Reclamation staff performs boat and trailer inspections at boat ramps around the lake, and a boater education program is offered to raise awareness of the risk posed by invasive mussels (Bureau of Reclamation 2008). At Lake Casitas, which is located in Ventura County where the risk of dreissenid mussel invasion is very high, strict restrictions have been placed on all types of watercraft; restrictions include a quarantine period, inspections by trained staff, a ban on some vessels (float tubes), and a boater education program (Casitas Municipal Water District 2012). Jurisdictions wishing to develop similar programs are well supported by data and guidance provided by CDFW and USFWS[44].

3.4.20.2.2 Education and Outreach

The Implementation Office will provide information to recreational boaters in the Plan Area regarding the potential threat of introductions of new aquatic invasive species, the presence and range of existing aquatic invasive species, the various vectors of aquatic invasive species, and the potential threat of the spread of existing aquatic invasive species within the Plan Area. The Implementation Office will implement education and outreach following the actions listed in the Education and Outreach section of the *California Aquatic Invasive Species Management Plan* (Objective 6; CAISMP) (California Department of Fish and Game 2008b). The first and most important of these actions is to inventory existing education and outreach efforts in the Plan Area, and then to use this information to prioritize new efforts and partner with existing efforts. Actions then taken under the program are likely to include, but not be limited to, the following.

- Develop and offer training for aquatic invasive species management to marina, boat ramp, and property owners in the Plan Area.
- Design and install permanent interpretive displays at appropriate marinas, boat ramps, and other fishing or boating access sites in the Plan Area.

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[44] See the CDFW invasive species web site at http://www.dfg.ca.gov/invasives, and the Stockton regional office of USFWS invasive species web site at http://www.fws.gov/stockton/AIS/index.html.

- Develop permanent interpretive displays along major roadways into the Plan Area (e.g., at highway rest stops and on billboards).
- Develop and distribute printed materials (e.g., posters, brochures, and articles) to recreational users in the Plan Area.
- Provide printed materials to bait and tackle shops and boat dealers in the Plan Area for distribution to customers.
- Distribute education and outreach materials to the public at boat and tackle shows, fishing tournaments, and other events promoting water-related recreational activities in the Plan Area.
- Distribute printed materials to waterfront and shoreline property owners in the Plan Area.

Education and outreach printed materials and interpretive displays will provide information regarding the presence and range of existing aquatic invasive species, the various vectors of aquatic invasive species, the threat of existing aquatic invasive species spreading within the Plan Area, and the risk of new aquatic invasive species introductions. These materials and displays will include the following.

- Descriptions and photos of existing aquatic invasive species and those aquatic invasive species that have the potential to be introduced into the Plan Area.
- Information regarding the effects of existing aquatic invasive species and how introductions of new aquatic invasive species would affect native species and habitat in the Plan Area.
- Maps that show the locations of existing aquatic invasive species.
- Information regarding how aquatic invasive species can be transported into and around the Plan Area via recreation watercraft, trailers, and other equipment.

Education and outreach materials will be printed in multiple languages in addition to English to ensure that education about IAV species and the threats they pose to regional ecosystems reaches a broad audience.

3.4.20.2.3 Watercraft Inspection

The Implementation Office will develop and implement protocols to screen, inspect, decontaminate, and if necessary, quarantine recreational watercraft, trailers, and other equipment prior to entering waters of the Plan Area to meet the goals of this conservation measure. The Implementation Office will design these actions for the Plan Area in accordance with the specifications for a Level 3 screening and inspection program, as set forth in the *Uniform Minimum Protocols and Standards for Watercraft Interception Programs for Dreissenid Mussels in the Western United States* (UMPS II) (Zook and Phillips 2012). UMPS II provides uniform minimum standards and protocols for developing and implementing aquatic invasive species watercraft inspection programs using the best available science, technology, and understanding. A Level 3 (Comprehensive) inspection program is recommended for all high-risk waters and large water bodies. This type of program involves screening interviews at the point of entry; a comprehensive inspection, performed by trained inspectors, of all high risk watercraft, trailers, and equipment identified as high-risk during the screening interview; decontamination and/or quarantine or exclusion of watercraft, trailers, and equipment that are not clean, drained, and dry; and optional vessel certification. For an area the size of the Plan Area, seven inspection and decontamination stations are appropriate.

To design appropriate actions, the Implementation Office will conduct an inventory of existing aquatic invasive species within the Plan Area, including their general location, range, and population sizes; and determine the risk of aquatic invasive species invasion and spread within the Plan Area. This inventory can largely be accomplished using existing knowledge and data. The Implementation Office will then design watercraft inspection actions using the protocols and standards outlined in UMPS II. Concurrently, the Implementation Office will consult with operators of existing watercraft inspection programs in California and the western United States to gain an understanding of the benefits and challenges and resulting successes and failures of watercraft inspection programs to help design BDCP actions. Throughout the permit term, the Implementation Office will continue to track other comparable programs in California and the western United States to ensure that the program continues to meet a "best available science" standard for inventory and implementation. Currently, examples of such regional programs include the following.

- The Aquatic Nuisance Species Task Force, an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species, and implementing the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990.
- The Western Regional Panel on Aquatic Nuisance Species, a panel of public and private entities formed by a provision in the National Invasive Species Act of 1996 (P.L. 101-636), the amendment to the 1990 Act.
- The 100th Meridian Initiative, a cooperative effort between local, state, provincial, regional, and federal agencies to prevent the westward spread of zebra/quagga mussels and other aquatic nuisance species in North America

Implementation of this conservation measure will begin in year 1; full program development will likely take approximately 3 years.

3.4.20.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of documenting the implementation of CM20 through annual budgets, reports, and work plans to demonstrate the appropriate use of available funds and actions accomplished.

Effectiveness monitoring will be conducted to evaluate progress toward advancing the biological objectives discussed below in Section 3.4.20.4, *Consistency with the Biological Goals and Objectives*. Effectiveness monitoring will consist of identifying the type, distribution, and abundance of aquatic invasive species detected during program implementation and reporting those species in the annual report.

Because this is essentially a preventative measure, the primary purpose of adaptive management will be to ensure that the measure remains focused on the principal invasive species of concern. Therefore, the annual work plan for the Delta Recreational Users Invasive Species Program will discuss the principal invasive species threats in the Delta, including new invasives discovered since the prior year's work plan and trends in the abundance and distribution of existing invasives. The inventory of new invasives and the proliferation of existing invasive species constitute the principal key uncertainty for this conservation measure. Through the adaptive management process, the

Adaptive Management Team will recommend appropriate responses to the appearance of new invasive species threats or the proliferation of existing invasive species by identifying research priorities or modifying conservation measure implementation to maintain focus on those invasive species that pose the greatest threat to Delta ecosystems and that can be dealt with by controlling the risk of accidental introduction. Such recommendations would be implemented upon approval by the Permit Oversight Group and the Authorized Entity Group.

3.4.20.4 Consistency with the Biological Goals and Objectives

CM20 will advance the biological goals and objectives as identified in Table 3.4.20-1. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.20-1. Biological Goals and Objectives Addressed by CM20

Biological Goal or Objective	How CM20 Advances Biological Objective
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.	
Objective L2.6: Increase native species diversity and relative cover of native plant species, and reduce the introduction and proliferation of nonnative species.	Preventing the introduction and reducing the spread of nonnative plant and animal species will better support ecosystem and natural community functions and allow for greater use of potential habitat by native plant and animal species.
Goal TPANC2: Tidal perennial aquatic natural community that supports viable populations of native fish.	
Objective TPANC2.1: Control invasive aquatic vegetation that adversely affects native fish habitat.	CM20 is intended to contribute to reducing the spread of existing IAV and preventing the introduction of new IAV in the Plan Area by helping to ensure that recreational users of Plan Area waters are not transporting and introducing or distributing invasive plants via watercraft, trailers, or other equipment.

CM20 is also intended to provide benefits beyond those specified as biological goals and objectives. Potential benefits of CM20 to ecosystems, natural communities, and covered species are described below.

Implementation of CM20 is intended to reduce the spread of existing invasive species such as the IAV discussed in detail in *CM13 Invasive Aquatic Vegetation Control*. By helping to minimize the risk of IAV competition for resources and support of habitat for nonnative predatory fishes, CM20 implementation should benefit both diversity and numbers of native plants and animals. CM20 is also intended to reduce the risk of introducing new invasive species, such as dreissenid mussels, into the Plan Area.

It is difficult to quantify these benefits, because CM20 is essentially a preventative measure intended to prevent further spread of invasive species that have already degraded natural communities in many parts of the Plan Area and to prevent new introductions that would have many unknown ecological consequences. Because CM20 does not control invasive species in their habitat, it is not likely to result in reductions in the extent of existing invasive species within the Plan Area; however, it may help to reduce the spread and introduction of those species to new locations, if CM13 and other actions (not undertaken as part of BDCP) are effective in controlling IAV in portions of the Plan Area.

3.4.21 Conservation Measure 21 Nonproject Diversions

Under *CM21 Nonproject Diversions,* the BDCP will provide for the funding of actions that will reduce potential entrainment of covered fish that may result from the operation of nonproject diversions (Hallock and Van Woert 1959; Hanson 2001; Nobriga et al. 2004; Moyle and Israel 2005). As described in Chapter 4, *Covered Activities and Associated Federal Actions*, nonproject diversions consist of infrastructure used to divert surface waters within the Plan Area and that is not associated with operations of the SWP or the CVP. Most of these nonproject diversions are used to support agriculture or to provide water for waterfowl rearing areas. The purpose of this conservation measure is to avoid or minimize incidental take of covered fish species associated with nonproject diversions whose owners voluntarily participate in this conservation measure. Nonproject diversions could result in incidental take of covered fish species by entrainment or impingement. Remediation of these nonproject diversions could eliminate or reduce this entrainment or impingement, and improve Delta ecosystem health by reducing the diversion of plankton and other nutritional resources, thereby benefiting all covered fishes.

This conservation measure is intended to avoid or minimize the effect of those nonproject diversions that have the greatest potential to result in incidental take of covered fishes. This would be achieved by consolidating, relocating, screening, removing, or otherwise remediating the harmful diversions. Remediation would be achieved via the methods described below, and also through the removal of some diversions in areas where cultivated lands or managed wetlands are converted into natural community types that do not require consumptive use of surface waters (*CM3 Natural Communities Protection and Restoration*). The number and size of the diversions that will be eliminated as a result of restoration of natural community types are not precisely known, because the affected parcels have not yet been identified and, moreover, some existing diversions may be remediated before restoration actions occur. Diversions that are removed as a result of those restoration activities are included in the overall diversion remediation commitment specified below in Section 3.4.21.2, *Implementation*. The entrainment risks posed by nonproject diversions in the Plan Area are discussed in Section 3.3.5.4, *Increasing Habitat Suitability for Covered Fish Species*. Refer to Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM21. Refer to Appendix 3.C, *Avoidance and Minimization Measures*, for a description of measures that will be implemented to avoid or minimize any adverse effects on covered species associated with actions that will be undertaken pursuant to this conservation measure.

3.4.21.1 Problem Statement

Within the Plan Area, approximately 2,589 nonproject diversions have been put in place (Figure 3.4-35). The majority of those structures divert water to agricultural fields between April to August, depending on the crop type. The timing of these diversions at least partially overlaps with the periods in which many of the covered species are present in the Delta (Hallock and Van Woert 1959). Over 95% of these nonproject diversions have not been screened to reduce fish entrainment (Herren and Kawasaki 2001). As such, there is potential for significant entrainment of fish to occur at these facilities (Hallock and Van Woert 1959 in Moyle and White 2002). Limited studies indicate that screens on agricultural diversions in the Delta are at least 99% effective in reducing fish entrainment, even for larval fish that are fewer than 25 millimeters in length (Nobriga et al. 2004).

The nonproject diversions are primarily located in areas with low salinity and freshwater aquatic habitats. Diversions occur in all habitats used by covered fish species; therefore, the benefits associated with screening these diversions would apply to a broad range of fish. The relative benefits are likely to vary depending on the abundance of each covered fish population in the area, with greater benefits to larval and juvenile life-history stages that have low swimming velocity or a propensity to move with the flow vector.

The entrainment risk associated with unscreened diversions in the Central Valley has been recognized for many years (e.g., Hallock and Van Woert 1959). The few studies that have compared entrainment densities to ambient densities have found that covered fish species are entrained into these small diversions at densities much lower than they occur in the adjacent channels (Hanson 2001; Nobriga et al. 2004; Enos et al. 2007). In the mid-1990s, Reclamation's Anadromous Fish Screen Program was initiated to screen irrigation diversions, with primary funding provided through the Central Valley Project Improvement Act restoration fund, and augmented on occasion by other Reclamation and CALFED funds. Currently, Reclamation's Anadromous Fish Screen Program and CDFW's Fish Screen and Passage Program are operated jointly, with the participation of Reclamation, USFWS, CDFW, NMFS, and DWR. These programs have thus far supported over 30 projects addressing unscreened diversions throughout the Central Valley, with the majority of projects implemented on relatively large diversions along the mainstem Sacramento River.

3.4.21.2 Implementation

This conservation measure will be implemented on a voluntary basis; specifically, it will be implemented in instances where the Implementation Office identifies a high-priority diversion for remediation (see Section 3.4.21.2.1, *Remedial Actions*, below, for details) and the selected in-Delta diverter opts to obtain take coverage for this covered activity.

This conservation measure has the potential to result in the remediation of an average estimated 100 cfs of diversion capacity per year, beginning in year 6 and continuing throughout the permit term. The level and extent of remediation that occur through this process will depend on the number of participating diverters, the diversion capacity of those participants' diversion facilities, and the cost of individual projects within the funding limits established for this measure. The estimate of an average of 100 cfs diversion capacity per year remediated is based on an evaluation of the level of landowner participation to date in the existing CDFW and Reclamation fish screen programs, and the expected increase in participation with the availability of new funds and the opportunity to obtain take authorization through the BDCP.

Remediation is defined to include application of any of the following methods for treatment of unscreened diversions.

- Installation of screens.
- Consolidation of multiple unscreened diversions into a single or fewer screened diversions placed in lower-value habitat.
- Relocation of diversions with substantial effects on covered species from high-value to lower-value habitat, in conjunction with screening.

- Reconfiguration and screening of individual diversions in high-value habitat to take advantage of small-scale distribution patterns and behavior of covered fish species relative to the location of individual diversions in the channel.
- Voluntary alteration of the daily and seasonal timing of diversion operation.
- Removal of individual diversions that have relatively large effects on covered fish species or as a consequence of transfer of cultivated lands or managed wetlands into the reserve system.

Additional methods may be implemented if the Implementation Office determines those methods to be appropriate.

3.4.21.2.1 Remedial Actions

Under this conservation measure, the following actions will be implemented over the term of the BDCP.

- The Implementation Office will form a technical team to inventory potential projects and rank those potential projects in order of priority. The technical team will include BDCP staff designated by the Science Manager, a representative of Reclamation's Anadromous Fish Screen Program, and a representative of CDFW's Fish Screen and Passage Program. Although the existing Reclamation and CDFW programs focus on achieving benefits to anadromous salmonids, the technical team will be charged to develop and apply criteria that consider potential effects on *all* covered fish species and that assign highest priority to cost-effective projects that maximize expected entrainment reductions.
- Landowners who operate diversions identified by the technical team as a high priority for remediation will be invited to participate in CM21 subject to funding availability. Operators who choose to be part of the program will sign a certificate of compliance committing them to the process and terms of this conservation measure. Operators who have signed a certificate of compliance will receive authorization for incidental take associated with diversion operation or remediation and will be referred to as Other Authorized Entities (Chapter 7, Section 7.1.2.2). Participating landowners will be covered for take associated with the operation of these diversions, as set out in Chapter 4, *Covered Activities and Associated Federal Actions*, including take that may occur as a result of the following circumstances.
    - Prior to remediation, incidental take may occur due to entrainment to the existing diversion or impingement on the existing screens, if any.
    - During the remediation process, incidental take may occur as a result of implementing the remedial measure. For instance, remediation that involves removing an existing diversion may result in take associated with in-water work required to remove screens, piping, and other materials related to the diversion, and potentially from incidental effects, such as temporary turbidity spikes associated with installation of earth or plant materials that may be required to restore the site. Remediation that involves consolidating multiple diversions and either installing a new diversion or refitting an existing one may cause take due to in-water work that potentially includes placement of temporary or permanent piling, temporary site dewatering, risk of hazardous material spills, and risk of turbidity or associated issues. These potential impacts would be minimized through the use of techniques described in Appendix 3.C, *Avoidance and Minimization Measures*, including but not limited to development of temporary erosion and sedimentation control plans and fish rescue and salvage plans.

  - Following remediation, incidental take may still occur through entrainment or impingement, although the risk of these impacts would be *de minimus* if the diversion were fitted with fish screens approved by the fish agencies. Remediation that entails altered timing of diversion operations would still entail a risk of incidental take, if individuals of covered species were present at times when diversions were operational.

- Remediation actions will be fully funded through the BDCP. These actions will be completed within 5 years of the execution of a certificate of compliance by the Implementation Office and the participating landowner.

- With regard to diversions selected for remediation, the Implementation Office will implement the remediation program consistent with all Anadromous Fish Screen Program and Fish Screen and Passage Program objectives, including the following objectives.

  - To provide funding and/or technical assistance for fish screen projects.
  - To conduct and assess fish entrainment monitoring at unscreened diversions.
  - To support and evaluate screen/diversion related research to help determine the following factors.
    - Critical factors resulting in fish losses at water diversions.
    - Potential lower-cost options for minimizing fish losses at diversions such as the use of behavioral devices at some diversions rather than use of more expensive positive barrier screens.
    - Cost-effective improvements to fish screen design.
  - To conduct postconstruction monitoring of fish screens to assure the effective operation of installed fish screens.

- The Implementation Office will prepare, either internally or in conjunction with the Anadromous Fish Screen Program and Fish Screen and Passage Program, annual summary reports describing prior year achievements of supported programs.

- The remediation program, including the execution of associated interagency agreements, creation of a technical team, development of selection criteria, and establishment of priorities, is expected to be in effect within 2 years and fully operational in year 3. Individual actions under the program are expected to take approximately 3 to 5 years to design, permit, and construct.

- Based on performance of the Anadromous Fish Screen Program and Fish Screen and Passage Program during the past 20 years, the highest priority projects, at least initially, may address the larger nonproject diversions (more than 100 cfs) located along major channels in the Delta. It is also likely that priority may be given to some smaller diversions occurring in locations that support relatively large concentrations of covered fish, and that other diversions will be given higher priority because their timing of operations is conducive to high risk of take of covered species. For example, diversions operated during the winter have a higher risk of entraining outmigrant winter-run Chinook salmon than diversions operated only in the late spring and summer.

This conservation measure does not include a list of specific candidate projects. Rather, projects will be identified through the review process, and will then be subject to a multiyear process that includes a feasibility study, preliminary design, final design, and construction. Other regulatory requirements also must be met.

The Implementation Office will, as appropriate, defer to the working procedures used in the existing Reclamation and CDFW programs. Work plans for diversions selected for remediation will be included in the BDCP Annual Work Plan and Budget. Any Supporting Entity (Chapter 7, Section 7.1.9, *Supporting Entities*) involved in the implementation of this conservation measure, including Reclamation or CDFW, will be responsible for developing and implementing a work plan and submitting reports to the Implementation Office demonstrating that the work plan has been successfully implemented.

The Implementation Office and Adaptive Management Team will review the reports prepared by Supporting Entities to assess program effectiveness, including approaches to management and funding, and may recommend changes to the conservation measure. If program assessments indicate that the program is not effective in achieving its stated objectives of providing benefits to covered species or their habitats, the Implementation Office may recommend that the program be terminated. If the Authorized Entity Group approve such a recommendation, take coverage will remain in place for any diversions that have already been remediated under the program.

3.4.21.2.2 Timing and Phasing

Implementation of this conservation measure would commence in year 1 and would continue throughout the term of the Plan. Budgeting for this program will be coordinated between the Implementation Office and the managers of the Reclamation and CDFW programs. See Chapter 6, *Plan Implementation*, for details on the timing and phasing of CM21.

3.4.21.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through monitoring, research actions, and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Monitoring will consist of documenting funding made available, notification and selection process for grants to landowners and water agencies, participation in program, and projects built to reduce covered fish species entrainment. Monitoring will be conducted to evaluate progress toward meeting the objectives discussed in Section 3.4.21.4, *Consistency with the Biological Goals and Objectives.* If necessary, the implementation actions described above will be adjusted through adaptive management to meet these objectives. Monitoring would typically occur for individual projects both before and after remediation to verify its effectiveness. Postproject monitoring would only be done for diversions that remained active (e.g., they had been screened or otherwise modified, rather than removed) and would be limited to verification that the remediated diversion was functioning as intended. Once this verification was achieved, no further monitoring would be needed.

Work done to date under the existing Reclamation and CDFW programs has found that preproject monitoring, in particular, is time-consuming and expensive because of the prolonged and intensive labor required to successfully detect incidents of entrainment that principally affect small, rare fish. The absence of a means for efficient, cost-effective preproject monitoring is thus a key uncertainty. The BDCP will support research to develop means of more quickly and effectively estimating preproject entrainment risk and project effectiveness in reducing entrainment risk. Scoping of this research and assessment of its results will be performed by the Adaptive Management Team, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

The Implementation Office may adjust its approach to the selection of diversions to be relocated or consolidated, design of intakes, or the means by which the effects of these diversions on covered species will be minimized. If the results of monitoring indicate that remediation of nonproject diversions does not substantially and cost-effectively benefit covered fish species, the Implementation Office may recommend termination of this conservation measure to the Authorized Entity Group.

3.4.21.4 Consistency with the Biological Goals and Objectives

CM21 will advance the biological goals and objectives as identified in Table 3.4.21-1. The rationale for each of these goals and objectives is provided in Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

Table 3.4.21-1. Biological Goals and Objectives Addressed by CM21

Biological Goals or Objective	How CM21 Advances Biological Objective
Goal L2: Ecological processes and conditions that sustain and reestablish natural communities and native species.	
Objective L2.9: Increase the abundance and productivity of plankton and invertebrate species that provide food for covered fish species in the Delta waterways.	Remediation of nonproject diversions reduces the potential for covered fish prey organisms to be diverted into waters where they no longer support covered fish species productivity.
Goal L4: Increased habitat suitability for covered fish species in the Plan Area.	
Objective L4.3: Reduce entrainment losses of covered fish species.	Remediation of nonproject diversions can avoid or minimize entrainment and impingement, reducing mortality of covered fish attributable to these causes.
Goal DTSM1: Increased end of year fecundity and improved survival of adult and juvenile delta smelt to support increased abundance and long-term population viability.	
Objective DTSM1.3: Achieve an improved Recovery Index.[a]	Eliminating those nonproject diversions with the greatest risk of entrainment to delta smelt is expected to contribute to reduced mortality and, thus, increased abundance.
Goal LFSM1: Increased fecundity and improved survival of adult and juvenile longfin smelt to support increased abundance and long-term population viability.	
Objective LFSM1.1: Achieve longfin smelt population growth.[a]	Eliminating those nonproject diversions with the greatest risk of entrainment to longfin smelt is expected to contribute to reduced mortality and, thus, population growth.
Goal WRCS1: Improved survival (to contribute to increased abundance) of immigrating and emigrating winter-run Chinook salmon through the Plan Area.	
Objective WRCS1.1: Improve through-Delta survival.[a]	Eliminating those nonproject diversions with the greatest risk of entrainment to covered juvenile salmonids is expected to contribute to increasing through-Delta survival by ensuring covered fish remain in channels connected to open water where migration through the Delta is feasible.

Biological Goals or Objective	How CM21 Advances Biological Objective
Goal SRCS1: Increased spring-run Chinook salmon abundance.	
Objective SRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.
Goal FRCS1: Increased fall-run/late fall–run Chinook salmon abundance.	
Objective FRCS1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.
Goal STHD1: Increased steelhead abundance.	
Objective STHD1.1: Improve through-Delta survival.[a]	See Objective WRCS1.1 above.
Goal GRST1: Increased abundance of green sturgeon in the Plan Area.	
Objective GRST1.1: Improve juvenile and adult survival.[a]	Eliminating those nonproject diversions with the greatest risk of entrainment to juvenile green sturgeon is expected to contribute to reduced mortality and, thus, increased abundance.
Goal WTST1: Increased abundance of white sturgeon in the Plan Area.	
Objective WTST1.1: Improve juvenile and adult survival.[a]	Eliminating those nonproject diversions with the greatest risk of entrainment to juvenile white sturgeon is expected to contribute to reduced mortality and, thus, increased abundance.

Note: Goals and objectives related to increasing abundance by reducing mortality are identified for all fish species. For all fish species, those goals and objectives would also be supported by this conservation measure, by the same rationale stated above for Objective L4.3.

[a] Summarized objective statement; full text presented in Table 3.3-1.

Remediation of nonproject diversions is anticipated to increase food availability for delta and longfin smelt (Lund et al. 2007, 2008), green sturgeon (Nilo et al. 2006; Wanner et al. 2007), white sturgeon (Brannon et al. 1985; Buddington and Christofferson 1985; Muir et al. 2000), splittail, Chinook salmon (all races), and steelhead through reduced entrainment of phytoplankton and zooplankton from the Delta.

Remediation of nonproject diversions is also anticipated to reduce entrainment mortality by nonproject diversions of covered fish species, including larval and juvenile delta and longfin smelt (Cook and Buffaloe 1998; Nobriga et al. 2004), juvenile green (Cook and Buffaloe 1998) and white sturgeon (Cook and Buffaloe 1998), juvenile splittail (Young and Cech 1996; Sommer et al. 1997, 2007b; Cook and Buffaloe 1998; Moyle et al. 2004; Matica and Nobriga 2005), and fry and juvenile Chinook salmon (all races) and steelhead (Hallock and Van Woert 1959; Cook and Buffaloe 1998).

3.4.22 Conservation Measure 22 Avoidance and Minimization Measures

Under *CM22 Avoidance and Minimization Measures,* the Implementation Office will implement measures to avoid and minimize effects on covered species and natural communities that could result from covered activities. The avoidance and minimization measures (AMMs) that will be implemented through this framework are detailed in Appendix 3.C, *Avoidance and Minimization Measures*. These measures will be implemented throughout the BDCP permit term.

The primary purpose of CM22 is to avoid or minimize incidental take (i.e., death, injury, harm, or harassment) of covered species and minimize impacts on natural communities that provide habitat for covered species. This conservation measure helps to satisfy regulatory requirements of the ESA and the Natural Community Conservation Planning Act. CM22 will also minimize adverse effects on natural communities, critical habitat, and jurisdictional wetlands and waters throughout the Plan Area.

3.4.22.1 Problem Statement

Careful design of covered activities will help avoid take of covered species, but specific AMMs are also required during implementation. It is the responsibility of the Implementation Office to ensure projects are designed and implemented in compliance with these measures.

ESA (Section 10[a][2][A][ii]) requires that an HCP applicant minimize and mitigate the impact of take of covered species to the maximum extent practicable. Fish & Game Code Section 2801(g) describes the NCCP program as providing a planning framework to avoid and minimize impacts on wildlife. The species-specific AMMs meet regulatory requirements for covered species and also contribute to the protection of covered species as required under Fish & Game Code Section 2820(b).

Consistent with Section 7(a)(2) of the ESA, the BDCP must ensure that covered activities do not result in adverse modification of designated critical habitat for federally listed species. The AMMs include measures that are necessary to ensure that future restoration projects are designed and covered activities are implemented to avoid adverse modification of critical habitat.

3.4.22.2 Implementation

3.4.22.2.1 Phases of Avoidance and Minimization Actions

Specific AMMs have been developed that will be implemented for each BDCP project. Identification and implementation of the appropriate AMMs for each project will occur in four phases.

- **Planning-level surveys and project planning.** Site-specific surveys will be conducted during the project planning phase to identify natural communities, covered species habitat, and covered species to which AMMs apply. Projects will be designed to avoid and minimize impacts based on information developed during the planning-level surveys.

- **Preconstruction surveys.** Biological surveys may be necessary during the months or weeks prior to project construction, depending on the results of the planning surveys. Results of the planning surveys will be used to determine which AMMs will be applied prior to or during construction (e.g., establishing buffers around kit fox dens or covered bird species nests). Preconstruction surveys may also involve site preparation actions such as collapsing unoccupied burrows.

- **Project construction.** Many AMMs will be implemented during project construction. For some activities, a biological monitor will be present to ensure that the measures are effectively implemented. For some species (e.g., California red-legged frog), the biological monitor will relocate individuals from the construction area to specified nearby safe locations.

- **Project operation and maintenance.** Some of the AMMs apply to long-term operation and maintenance activities, such as operation and maintenance of the water conveyance facilities and ongoing covered species' habitat enhancement and management These AMMs will be implemented throughout the life of the project. AMMs applicable to long-term enhancement and management will be incorporated into site-specific management plans.

Table 3.4.22-1. Summary of the Avoidance and Minimization Measures

Number	Title	Summary
Benefit All Natural Communities and Covered Species		
AMM1	Worker Awareness Training	Includes procedures and training requirements to educate construction personnel on the types of sensitive resources in the project area, the applicable environmental rules and regulations, and the measures required to avoid and minimize effects on these resources.
AMM2	Construction Best Management Practices and Monitoring	Standard practices and measures that will be implemented prior, during, and after construction to avoid or minimize effects of construction activities on sensitive resources (e.g., species, habitat), and monitoring protocols for verifying the protection provided by the implemented measures.
Primarily Benefit Covered Fishes		
AMM3	Stormwater Pollution Prevention Plan	Includes measures that will be implemented to minimize pollutants in stormwater discharges during and after construction related to covered activities, and that will be incorporated into a stormwater pollution prevention plan to prevent water quality degradation related to pollutant delivery from project area runoff to receiving waters.
AMM4	Erosion and Sediment Control Plan	Includes measures that will be implemented for ground-disturbing activities to control short-term and long-term erosion and sedimentation effects and to restore soils and vegetation in areas affected by construction activities, and that will be incorporated into plans developed and implemented as part of the National Pollutant Discharge Elimination System permitting process for covered activities.
AMM5	Spill Prevention, Containment, and Countermeasure Plan	Includes measures to prevent and respond to spills of hazardous material that could affect navigable waters, including actions used to prevent spills, as well as specifying actions that will be taken should any spills occur, and emergency notification procedures.
AMM6	Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material	Includes measures for handling, storage, beneficial reuse, and disposal of excavation or dredge spoils and reusable tunnel material, including procedures for the chemical characterization of this material or the decant water to comply with permit requirements, and reducing potential effects on aquatic habitat, as well as specific measures to avoid and minimize effects on species in the areas where reusable tunnel material would be used or disposed.
AMM7	Barge Operations Plan	Includes measures to avoid or minimize effects on aquatic species and habitat related to barge operations, by establishing specific protocols for the operation of all project-related vessels at the construction and/or barge landing sites. Also includes monitoring protocols to verify compliance with the plan and procedures for contingency plans.
AMM8	Fish Rescue and Salvage Plan	Includes measures that detail procedures for fish rescue and salvage to avoid and minimize the number of Chinook salmon, steelhead, green sturgeon, and other covered fish stranded during construction activities, especially during the placement and removal of cofferdams at the intake construction sites.

Number	Title	Summary
AMM9	Underwater Sound Control and Abatement Plan	Includes measures to minimize the effects of underwater construction noise on fish, particularly from impact pile–driving activities. Potential effects of pile driving will be minimized by restricting work to the least sensitive period of the year and by controlling or abating underwater noise generated during pile driving.
Primarily Benefit Covered Plants, Wildlife, or Natural Communities		
AMM10	Restoration of Temporarily Affected Natural Communities	Restore and monitor natural communities in the Plan Area that are temporarily affected by covered activities. Measures will be incorporated into restoration and monitoring plans and will include methods for stockpiling and storing topsoil, restoring soil conditions, and revegetating disturbed areas; schedules for monitoring and maintenance; strategies for adaptive management; reporting requirements; and success criteria.
AMM11	Covered Plant Species	Conduct botanical surveys during the project planning phase and implement protective measures, as necessary. Redesign to avoid indirect effects on modeled habitat and effects on core recovery areas.
AMM12	Vernal Pool Crustaceans	Includes provisions to require project design to minimize indirect effects on modeled habitat, avoid effects on core recovery areas, minimize ground-disturbing activities or alterations to hydrology, conduct protocol-level surveys, and redesign projects to ensure that no suitable habitat within these areas.
AMM13	California Tiger Salamander	During the project planning phase, identify suitable habitat within 1.3 miles of the project footprint, ash survey aquatic habitats in potential work areas for California tiger salamander. If California tiger salamander larvae or eggs are found, implement prescribed mitigation.
AMM14	California Red-Legged Frog	During the project planning phase, identify suitable habitat within 1 mile of the project footprint, conduct a preconstruction survey, implement protective measures for areas where species presence is known or assumed, and establish appropriate buffer distances. If aquatic habitat cannot be avoided, implement prescribed surveys and mitigation.
AMM15	Valley Elderberry Longhorn Beetle	During the project planning phase, conduct surveys for elderberry shrubs within 100 feet of covered activities involving ground disturbance, and design project to avoid effects within 100 feet of shrubs, if feasible. Implement additional protective measures, as stipulated in AMM2. Elderberry shrubs identified within project footprints that cannot be avoided will be transplanted to previously approved conservation areas in the Plan Area.
AMM16	Giant Garter Snake	During the project planning phase, identify suitable aquatic habitat (wetlands, ditches, canals) in the project footprint. Conduct preconstruction surveys and implement protective measures.
AMM17	Western Pond Turtle	Identify suitable aquatic habitat and upland nesting and overwintering habitat in the project footprint. Conduct preconstruction surveys in suitable habitat twice including 1 week before and within 48 hours of construction. Implement protective measures as described.
AMM18	Swainson's Hawk and White-Tailed Kite	Conduct preconstruction surveys of potentially occupied breeding habitat in and within 0.25 mile of the project footprint to locate active nest sites.
AMM19	California Clapper Rail and California Black Rail	Identify suitable habitat in and within 500 feet of the project footprint. Perform surveys and implement prescribed protective measures in areas where species is present or assumed to be present.

Number	Title	Summary
AMM20	Greater Sandhill Crane	Conduct preconstruction surveys to determine winter roost occupancy within 0.5 mile of the project footprint and determine related areas of foraging habitat. Implement protective measures in occupied areas. Minimize indirect effects of conveyance facility construction through temporary (during construction) establishment of 700 acres of roosting/foraging habitat.
AMM21	Tricolored Blackbird	Conduct preconstruction surveys in breeding habitat within 1,300 feet of the project footprint, if the project is to occur during the breeding season. Avoid any construction activity within 250 feet of an active tricolored blackbird nesting colony, and minimize such activity within 1,300 feet.
AMM22	Suisun Song Sparrow, Yellow-Breasted Chat, Least Bell's Vireo, Western Yellow-Billed Cuckoo	Conduct preconstruction surveys of potential breeding habitat in and within 500 feet of project activities. It may be necessary to conduct the breeding bird surveys during the preceding year depending on when construction is scheduled to start. Implement protective measures in occupied areas.
AMM23	Western Burrowing Owl	Perform surveys where burrowing owl habitat (or sign) is encountered within 150 meters of a proposed construction area. If burrowing owls or suitable burrowing owl burrows are identified during the habitat survey, and if the project does not fully avoid direct and indirect impacts on the suitable habitat, perform preconstruction surveys and implement certain minimization measures.
AMM24	San Joaquin Kit Fox	Conduct habitat assessment in and within 250 feet of project footprint. If suitable habitat is present, conduct a preconstruction survey and implement U.S. Fish and Wildlife Service guidelines. Implement protective measures in occupied areas.
AMM25	Riparian Woodrat and Riparian Brush Rabbit	Conduct surveys for projects occurring within suitable habitat as identified from habitat modeling and by additional assessments conducted during the planning phase of construction or restoration projects following U.S. Fish and Wildlife Service *Draft Habitat Assessment Guidelines and Survey Protocol for the Riparian Brush Rabbit and the Riparian Woodrat*. Implement protective measures in suitable habitat.
AMM26	Salt Marsh Harvest Mouse and Suisun Shrew	Identify suitable habitat in and within 100 feet of the project footprint for projects in the species range. Ground disturbance will be limited to the period between May 1 and November 30, to avoid destroying nests with young. Prior to ground-disturbing activities, vegetation will first be removed with nonmechanized hand tools (e.g., goat or sheep grazing, or in limited cases where the biological monitor can confirm that there is no risk of harming salt marsh harvest mouse or Suisun shrew, hoes, rakes, and shovels may be used). Implement protective measures in suitable habitat.
AMM27	Selenium Management	Develop a plan to evaluate site-specific restoration conditions and include design elements that minimize any conditions that could be conducive to increases of bioavailable selenium in restored areas. Before ground-breaking activities associated with site-specific restoration occurs, identify and evaluate potentially feasible actions for the purpose of minimizing conditions that promote bioaccumulation of selenium in restored areas.
AMM28	Geotechnical Studies	Conduct geotechnical investigations to identify the types of soil avoidance or soil stabilization measures that should be implemented to ensure that the facilities are constructed to withstand subsidence and settlement and to conform to applicable state and federal standards.

Number	Title	Summary
AMM29	Design Standards and Building Codes	Ensure that the standards, guidelines, and codes, which establish minimum design criteria and construction requirements for project facilities, will be followed. Follow any other standards, guidelines, and code requirements that are promulgated during the detailed design and construction phases and during operation of the conveyance facilities.
AMM30	Transmission Line Design and Alignment Guidelines	Design the alignment of proposed transmission lines to minimize impacts on sensitive terrestrial and aquatic habitats when siting poles and towers. Restore disturbed areas to preconstruction conditions. In agricultural areas, implement additional BMPs. Site transmission lines to avoid greater sandhill crane roost sites or, for temporary roost sites, by relocating roost sites prior to construction if needed. Site transmission lines to minimize bird strike risk.
AMM31	Noise Abatement	Develop and implement a plan to avoid or reduce the potential in-air noise impacts related to construction, maintenance, and operations.
AMM32	Hazardous Material Management	Develop and implement site-specific plans that will provide detailed information on the types of hazardous materials used or stored at all sites associated with the water conveyance facilities and required emergency-response procedures in case of a spill. Before construction activities begin, establish a specific protocol for the proper handling and disposal of hazardous materials.
AMM33	Mosquito Management	Consult with appropriate mosquito and vector control districts before the sedimentation basins, solids lagoons, and the intermediate forebay inundation area become operational. Once these components are operational, consult again with the control districts to determine if mosquitoes are present in these facilities, and implement mosquito control techniques as applicable. Consult with the control districts when designing and planning restoration sites.
AMM34	Construction Site Security	Provide all security personnel with environmental training similar to that of onsite construction workers, so that they understand the environmental conditions and issues associated with the various areas for which they are responsible at a given time.
AMM35	Fugitive Dust Control	Implement basic and enhanced control measures at all construction and staging areas to reduce construction-related fugitive dust and ensure the project commitments are appropriately implemented before and during construction, and that proper documentation procedures are followed.
AMM36	Notification of Activities in Waterways	Before in-water construction or maintenance activities begin, notify appropriate agency representatives when these activities could affect water quality or aquatic species.
AMM37	Recreation	Implement avoidance and minimization measures for recreational use within the reserve system. Measures to be implemented address the siting, designing, and construction of trails and other recreational facilities. Allowable recreational uses will be controlled using a variety of techniques including fences, gates, clearly signed trails, educational kiosks, trail maps and brochures, interpretive programs, patrol by land management staff, and restrictions by area and time.

3.4.22.2.2 Measures Benefitting All Covered Species and Natural Communities

AMM1 Worker Awareness Training and *AMM2 Construction Best Management Practices and Monitoring* are applicable to all projects that entail in-water work and/or ground disturbance or other demolition or construction activity (e.g., removal of derelict vessels as prescribed under *CM15 Localized Reduction of Predatory Fish*). AMM1 provides worker awareness training to ensure awareness of the AMM requirements by all jobsite personnel, and AMM2 provides for specification of numerous project-specific construction BMPs.

3.4.22.2.3 Measures Primarily Benefiting Covered Fishes

AMM3 through AMM9 will be implemented when construction activities or other covered activities occur in the vicinity of aquatic resources potentially occupied by covered fishes, as well as when performing construction activities that entail ground disturbance and associated potential impacts such as erosion, sedimentation, or materials spills. These AMMs will also benefit other native aquatic species, including covered species other than fish, such as giant garter snake and western pond turtle.

- *AMM3 Stormwater Pollution Prevention Plan* and *AMM4 Erosion and Sediment Control Plan* will be implemented for all projects entailing substantial ground disturbance. These measures minimize the risk of project-related sedimentation or turbidity causing adverse effects on water quality, which otherwise could harm covered species.
- *AMM5 Spill Prevention, Containment, and Countermeasure Plan* will be implemented for all projects where materials spills could result in contamination of surface waters. This measure minimizes the risk of project-related toxicant effects on covered species.
- *AMM6 Spoils, Tunnel Muck, and Dredged Material Disposal Plan* will be implemented for all projects that entail dredging, tunneling, or other substantial excavation such that excavated material must be disposed. This measure minimizes the risk of water quality or habitat degradation caused by dewatering from excavated materials or improper disposal of excavated materials.
- *AMM7 Barge Operations Plan* addresses potential adverse effects (such as grounding) arising from the use of barges to transport construction project equipment and materials. This measure serves to minimize the risk of harm to covered species or impairment of their habitat that might otherwise result from barge operations.
- *AMM8 Fish Rescue and Salvage Plan* describes protocols and approaches to perform fish rescue and salvage in cases where a potentially fish-bearing water body must be dewatered. It would primarily be implemented during cofferdam installation but would also have broader applications during construction of some restoration projects. It serves to minimize the risk of incidental take of covered fishes in association with dewatering of their habitat.
- *AMM9 Underwater Sound Control and Abatement Plan* would apply primarily to activities that entail pile driving in or near water bodies supporting covered fishes. It requires measures to minimize the risk of producing underwater sound of intensities and durations sufficient to harm covered fishes.

3.4.22.2.4 Measures Primarily Benefiting Plants, Animals, or Natural Communities

AMM10 Restoration of Temporarily Affected Natural Communities requires restoration for construction-related activities temporarily affecting natural communities, and prescribes the content of such a plan. It minimizes the risk of permanent impairment of natural communities or of habitat for the covered species they support.

AMM11 through AMM26 address needs unique to individual covered species or (for plants and vernal pool crustaceans) a group of covered species. These measures generally require preconstruction surveys and/or habitat assessments, but may also allow assumptions of presence. Depending on the species, they may also require the following precautions.

- During the design phase, evaluate site-specific conditions and design projects to avoid particularly sensitive areas (e.g., sandhill crane roost sites) to the extent practicable and incorporate other design measures as appropriate to avoid and minimize incidental take.
- Implement seasonal or timing restrictions for activities in sensitive areas (e.g., to avoid critical times for nesting or dispersal).
- Passively or actively relocate individuals out of construction areas. An example of passive relocation is the installation of one-way doors on burrowing owl burrows and collapsing burrows after verifying that no owls are present.

3.4.22.2.5 Measures Primarily Benefiting the Protection of All Natural Communities and Covered Species

AMM27 through AMM36 focus primarily on the protection of all natural communities and covered species. When implemented the measures will minimize the risk of BDCP activities on human health and the natural environment.

- *AMM27 Selenium Management* describes a process to identify and evaluate potentially feasible actions for the purpose of minimizing conditions that promote bioaccumulation of selenium in restored areas. It is currently unknown if the effects of increased residence time, and thus potential increases in selenium bioavailability, associated with restoration-related conservation measures will lead to adverse effects on fish and wildlife, which potentially include covered species.
- *AMM28 Geotechnical Studies* describes subsurface investigations that will be performed at the locations of the water conveyance alignment and facility locations and at material borrow areas. The main geotechnical issues in the Delta include stability of canal embankments and levees, liquefaction of Delta soils (particularly loose, saturated sands), seepage through coarse-grained soils, settlement of embankments and structures, subsidence, and soil-bearing capacity.
- *AMM29 Design Standards and Building Codes* ensures that standards, guidelines, and codes establishing minimum design criteria and construction requirements for project facilities will be followed by the BDCP engineers.
- *AMM30 Transmission Line Design and Alignment Guidelines* describes transmission line alignment measures to avoid impacts on biological resources and the routine magnetic field reduction measures that all regulated California electric utilities will consider for new and upgraded transmission line and transmission substation construction.

- *AMM31 Noise Abatement* describes components that will be included in a noise abatement plan to avoid or reduce potential in-air noise impacts related to construction, maintenance, and operation.
- *AMM32 Hazardous Material Management* ensures that each BDCP contractor responsible for construction of a BDCP facility or project will develop and implement a hazardous materials management plan (HMMP) before beginning construction. The HMMPs will provide detailed information on the types of hazardous materials used or stored at all sites associated with the water conveyance facilities (e.g., intake pumping plants, maintenance facilities) and will include appropriate practices to reduce the likelihood of a spill of toxic chemicals and other hazardous materials during construction and facilities operation and maintenance.
- *AMM33 Mosquito Management* ensures that consultation on implementing mosquito control techniques with appropriate mosquito and vector control districts, including the San Joaquin County and Sacramento-Yolo Mosquito and Vector Control Districts, will occur.
- *AMM34 Construction Site Security* ensures that all security personnel will receive environmental training similar to that of onsite construction workers so that they understand the environmental conditions and issues associated with the various areas for which they are responsible at a given time.
- *AMM35 Fugitive Dust Control* describes basic and enhanced control measures that will be implemented at all construction and staging areas to reduce construction-related fugitive dust.

AMM36 Notification of Activities in Waterways ensures appropriate agency representatives will be notified when BDCP activities could affect water quality or aquatic species.

3.4.22.2.6 Measures to Minimize Impacts Associated with Recreation

AMM37 Recreation describes measures that will be implemented for construction of trails and other recreational facilities and recreational use in the reserve system. These measures, once implemented, will minimize impacts on biological resources and specific natural communities and wildlife species.

3.4.22.3 Adaptive Management and Monitoring

Implementation of this conservation measure will be informed through compliance and effectiveness monitoring and adaptive management, as described in Section 3.6, *Adaptive Management and Monitoring Program*.

Compliance monitoring will consist of conducting preconstruction surveys for covered species and preparing reports to document methods and results, and compliance with BMPs associated with construction activities in biological monitor reports.

Effectiveness monitoring will consist of summarizing, in the annual progress report, the prior year's results of compliance monitoring done in support of the implementation of AMMs required under CM22.

No key uncertainties have been identified in connection with this conservation measure. However, AMMs may be modified through adaptive management, if new information becomes available indicating that a different survey methodology or minimization and avoidance technique should be implemented. Modifications to AMMs will be subject to recommendation by the Adaptive

Management Team and will only be implemented if approved by the Permit Oversight Group and the Authorized Entity Group.

3.4.23 Resources to Support Adaptive Management

The conservation strategy sets out a comprehensive set of conservation measures that are expected to achieve a range of identified measurable biological goals and objectives. As described in this chapter, the conservation measures include certain actions to improve flow conditions, increase food production, restore habitat, and reduce the adverse effects of other stressors. The conservation strategy also recognizes the considerable uncertainty that exists regarding the understanding of the Delta ecosystem and the likely outcomes of implementing the conservation measures, both in terms of the nature and the magnitude of the response of covered species and of ecosystem processes that support the species. To effectively address such uncertainty, the conservation strategy includes an adaptive management program that provides for flexibility in the implementation of the conservation measures.

Under the adaptive management program, the conservation measures may be modified or adjusted, through the process described in Section 3.6, *Adaptive Management and Monitoring Program*, to further advance the biological objectives. Any such changes to conservation measures must be consistent with the commitments and cost estimates set out in Chapter 8, *Implementation Costs and Funding Sources*, including those reflected in the Supplemental Adaptive Management Fund (Section 3.4.23.5). Similarly, biological objectives may also be adjusted through the adaptive management process (Section 3.6.3.5.3, *Changing a Conservation Measure or Biological Objective*). Strategies for making adaptive management changes to the conservation strategy will include the following.

- Changing approaches to the implementation of the conservation measures.
- Shifting resources from less effective to more effective conservation measures.
- Adding new conservation measures.
- Revising biological objectives.
- Utilizing the Supplemental Adaptive Management Fund (Section 3.4.23.5).

These strategies will be evaluated by the parties involved in the adaptive management process, as described in Section 3.6.3.5.3, as they consider changes to the conservation measures and biological objectives. Such strategies may be applied to any of the conservation measures, including those that involve water operations, habitat restoration, or other stressors, to benefit the aquatic or terrestrial species covered by the Plan. Any potential adaptive management change to a conservation measure, either individually or cumulatively, may not require the commitment of resources in excess of those provided for under these strategies, including the Supplemental Adaptive Management Fund, or under the commitments of the Plan participants, including the Authorized Entities, set out in Table 8-41, *BDCP Funding Provided by Participating State and Federal Water Contractors* (Chapter 8).

As part of the adaptive management process, adjustments to water operations criteria established under *CM1 Water Facilities and Operation* may be necessary. Every 5 years, water facility operating criteria will be comprehensively reevaluated as part of the program-level assessment conducted by Implementation Office, as described in Chapter 6, Section 6.3.5, *Five-Year Comprehensive Review*. In the event that changes to CM1 are adopted through the adaptive management process, the resources needed to implement such changes will be drawn from the following sources and in the order of priority set out below.[45]

1. Interannual adjustments in operations.
2. Sharing of water supply improvements.
3. Funding shifts to the most effective conservation measures.
4. Enhanced environmental flows.
5. Supplemental Adaptive Management Fund.

The following describes each of the potential resources available to support an adaptive management change to CM1 and the extent to which these resources may be available for such purposes.

3.4.23.1 Interannual Adjustments in Operations

Interannual adjustments in operations involve voluntary actions to modify water facility operations to provide additional benefits for covered fish species. These reoperations would not alter water operating parameters, but rather would allow for certain adjustments to be made to water operations that produce benefits for covered fish species. Under this approach, adjustments would be water-neutral. A number of water management tools, such as use of available stored reservoir or groundwater, source shifting, and borrowed water allocable to SWP or CVP water contractors, would be used to allow for these adjustments to occur. To the extent these tools are available, additional water could be provided to support changes to water operations made through the adaptive management process. Specific actions would be developed on an annual basis by the Authorized Entities and would be applied on a case-by-case basis, pursuant to a water management plan that confirms that the proposed reoperation would be water-neutral and otherwise acceptable to the Authorized Entities. This approach would not be adopted if the proposed adjustment to water operations would have an adverse effect on listed species located upstream of the Delta.

Water-neutral means that there will be no net annual water supply impact, defined as follows.

- No adverse impact on water contract allocations or involuntary impacts on delivery schedules in the year of action or in future years.
- No adverse impact on end of water-year storage at upstream facilities.
- No adverse impact on San Luis Reservoir low point[46].

[45] That is, if the resources necessary to implement the change can be obtained through a higher-priority source, lower-priority sources will not be used.

[46] The San Luis Reservoir low point is defined as the reservoir level at which 300 thousand acre-feet of storage is achieved (equivalent to a water surface elevation of 369 feet). At or below this level, deliveries to the San Felipe Division of the CVP can be seriously affected by degraded water quality from algal blooms or by reduced pumping capability when the lower Pacheco Pumping Plant intake is exposed.

3.4.23.2 Sharing of Water Supply Improvements

Adaptive management changes to CM1 may result in increased water supplies for SWP/CVP purposes beyond prior annual or long-term projections. If this occurs, the additional water supply will be divided equally between the SWP/CVP water contract deliveries and the conservation strategy through supplemental flows or other approaches designed to enhance aquatic conditions.

3.4.23.3 Redirected Funding to the Most Effective Conservation Measures

An important purpose of the adaptive management program is to identify conservation measures that are effective and those that are not (Section 3.6, *Adaptive Management and Monitoring Program*). Conservation measures that have been funded and implemented properly and, nonetheless, are not achieving their intended outcomes may be considered less than effective and not worth continuing to implement (or continuing at a reduced effort). Funding dedicated for conservation measures that later prove less than effective could be reallocated to further support more effective conservation measures, within the scope of the Plan commitments and consistent with available funding. This approach could be used to support adaptive management changes not only to CM1, but to any of the conservation measures. Under this approach, any reallocation of funding would be expected to produce an overall net conservation benefit and would be otherwise consistent with the regulatory authorizations issued under the Plan.

3.4.23.4 Enhanced Environmental Flows

Through the implementation of various strategies such as water use efficiency programs, reservoir reoperations, water system improvements, and other incentive-based measures, BDCP participants may realize additional yields or otherwise acquire from voluntary sellers long-term access to water for the purposes of, among other things, enhancing environmental conditions in the Delta and improving water supply reliability. Water used for environmental enhancement could be used to augment outflow established through the decision-tree process, as reflected in CM1, for the benefit of longfin smelt and delta smelt or south Delta operating criteria. Water that was not used to benefit longfin smelt or delta smelt or to support south Delta operating criteria could then be used, first, to benefit other covered species or support other adaptive changes to CM1 and, second, to serve other environmental purposes.

3.4.23.5 Supplemental Adaptive Management Fund

In the event that the resources necessary to support an adaptive management change cannot be secured through any of the foregoing approaches, funding to accommodate the change will be made available from the Supplemental Adaptive Management Fund. This Supplemental Adaptive Management Fund, which will be at least $450 million, will be used to support adaptive management changes to CM1, as well as to other conservation measures, determined to be necessary during Plan implementation. Funding for the Supplemental Adaptive Management Fund will be jointly provided by the Authorized Entities, the State of California, and the United States.

The components of the fund and the process by which it would be made available to support changes to conservation measures through the adaptive management process are as follows. The Supplemental Adaptive Management Fund would be accessed after the other approaches described in this section were determined to be unavailable or insufficient. Although the Supplemental

Adaptive Management Fund could be accessed earlier, it is anticipated that the first time the fund would be accessed would be no earlier than 5 years after CM1 operations begin. Any decision to access the fund would be considered in the context of a proposed change to CM1, or any other conservation measure, as part of the adaptive management process, which is expected to occur in association with the 5-year review process. The fund, however, would be available at any time to support an adaptive management change to a conservation measure.

Before the fund could be accessed, the following actions will have been taken or determinations made.

- A periodic review has determined that one or more of biological objectives are unlikely to be achieved through implementation of the existing conservation measures (Section Chapter 6, 6.3, *Planning, Compliance, and Progress Reporting*).
- The biological objectives have been assessed in light of their achievability under the Plan and, if circumstances and the new scientific information warranted, adjustments to such objectives were made.
- A lack of progress toward achieving one or more biological objectives is related to or caused by the covered activities or conservation measures.
- Adjustments to one or more conservation measures (e.g., more flow, changes in habitat restoration targets or locations) are likely to address the problem.
- To the extent appropriate, existing assets have been reallocated to support adequate changes to conservation measures (Section 3.4.23.3, *Redirected Funding to the Most Effective Conservation Measures*).
- Measures that do not adversely affect water supply, if any, have been implemented.

If the consideration of the foregoing factors confirms the need to use the fund, the Implementation Office, pursuant to the direction provided through the adaptive management process, would initiate actions to deploy the money available through the Supplemental Adaptive Management Fund to provide the additional resources necessary to implement the adaptive management change. These funds could be used, for instance, to acquire supplemental flows, additional natural community restoration, other actions, or a combination of approaches. If, for example, additional outflow was determined to be necessary, supplemental water could be provided through water acquired from voluntary sellers. If additional natural community restoration or more investment in predation reduction were determined to be necessary, these actions could also be funded through the Supplemental Adaptive Management Fund.

3.4.24 References Cited

3.4.24.1 Literature Cited

Akers, P. 2010. *The California Department of Food and Agriculture Hydrilla Eradication Program Annual Progress Report 2010*. Sacramento, CA. Available: <http://www.cdfa.ca.gov/plant/ipc/hydrilla/pdfs/hydrilla2010_annualreport-contents.pdf>. Accessed: February 2012.

Alpers, C. N., C. Eagles-Smith, C. Foe, S. Klasing, M. C. Marvin-DiPasquale, D. G. Slotton, and L. Windham-Myers. 2008. *Mercury Conceptual Model*. Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan.

Alpine, A. E., and J. E. Cloern. 1992. Trophic Interactions and Direct Physical Effects Control Phytoplankton Biomass and Production in an Estuary. *Limnology and Oceanography* 37:946–955.

Amweg, E. L., D. P. Weston, J. You, and M. Lydy. 2006. Pyrethroid Insecticides and Sediment Toxicity in Urban Creeks from California and Tennessee. *Environmental Science and Technology* 40(5):1700–1706.

Amyot, M., D. J. McQueen, G. Mierle, and D. R. S. Lean. 1994. Sunlight-induced Formation of Dissolved Gaseous Mercury in Lake Waters. *Environmental Science and Technology* 28(13):2366–2371.

Anderson, E. K., Z. Q. Richard Chen, H. Bandeh, M. Hannum, K. Carr, M. Cayar, I. Haltas, M. L. Kavvas, D. Cocherell, A. Kawabata, D. Kratville, S. Hamilton, T. MacColl, L. Kanemoto, J. Webber, J. J. Cech Jr., C. Wilkinson, M. M. Rotondo, R. Padilla, J. Miranda, and R. Churchwell. 2007. *Through-Delta Facility White Sturgeon Passage Ladder Study*. Prepared for the California Department of Water Resources, Sacramento, CA.

Anderson, J. J., J. A. Gore, R. T. Kneib, M. S. Lorang, J. M. Nestler, and J. Van Sickle. 2012. *Report of the 2012 Delta Science Program Independent Review Panel (IRP) on the Long-term Operations Opinions (LOO) Annual Review*. December 1.

Anderson, L. 2008. Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). Administrative Draft Ecosystem Conceptual Model, Aquatic Vegetation Growth. Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan. January 18.

Anderson, L., and P. Akers. 2011. Spongeplant: A New Aquatic Weed Threat in the Delta. *Cal-IPC News* 19:1–4.

Baerwald, M. R., B. M. Schreir, G. Schumer, and B. May. 2012. Detection of Threatened Delta Smelt in the Gut Contents of the Invasive Mississippi Silverside in the San Francisco Estuary Using TaqMan Assays. *Transaction of the American Fisheries Society* 141:1600–1607.

Baker, P. F., and J. E. Morhardt. 2001. Survival of Chinook salmon smolts in the Sacramento-San Joaquin Delta and Pacific Ocean. *California Department of Fish and Game Fish Bulletin* 179(2):163–182.

Baker, P. F., T. P. Speed, and P. K. Ligon. 1995. Estimating the Influence of Temperature in the Survival of Chinook Salmon Smolts (*Oncorhynchus tshawytscha*) Migrating through the Sacramento–San Joaquin River Delta of California. *Canadian Journal of Fisheries and Aquatic Sciences* 52:855–863.

Balirwa, J. S., C. A. Chapman, L. J. Chapman, I. G. Cowx, K. Geheb, L. Kaufman, R. H. Low-McConnel, O. Seehausen, J. H. Wanink, R. L. Welcomme, and F. Witte. Biodiversity and Fishery Sustainability in the Lake Victoria Basin: An Unexpected Marriage? *BioScience* 53:703–715.

Baraona, M., T. Ippolito, and W. Renz. 2007. *Post-Project Appraisals of Constructed Vernal Pools in Solano, County, California*. Water Resources Center Archives, University of California. Berkeley, CA.

Barbour, M., T. Keeler-Wolf, and A. A. Schoenherr (eds.). 2007. *Terrestrial Vegetation of California*. 3rd edition. University of California Press.

Barry, S., S. Larson, and M. George. 2006. California Native Grasslands, a Historical Perspective: a Guide for Developing Realistic Restoration Objectives. *Grasslands.* 16:7–11.

Baskerville-Bridges, B., J. C. Lindberg, and S. I. Doroshov. 2004. The Effect of Light Intensity, Alga Concentration, and Prey Density on the Feeding Behavior of Delta Smelt Larvae. *American Fisheries Society Symposium* 39:219–228.

Baxter, R. D., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Müller -Solger, M. Nobriga, T. Sommer, K. Souza. 2008. *Pelagic Organism Decline Progress Report: 2007 Synthesis of Results*. January 15. Interagency Ecological Program for the San Francisco Estuary, Technical Report 227. Available: <http://www.waterrights.ca.gov/baydelta/docs/pelagicorganism/pod_ieppodmt_2007synthesis_011508.pdf>.

Baxter, R. R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Müller -Solger, T. Sommer, and K. Souza. 2010. *2010 Pelagic Organism Decline Work Plan and Synthesis of Results*. Interagency Ecological Program for the San Francisco Estuary, Sacramento, CA. Available: <www.water.ca.gov/iep/docs/FinalPOD2010Workplan12610.pdf>.

Baxter, R. D., K. Hieb, S. DeLeon, K. Fleming, and J. Orsi. 1999. *Report on 1980–1995 Fish, Shrimp and Crab Sampling in the San Francisco Estuary, California*. Technical Report 63. Interagency Ecological Program for the Sacramento-San Joaquin Estuary.

Bay-Delta Oversight Council. 1995. *An Introduction to Harvest and Its Effects on Selected Species of Fish of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Draft briefing paper.* March. California Resources Agency. Sacramento, CA.

Bay Delta Oversight Council. 2002. *Delta Levee and Channel Repair and Maintenance Issues*. Available: <http://www.calwater.ca.gov/Admin_Record/D-000742.pdf>.

BDCP Integration Team. 2009. *Yolo Technical Study 2*.

Beagle, J., A. Whipple, R. M. Grossinger. 2012. *Historical Ecology and Landscape-Scale Restoration.* Application to the McCormack-Williamson Tract. 7th Biennial Bay-Delta Science Conference 2012. Available: <http://www.sfei.org/sites/default/files/Beagle_MWT%20for%20Delta%20Science%20conf%202012-web.pdf>.

Beamesderfer, R. C. P. 2000. Managing Fish Predators and Competitors: Deciding When Intervention Is Effective and Appropriate. *Fisheries* 25(6):18–23.

Beamesderfer, R. C. P, M. L. Simpson, and G. L. Kopp. 2007. Use of Life History Information in a Population Model of Sacramento Green Sturgeon. *Environmental Biology of Fishes* 70:315–337.

Begon, M, J. L. Harper, and C. R. Townsend. 1996. *Ecology: Individuals, Populations and Communities.* 3rd ed. Oxford: Blackwell Scientific Publications.

Beier, P., and R. Noss. Do Habitat Corridors Provide Connectivity? *Conservation Biology* 12(6):1241–1252.

Benigno, G. M., and T. R. Sommer. 2008. Just Add Water: Sources of Chironomid Drift in a Large River Floodplain. *Hydrobiologia* 600(1):297–305.

Bennett, W. A. 2005. Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California. *San Francisco Estuary and Watershed Science* 3(2):Article 1. Available: <http://escholarship.org/uc/item/0725n5vk>.

Black & Veatch Corporation. 2012. *Delta Habitat Conservation & Conveyance Program Creation of up to 100,000 Acres of Intertidal and Associated Subtidal Habitat: Feasibility Level Assessment based on Elevation & Land Acquisition Considerations*. Technical memorandum. February 27. Water Division, San Francisco, CA. Prepared for California Department of Water Resources, Sacramento, CA.

Boreman, J. 1997. Sensitivity of North American Sturgeons and Paddlefish to Fishing Mortality. *Environmental Biology of Fishes* 48:399–405.

Bowen, M. D., and R. Bark. 2010. *2010 Effectiveness of a Non-Physical Fish Barrier at the Divergence of the Old and San Joaquin Rivers (CA)*. Draft. Technical Memorandum. September. U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center, Denver, CO.

Bowen, M. D., L. Hanna, R. Bark, V. Maisonneuve, and S. Hiebert. 2008. *Non-Physical Barrier Evaluation, Physical Configuration I*. U.S. Technical Memorandum. Department of the Interior, Bureau of Reclamation, Technical Service Center, Denver, CO.

Bowen, M. D., S. Hiebert, C. Hueth, and V. Maisonneuve. 2009. *Effectiveness of a Non-Physical Fish Barrier at the Divergence of the Old and San Joaquin Rivers (CA)*. Technical Memorandum 86-68290-09-05. Department of the Interior, Bureau of Reclamation, Technical Service Center, Denver, CO.

Boyer, K. E. 2010. *Salinity Effects on Native and Introduced SAV of Suisun Bay and the Delta*. Project proposal. Available: <nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=27849>.

Boyer, K. E. 2012. *Pondweeds!* Research summary. February. Available: <http://online.sfsu.edu/~katboyer/Boyer_Lab/Pondweeds%21.html>.

Brandes, P. L., and J. S. McLain. 2001. Juvenile Chinook Salmon Abundance, Distribution, and Survival in the Sacramento–San Joaquin Estuary. *California Department of Fish and Game Fish Bulletin* 179(2):39–138.

Brannon, E., S. Brewer, A. Setter, H. Miller, F. Utter, and W. Hershberger. 1985. *Columbia River White Sturgeon (Acipenser transmontanus) Early Life History and Genetics Study: Final Report*. Project No. 83-316. December. U.S. Department of Energy.

Brown, L. R. 2003. Will Tidal Wetland Restoration Enhance Populations of Native Fishes? In Larry R. Brown (ed.), Issues in San Francisco Estuary Tidal Wetlands Restoration. *San Francisco Estuary and Watershed Science* 1(1):Article 2. Available: <http://escholarship.org/uc/item/2cp4d8wk>.

Brown, L. R., and D. Michniuk. 2007. Littoral Fish Assemblages of the Alien-dominated Sacramento–San Joaquin Delta, California, 1980–1983 and 2001–2003. *Estuaries and Coasts* 30:186–200.

Brown, L. R., and P. B. Moyle. 1991. Changes in Habitat and Microhabitat Use of an Assemblage of Stream Fishes in Response to Predation by Sacramento Squawfish (*Ptychocheilus grandis*). Canadian Journal of Fisheries and Aquatic Sciences 48:849–856.

Bryant, L. D. 1982. Response of Livestock to Riparian Zone Exclusion. *Journal of Range Management* 35(6).

Buddington, R. K., and J. P. Christofferson. 1985. Digestive and Feeding Characteristics of the Chondrosteans. *Environmental Biology of Fishes* 14:31–41.

Bureau of Reclamation. 2008. *Reclamation Begins Boat Inspections at Lake Berryessa*. Available: <http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=22281>. Accessed: July 27, 2012.

Bureau of Reclamation. 2008. *Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment*. May 22. Mid-Pacific Region, Sacramento, CA.

Bureau of Reclamation. 2009. 2009 Effectiveness of a Non-Physical Fish Barrier at the Divergence of the Old and San Joaquin Rivers (CA). Technical Memorandum 86-68290-09-05. Denver, CO. <http://www.sjrg.org/peerreview/InitialDraftNonPhysicalBarrier_MarkBowen.pdf>.

Bureau of Reclamation. 2011. *Central Valley Project Improvement Act Habitat Restoration Program.* Available: <http://www.usbr.gov/mp/cvpcp/program_hrp/index.html>. Accessed: August 1, 2012.

Bureau of Reclamation. 2012. *Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan*. Long-Term Operation of the Central Valley Project and State Water Project Biological Opinion. Reasonable and Prudent Alternative Actions I.6.1 and I.7. Sacramento, CA.

Bureau of Reclamation and Department of Water Resources. 2012. Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan: Long-term operation of the Central Valley Project and State Water Project Biological Opinion, Reasonable and Prudent Alternative Actions I.6.1 and I.7. Sacramento, CA.

Bureau of Reclamation, U.S. Fish and Wildlife Service, and California Department of Fish and Game. 2011. Suisun Marsh Habitat Management, Preservation, and Restoration Plan: Final Environmental Impact Statement/Environmental Impact Report. November. With assistance from ICF International, Sacramento, CA.

Butterwick, M. 1998. The Hydrogeomorphic Approach and Its Use in Vernal Pool Functional Assessment. Pages 50–55 in C. W. Witham, E. T. Bauder, D. Belk, W. R. Ferren Jr. and R. Ornduff (eds.), *Ecology, Conservation, and Management of Vernal Pool Ecosystems—Proceedings from a 1996 Conference*. California Native Plant Society, Sacramento, CA.

Byington, A. 2007. *Photo-Degradation of Methyl Mercury in the Sacramento–San Joaquin Delta Estuary*. Thesis Report Presented to Gary Gill to be Submitted to the CALFED Bay-Delta Program for the Project Transport, Cycling and Fate of Mercury and Monomethylmercury in the San Francisco Delta and Tributaries Task 5.1. Central Valley Regional Water Quality Control Board. Available: <http://mercury.mlml.calstate.edu/reports/reports/>.

Cabrero Walsh, G., Y. M. Dalto, F. Mattioli, R. Carruthers, and L. Anderson. In press. Biology and Ecology of Brazilian Elodea (*Egeria Densa*) and Its Specific Herbivore Hydrellia sp. in Argentina. *Biocontrol.* Accepted July 25, 2012.

CALFED Bay-Delta Program. 2000. *Ecosystem Restoration Program Plan. Volume II: Ecological Management Zone Visions*. Final programmatic EIS/EIR technical appendix. Available: <http://www.delta.dfg.ca.gov/erp/docs/reports_docs/ERPP_Vol_2.pdf>.

CALFED Bay-Delta Program. 2001. *Scrutinizing the Delta Cross-Channel*. News from the CALFED Bay-Delta Science Program.

Calflora. 2012. Information on California Plants for Education, Research and Conservation. Berkeley, California. Available: <http://www.calflora.org>. Accessed: January and February 2012.

California Department of Boating and Waterways. 2001. *Egeria Densa Control Program (EDCP): Environmental Impact Report, Vol. III, Response to Comments and EIR Errata.* March. Sacramento, CA.

California Department of Boating and Waterways. 2003. *Aquatic Pest Control: Water Hyacinth and Egeria Densa.* Available: <http://www.dbw.ca.gov/aquatic.htm>.

California Department of Boating and Waterways. 2006. Egeria densa *Control Program Second Addendum to 2001 Environmental Impact Report with Five-Year Program Review and Future Operations Plan*. U.S. Department of Agriculture, Sacramento, CA.

California Department of Boating and Waterways. 2008. *Egeria densa* Control Program Annual Report 2007 Application Season. U.S. Department of Agriculture, Sacramento, CA.

California Department of Boating and Waterways 2009a. *Water Hyacinth Control Program Draft Programmatic Environmental Impact Report*. September 10. Sacramento, CA.

California Department of Boating and Waterways 2009b. *Water Hyacinth Control Program Operations Management Plan 2009 Updated Manual*. Available: <http://www.agriculturedefensecoalition.org/sites/default/files/file/contra_costa_wh_73/73X_2009_CA_Boating_Waterways_Department_WHCP_Operations_Management_Plan_Manual_2009_04_Appx_C_WHCP_OMP.pdf>.

California Department of Fish and Game. 1998. *California Vernal Pool Assessment, Preliminary Report. Appendix C. Plant and Animal Taxa Known to be Associated with Vernal Pools*.

California Department of Fish and Game. 2003a. Pogonichthys Macrolepidotus *(Sacramento Splittail) Static Definitive Acute Toxicity Test Data (96-hour) for Exposure to Various Aquatic Herbicides*. Aquatic Toxicology Laboratory, Elk Grove, CA.

California Department of Fish and Game. 2003b. Ceriodaphnia Dubia *(Water Flea) Static Definitive Chronic Toxicity Test Data (7-Day) for Exposure to Various Aquatic Herbicides*. Aquatic Toxicology Laboratory, Elk Grove, CA.

California Department of Fish and Game. 2007a. *Delta-Bay Enhanced Enforcement Project: Annual Report July 2006-June 2007*. Sacramento, CA.

California Department of Fish and Game. 2007b. *California Steelhead Fishing Report-Restoration Card*. Report to the Legislature. July. Sacramento, CA.

California Department of Fish and Game. 2008a. *Yolo Bypass Wildlife Area Land Management Plan*.

California Department of Fish and Game. 2008b. *California Aquatic Invasive Species Management Plan*. January. Available: <www.dfg.ca.gov/invasives/plan>. Accessed: May 29, 2008.

California Department of Fish and Game. 2008c. *2007 Sturgeon Fishing Report Card: Preliminary Data Report*. Sacramento, CA.

California Department of Fish and Game. 2008d. *Central Valley Angler Survey*. December 27. Sacramento, CA.

California Department of Fish and Game. 2009. California Endangered Species Act Incidental Take 17 Permit No. 2081-2009-001-03, Department of Water Resources, California State Water Project 18 Delta Facilities and Operations. Available: <http://www.dfg.ca.gov/delta/data/longfinsmelt/documents/ITP-Longfin-1a.pdf>. Accessed: October 10, 2013.

California Department of Fish and Game. 2010a. *The Vegetation Classification and Mapping Program. Natural Communities List. Forest and Woodlands Alliances and Stands.* September. Available: <http://www.dfg.ca.gov/biogeodata/vegcamp/pdfs/natcomlist.pdf>.

California Department of Fish and Game. 2010b. *Suisun Marsh Habitat Management, Preservation, and Restoration Plan. Environmental Impact Statement/Environmental Impact Report. Draft*. October. SCH#: 2003112039. Prepared in association with U.S. Department of the Interior, Bureau of Reclamation and U.S. Fish and Wildlife Service, Sacramento, CA. Prepared with assistance from ICF International, Sacramento, CA. Available: <http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=781>.

California Department of Fish and Game. 2011. *Memorandum—Fremont Weir Sturgeon Rescue*. Rancho Cordova, CA.

California Department of Fish and Game. 2012a. Issue Statement Regarding Delta/Bay Enforcement Proposal. Sacramento, CA. Email 4/18/2012

California Department of Fish and Game. 2012b. *Watercraft Inspection Programs in California*. <http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=46843>. Accessed: June 27, 2012. Last updated: May 15, 2012.

California Department of Food and Agriculture. 2011. *Beneficial Bugs in the Delta: CDFA Begins Releasing Insects that Feed on Invasive Water Hyacinth*. July 28. News Release #11-041. Sacramento, CA. Available: <http://www.cdfa.ca.gov/egov/Press_Releases/Press_Release.asp?PRnum=11-041>. Accessed June 2012.

California Department of Food and Agriculture and California Invasive Weed Awareness Coalition. 2005. *California Noxious & Invasive Weed Action Plan*. S. Schoenig (ed.). Sacramento, CA.

California Department of Water Resources. 1999. *Biological Assessment: Suisun Marsh Preservation Agreement as Modified by Amendment Three*.

California Department of Water Resources. 2007. *Through Delta Facility White Sturgeon Passage Ladder Study*. Sacramento, CA: Fisheries Improvements Section, Bay-Delta Office.

California Department of Water Resources. 2010a. *Fact Sheet Sacramento River Flood Control Project Weirs and Flood Relief Structures*. Sacramento, CA: Flood Operations Branch.

California Department of Water Resources. 2010b. *Release Site Predation Study*. Technical Report. Principle Investigators: J. Miranda and R. Padilla, Fishery Improvements Section, Bay-Delta Office. Sacramento, CA.

California Department of Water Resources. 2012a. *2012 Central Valley Flood Protection Plan: A Path for Improving Public Safety, Environmental Stewardship, and Long-Term Economic Stability*. Sacramento, CA.

California Department of Water Resources. 2012b. *Fact Sheet: Sacramento River Flood Protection System Weirs and Flood Relief Structures*. Division of Flood Management, Hydrology and Flood Operations Office. Sacramento, CA.

California Department of Water Resources. 2012c. 2011 *Georgaina Slough Non-Physical Barrier Performance Evaluation Project Report*. Sacramento, CA.

California Department of Water Resources and California Department of Fish and Game. 1986. *Agreement between the Department of Water Resources and the Department of Fish and Game to Offset Direct Fish Losses in Relation to the Harvey O. Banks Delta Pumping Plant*. December 30.

California Native Plant Society. 1992. *Policy on Appropriate Application of* Ex Situ *Conservation Techniques*. Adopted: September 1992. Available: <http://www.cnps.org/cnps/archive/ex_situ.pdf>.

California Native Plant Society. 2001. *Guidelines for Landscaping to Protect Native Vegetation from Genetic Degradation*. Sacramento, CA.

California State Parks. 2007. *Henry W. Coe State Park Wildfire Local Operating Agreement*. March. Monterey, California: Monterey District.

California Stormwater Quality Association. 1993. *Stormwater Best Management Practice (BMP) Handbooks*. Available: <http://www.cabmphandbooks.com/>.

Carolsfeld, J., M. Tester, H. Kreiberg, and N. M. Sherwood. 1997. Pheromone-Induced Spawning of Pacific Herring. *Horm Behav* 31(3):256–268.

Carpenter, S. R., J. J. Cole, J. R. Hodgson, J. F. Kitchell, M. L. Pace, D. Bade, K. L. Cottingham, T. E. Essington, J. N. Houser, and D. E. Schindler. 2001. Trophic Cascades, Nutrients, and Lake Productivity: Whole-Lake Experiments. *Ecological Monographs*. 71:163–186.

Casitas Municipal Water District. 2012. Quagga/Boating | Lake Casitas Recreation Area. <http://www.casitaswater.org/lower.php?url=quaggaboating>. Accessed: June 27, 2012.

Castillo G., J. Morinaka, J. Lindberg, B. Fujimura, J. Hobbs, G. Tigan, L. Ellison, B. Baskerville-Bridges. 2009. An Experimental Approach to Evaluate Entrainment Losses of Delta Smelt in the South Delta. *2009 State of the Estuary*. September 29–November 1, 2009. Oakland, CA

Castillo, G., J. Morinaka, J. Lindberg, R. Fujimura, B. Baskerville-Bridges, J. Hobbs, G. Tigan, and L. Ellison. In press. Pre-Screen Loss and Fish Facility Efficiency for Delta Smelt at the South Delta's State Water Project, California. *San Francisco Estuary and Watershed Science.* Available: <http://www.fws.gov/stockton/jfmp/docs/DRAFT-Delta-Smelt-Pre-Screen-Losses-SWP.pdf>. Accessed: April 2, 2012.

Cavallo, B., J. Merz, and J. Setka. 2012. Effects of Predator and Flow Manipulation on Chinook Salmon (*Oncorhynchus tshawytscha*): Survival in an Imperiled Estuary. *Environmental Biology of Fishes.* Netherlands: Springer.

Cayan, D., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. *Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment*. Prepared by the California Climate Change Center for the California Energy Commission. CEC-500-2009-014-D. Sacramento, CA.

Cech, J. J., and C. E. Crocker. 2002. Physiology of Sturgeon: Effects of Hypoxia and Hypercapnia. *Journal of Applied Ichthyology* 18:320–324.

Center for Plant Conservation. 1991. Appendix. Genetic Sampling Guidelines for Conservation Collections of Endangered Plants. Pages 225–238 in D. A. Falk and K. E. Holsinger (eds.), *Genetics and Conservation of Rare Plants*. New York, Oxford University Press.

Center, T. D., M. P. Hill, H. Cordo, and M. H. Julien. 2002. Waterhyacinth. Pages 41–64 in F. V. Driesche, B. Blossey, M. Hoodle, S. Lyon, and R. Reardon (eds.), *Biological Control of Invasive Plants in the Eastern United States*. U.S. Department of Agriculture Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV. FHTET-2002-04. August.

Central Valley Joint Venture. 2006. *Central Valley Joint Venture Implementation Plan—Conserving Bird Habitat*. U.S. Fish and Wildlife Service, Sacramento, CA.

Central Valley Regional Water Quality Control Board. 2005. *Resolution No. R5-2005-0005: Amending the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control Program for Factors Contributing to the Dissolved Oxygen Impairment in the Stockton Deep Water Ship Channel*.

Central Valley Regional Water Quality Control Board. 2007. *The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board Central Valley Region*. 4th edition. Revised October 2007 (with approved amendments). Available: <www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/sacsjr.pdf>.

Central Valley Regional Water Quality Control Board. 2010. *Resolution R5-2010-043 Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary.*

Central Valley Regional Water Quality Control Board. 2011a. *Sacramento-San Joaquin Delta Methylmercury TMDL*. Last revised: November 9, 2011. Available: <http://www.waterboards.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/delta_hg>. Accessed: November 11, 2011.

Central Valley Regional Water Quality Control Board. 2011b. *Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary – Attachment 1 to Resolution No. R5-2010-0043*. October 20.

Cheong, T. S., M. L. Kavvas, and E. K. Anderson. 2006. Evaluation of Adult White Sturgeon Swimming Capabilities and Applications to Fishway Design. *Environmental Biology of Fishes* 77:197–208.

Chotkowski M. 1999. List of Fishes Found in San Francisco Bay-Delta Shallow Water Habitats. *Interagency Ecological Program Newsletter* 12(3):12–18. As cited in Brown, L. R. 2003. Will Tidal Wetland Restoration Enhance Populations of Native Fishes? In Larry R. Brown (ed.), Issues in San Francisco Estuary Tidal Wetlands Restoration. *San Francisco Estuary and Watershed Science* 1(1):Article 2. Available: <http://escholarship.org/uc/item/2cp4d8wk>.

Circuit Rider Productions. 2004. *California Salmonid Stream Habitat Restoration Manual*. Windsor, CA. Prepared for the California Department of Fish and Game, Sacramento, CA.

Clarke, B. 2008. *USFWS Plans for Captive Propagation of Delta Smelt.* CALFED Science Program Workshop: The Use of Artificial Propagation as a Tool for Central Valley Salmonid and Delta Smelt Conservation, Sacramento, CA, July 14, 2008.

Clark, K. W., M. D. Bowen, R. B. Mayfield, K. P. Zehfuss, J. D. Taplin, and C. H. Hanson. 2009. *Quantification of Pre-Screen Loss of Juvenile Steelhead in Clifton Court Forebay*. Fishery Improvements Section, Bay-Delta Office, California Department of Water Resources: Sacramento, CA. Available: <http://baydeltaoffice.water.ca.gov/ndelta/fishery/documents/2009_clark_et_al_quantification_of_steelhead_pre-screen_loss.pdf>.

Claudi, R., and K. Prescott. 2011. *Examination of Calcium and pH as Predictors of Dreissinid Mussel Survival in the California State Water Project*. Prepared for California Department of Water Resources Division of Operations and Maintenance Aquatic Nuisance Species Program. March 11. Picton, Ontario: RNT Consulting Inc.

Cloern, J. E. 2007. Habitat Connectivity and Ecosystem Productivity: Implications from a Simple Model. *American Naturalist* 169(1):E21-E33. Available: <http://sfbay.wr.usgs.gov/publications/pdf/cloern_2007_connectivity.pdf>.

Cloern, J. E., N. Knowles, L. R. Brown, D. Cayan, M. D. Dettinger, T. L. Morgan, D. H. Schoelhamer, M. T. Stacey, M. van der Wegen, R. W. Wagner, and A. D. Jassby. 2011. *Projected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change*. PLoS One 6:e24465. Available: <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0024465>.

Close, D. A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status Report of the Pacific Lamprey (*Lampetra tridentata*) in the Columbia River Basin. Project No. 94-026, Contract No. 95BI39067. Report to the U.S. Department of Energy, Bonneville Power Administration, Portland, OR.

Cohen, S. E., and S. M. Bollens. 2008. Diet and Growth of Non-Native Mississippi Silversides and Yellowfin Gobies in Restored and Natural Wetlands in the San Francisco Estuary. *Marine Ecology Progress Series* 368:241–258.

Cohen, A. N., and J. T. Carlton. 1998. Accelerating Invasion Rate in a Highly Invaded Estuary. *Science* 279:555–558.

Conomos, T. J., R. E. Smith, and J. W. Gartner. 1985. Environmental Setting of San Francisco Bay. *Hydrobiologia* 129:1–12.

Conrad, J. L., K. L. Weinersmith, M. J. Young, D. de Carion, E. Hestir, M. Santos, P. Crain, S. Ustin, P. B. Moyle, and A. Sih. 2010. More Big Bass: Understanding the Role of Largemouth Bass as Top Predators in the Littoral Zone. Available: <http://www.water.ca.gov/aes/predators/largemouthbass.cfm>. Accessed: December 14, 2011.

Contra Costa Water District. 2002. *Los Vaqueros Project 2001 Annual California Red-Legged Frog and Predator Control Monitoring Report*. January. (J&S 01-356.) Brentwood, CA. Prepared with assistance from Jones & Stokes, Sacramento, CA.

Cook, L., and L. D. Buffaloe. 1998. *Delta Agricultural Diversion Evaluation Summary Report, 1993-1995*. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report Number 61. Sacramento, CA.

Crain P. K., K. Whitener, and P. B. Moyle. 2004. Use of a Restored Central California Floodplain by Larvae of Native and Alien Fishes. Pages 125–140 in F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi (eds.), *Early Life History of Fishes in the San Francisco Estuary and Watershed.* Bethesda, MD: American Fisheries Society. Available: <http://baydelta.ucdavis.edu/crg_data/albums/userpics/10001/Crain_et_al2004.pdf>.

Cushman, S. A. 2006. Effects of Habitat Loss and Fragmentation on Amphibians: A Review and Prospectus. *Biological Conservation* 128(2):231–240.

Deblois, E. M., and W. C. Leggett. 1993. Importance of biotic and abiotic regulators of abundance of the intertidal amphipod *Calliopius laeviusculus* (*Amphipoda: Gammaridae*) and assessment of the accuracy and precision of sampling methods for detecting abundance changes. *Marine Biology* 115: 75-83.

Dege, M. and L. R. Brown. 2004. Effect of Outflow on Spring and Summertime Distribution and Abundance of Larval and Juvenile Fishes in the upper San Francisco Estuary. *American Fisheries Society Symposium* 39:49–66. As cited in Rosenfield, J. A. 2010. *Life History Conceptual Model and Sub-Models for Longfin Smelt, San Francisco Estuary Population for the Delta Regional Ecosystem Restoration Implementation Plan*.

Delta Stewardship Council. 2010. *Fall Low Salinity Habitat (FLaSH) Studies and Adaptive Management Plan Review*. Available: <http://deltacouncil.ca.gov/science-program/fall-low-salinity-habitat-flash-studies-and-adaptive-management-plan-review-0>. Accessed: November 6, 2012.

DiPietro, D., M. Kelly, S. Schoenig, D. Johnson, and R. Yacoub. 2002. *California Weed Mapping Handbook.* Draft. September. California Department of Food and Agriculture. Available: <http://www.cdfa.ca.gov/plant/ipc/noxweedinfo/pdfs/handbook_sept.pdf>. Accessed: June 2012.

DiTomaso, J. M., K. L. Heise, G. B. Kyser, A. M. Merenlender, and R. J. Keiffer. 2001. Carefully Timed Burning Can Control Barb Goatgrass. *California Agriculture* 55:47–53.

Doubledee, R. A., E. B. Muller, and R. M. Nisbet. 2003. Bullfrogs, Disturbance Regimes, and the persistence of California Red-Legged Frogs. *Journal of Wildlife Management* 67:424–438.

Ducks Unlimited and ICF International 2012. *Effects Analysis of BDCP Covered Activities on Waterfowl and Shorebirds in the Yolo, Delta, and Suisun Basins*.

Enos, C., J. Sutherland, and M. Nobriga. 2007. Results of a Two-Year Fish Entrainment Study at Morrow Island Distribution System in Suisun Marsh. *Interagency Ecological Program Newsletter* 20(1):10–19. Available: <http://www.iep.ca.gov/report/newsletter/2007_newsletters/IEPNewsletterfinal3_winter2007.pdf>.

Enright, C., S. D. Culberson, J. R. Burau. 2013. Broad Timescale Forcing and Geomorphic Mediation of Tidal Marsh Flow and Temperature Dynamics. *Estuaries and Coast* May 8:26.

Essex Partnership. 2009. *DRERIP Evaluations of BDCP Draft Conservation Measures. Summary Report*. Draft. May 21. Available: <http://science.calwater.ca.gov/pdf/workshops/workshop_eco_052209_BDCP-DRERIP_Summary_with_Appendices1.pdf>. Accessed: December 9, 2011.

Essington, T. E., and S. Hansson. Predatory-Dependent Functional Responses and Interaction Strengths in a Natural Food Web. *Canadian Journal of Fisheries and Aquatic Sciences* 61:2215–2226.

Estes, J. A., J. Terborgh, J. S. Brashares, M. E. Power, and others. 2011. Trophic Downgrading of Planet Earth. Science 333:301–306.

Evans, F. E., N. J. Hostetter, D. D. Roby, K. Collis, D. E. Lyons, B. P. Sandford, R. D. Ledgerwood, S. Sebring. 2011. Systemwide Evaluation of Avian Predation on Juvenile Salmonids from the Columbia River based on Recoveries of Passive Integrated Transponder Tags. *Transactions of the American Fisheries Society* 141:975–989.

Federal Interagency Stream Restoration Working Group. 1999. *Stream Corridor Restoration: Principles, Processes and Practices*. (GPO item #0120-A.) Available: <http://www.nrcs.usda.gov/technical/stream_restoration>.

Feyrer, F., and M. P. Healey. 2003. Fish Community Structure and Environmental Correlates in the Highly Altered Southern Sacramento–San Joaquin Delta. *Environmental Biology of Fishes* 66(2):123–132.

Feyrer, F., B. Herbold, S. A. Matern, and P. B. Moyle. 2003. *Dietary Shifts in a Stressed Fish Assemblage: Consequences of a Bivalve Invasion in the San Francisco Estuary*. *Environmental Biology of Fishes* 67:277–288.

Feyrer, F., T. R. Sommer, and R. D. Baxter. 2005. Spatial-Temporal Distribution and Habitat Associations of Age-0 Splittail in the Lower San Francisco Estuary Watershed. *Copeia* 2005:159–168.

Feyrer, F., T. Sommer, and W. Harrell. 2006. Managing Floodplain Inundation for Native Fish: Production Dynamics of Age-0 Splittail (*Pogonichthys macrolepidotus*) in California's Yolo Bypass. *Hydrobiologia* 573:213–226.

Feyrer, F., T. Sommer, and J. Hobbs. 2007. Living in a Dynamic Environment: Variability in Life History Traits of Age-0 Splittail in Tributaries of San Francisco Bay. *Transactions of the American Fisheries Society* 136:1393–1405.

Finlayson, B., R. Schnick, D. Skaar, J. Anderson, L. Demong, D. Duffield, W. Horton, and J. Steinkjer. 2010. *Planning and Standard Operating Procedures for the Use of Rotenone in Fish Management – Rotenone SOP Manual*. American Fisheries Society, Bethesda, MD.

Fish Facilities Technical Team. 2013. *Work Plan—Intake Design Criteria and Performance Monitoring Development*. June 28. California Department of Water Resources, California Department of Fish and Wildlife, U. S. Bureau of Reclamation, U. S. Fish and Wildlife Service, and the National Marine Fisheries Service.

Fisch, K. M. 2011. *Conservation Genetics of the Endangered Delta Smelt* (Hypomesus transpacificus) *in the San Francisco Estuary*. Dissertation. University of California, Davis, CA.

Fisch, K., B. Mahardja, T. Rettinghouse, L. Ellison, G. Tigan, J. Lindberg, and B. May. 2010. Captive Breeding Plan for the Endangered Delta Smelt: Genetic Management and Fish Rearing Modification for 2010. *Interagency Ecological Program for the San Francisco Estuary Newsletter* 23(3):13–20.

Fisch, K., T. Rettinghouse, L. Ellison, G. Tigan, J. Lindberg, and B. May. 2009. Delta Smelt Refugial Population Development and Genetic Management, 2009 Season Summary. *Interagency Ecological Program for the San Francisco Estuary Newsletter* 22(3):3–9.

Flagg, T. A., B. A. Berejikian, J. E. Colt, W. W. Dickhoff, L. W. Harrell, D. J. Maynard, C. E. Nash, M. S. Strom, R. N. Iwamoto, and C. V. W. Mahnken. 2000. *Ecological and Behavioral Impacts of Artificial Production Strategies on the Abundance of Wild Salmon Populations: A Review of Practices in the Pacific Northwest*. NOAA Technical Memorandum NMFS-NWFSC-XX. Seattle, WA.

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. *California Salmonid Stream Habitat Restoration Manual*. 3rd edition. Prepared by California Department of Fish and Game, Sacramento, CA.

Foe, C., S. Louie, and D. Bosworth. 2008. Methylmercury *Concentrations and Loads in the Central Valley and Freshwater Delta*. Final Report Submitted to the CALFED Bay-Delta Program for the Project Transport, Cycling and Fate of Mercury and Monomethylmercury in the San Francisco Delta and Tributaries Task 2. Central Valley Regional Water Quality Control Board. Central Valley Regional Water Quality Control Board: Central Valley Region. Available: <http://mercury.mlml.calstate.edu/reports/reports/>. Accessed: September 28, 2011.

Frank, K. T., B. Petrie, J. S. Choi, and W. C. Leggett. 2005. Trophic Cascades in a Formerly Cod-Dominated Ecosystem. *Science* 308:1621–1623.

Fresh, K. L. 2006*. Juvenile Pacific Salmon in Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-06*. Seattle, WA: U.S. Army Corps of Engineers. Available: <www.pugetsoundnearshore.org.www.pugetsoundnearshore.org>.

Fuhlendorf, S. D., and D. M. Engle. 2001. Restoring Heterogeneity on Rangelands: Ecosystem Management Based on Evolutionary Grazing Patterns. *BioScience* 52(8):625–632.

Fujimura R. W., G. Edwards, D. Killam, T. M. Frink, and L. Millett. 2000. Evaluation of Adult Salmon Migration Passage at the Suisun Marsh Salinity Control Gates in Montezuma Slough, California. Pages 68–75 in J. H. Eiler, D. J. Alcorn, and M. R. Neuman (eds.), *Biotelemetry 15: Proceedings of the 15th International Symposium on Biotelemetry.* Juneau, Alaska, May 9–14, 1999.

Futuyma, D. J. 1998. Evolutionary Biology. 3rd edition. Sinauer Associates. Sunderland, MA.

Gadomski, D. M., and M. J. Parsley. 2005. Effects of Turbidity, Light Level, and Cover on Predation of White Sturgeon Larvae by Prickly Sculpins. *Transactions of the American Fisheries Society* 134:369–374.

Gill, G. 2008. *Monomethylmercury Photo-Degradation* Studies. Final Report Submitted to the CALFED Bay-Delta Program for the Project Transport, Cycling and Fate of Mercury and Monomethylmercury in the San Francisco Delta and Tributaries Task 5.1. Central Valley Regional Water Quality Control Board. Central Valley Regional Water Quality Control Board: Central Valley Region. Available: <http://mercury.mlml.calstate.edu/reports/reports/>. Accessed: September 28, 2011.

Gillespie, I. G., and E. A. Allen. 2004. Fire and Competition in a Southern California Grassland: Impacts on the Rare Forb *Erodium macrophyllum*. *Journal of Applied Ecology* 41:643–652.

Gilmer, D. S., M. L. Miller, R. B. Bauer, and J. R. LeDonne. 1982. California's Central Valley and Challenges. *Transactions of the North American Wildlife and Natural Research Conference* 47: 441–452.

Gingras, M. 1997. *Mark/Recapture Experiments at Clifton Court Forebay to Estimate Pre-Screening Loss to Entrained Juvenile Fishes: 1976–1993*. Interagency Ecological Program Technical Report 55. November. Interagency Ecological Program for the San Francisco Bay/Delta Estuary.

Godfrey, K. 2000. *Eichhornia Crassipes*. Pages 171–175 in C. C. Bossard, J. M. Randall, and M. C. Hoshovsky (eds.), *Invasive Plant of California's Wildlands*. Berkeley, CA: University of California Press.

Goldschmidt, T. E., F. Witte, and J. Wanink. 1993. Cascading Effects of the Introduced Nile Perch on the Detritivorous/Phytoplanktivorous Species in the Sublittoral Areas of Lake Victoria. *Conservation Biology* 7:686–700.

Goudswaard, P. C., F. Witte, E. F. B. Katunzi. 2002. The Tilapiine Fish Stock of Lake Victoria before and after the Nile Perch Upsurge. *Journal of Fish Biology* 60(4):838–856. Available: <http://onlinelibrary.wiley.com/doi/10.1111/j.1095-8649.2002.tb02413.x/abstract>.

Gregory, R. S., and C. D. Levings. 1998. Turbidity Reduces Predation on Migrating Juvenile Pacific Salmon. *Transactions of the American Fisheries Society* 127(2):275–285

Grewell, B. 2005. *Population Census and Status of the Endangered Soft Bird's Beak (*Cordylanthus mollis ssp. mollis*) at Benecia State Recreation Area and Rush Ranch in Solano County, California. Final Report*. Sacramento, CA: Solano County Water Agency.

Grimaldo, L., R. E. Miller, C. M. Peregrin, and Z. Hymanson. 2012. Fish Assemblages in Reference and Restored Tidal Freshwater Marshes of the San Francisco Estuary. *San Francisco Estuary and Watershed Science* 10(1). Available: <http://escholarship.org/uc/item/52t3x0hq>.

Grimaldo, L., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. Moyle, P. Smith, and B. Herbold. 2009. Factors Affecting Fish Entrainment into Massive Water Diversions in a Freshwater Tidal Estuary: Can Fish Losses Be Managed? *North American Journal of Fisheries Management* 29:1253–1270.

Grosholz, E., and E. Gallo, 2006. The Influence of Flood Cycle and Fish Predation on Invertebrate Production on a Restored California Floodplain. *Hydrobiologia* 568:91–109.

Groom, M., G. Meffe, and C. Carroll. 2006. *Principles of Conservation Biology*. 3rd Edition. Sinauer Associates, Inc.

Grossinger, R. M., R. A. Askevold, J. Beagle, E. E. Beller, E. Brewster, S. Gardner, S. Pearce, J. Ruygt, M. Salomon, C. J. Striplen, B. Stanford and A. W. Whipple. *Napa Valley Historical Atlas: Exploring a Hidden Landscape of Transformation and Resilience*. San Francisco Estuary Institute.

Grossinger, R., A. Whipple, and C. Wilcox. 2008. *Pre-Modification Habitat Mosaics of the Delta: Looking to the Past to Envision the Future*. Sacramento, CA: CalFed Conference.

Guerrant, Edward O. Jr., Kayri Havens, and Mike Maunder (eds.). 2004. *Ex Situ Plant Conservation: Supporting Species Survival in the Wild*. Center for Plant Conservation. Island Press: Washington, D.C.

Hallock, R. J., and W. F. Van Woert. 1959. A Survey of Anadromous Fish Losses in Irrigation Diversions from the Sacramento and San Joaquin Rivers. *Calif. Fish and Game* 45 (4): 227–266. As cited in: Moyle P. B., and D. White. 2002. Effects of screening diversions on fish populations in the Central Valley: what do we know? *Report for the Science Board, CALFED Ecosystem Restoration Program*. January.

Hallock, R. J., R. F. Elwell, and D. H. Fry, Jr. 1970. *Migrations of Adult King Salmon,* Oncorhynchus tshawytscha*, in the San Joaquin Delta*. California Fish and Game 151, Sacramento, CA.

Hamilton, J. G., J. R. Griffin, and M. R. Stromberg. 2002. Long-Term Population Dynamics of Native *Nassella* (Poaceae) Bunchgrasses in Central California. *Madroño* 49:274–284.

Hanson, C. H. 2001. Are Juvenile Chinook Salmon Entrained at Unscreened Diversions in Direct Proportion to the Volume of Water Diverted? Pages 331–342 in R. L. Brown (ed.), *Contributions to the Biology of Central Valley Salmonids.* Volume 2. California Department of Fish and Game Fish Bulletin 179.

Harrell, W. C., and T. R. Sommer. 2003. Patterns of Adult Fish Use on California's Yolo Bypass Floodplain. Pages 88–93 in P. M. Faber (ed.), *California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration, 2001 Riparian Habitat and Floodplains Conference Proceedings.* Sacramento, CA: Riparian Habitat Joint Venture.

Harrison, S., B. D. Inouye, and H. D. Safford. 2003. Ecological Heterogeneity in the Effects of Grazing and Fire on Grassland Diversity. *Conservation Biology* 17(3):837–845.

Hayes, G., and K. Holl. 2003. Cattle grazing impacts on annual forbs and vegetation composition in mesic grasslands in California. *Conservation Biology* 17:1694–1702.

Hays, D. W., K. R. McAllister, S. A. Richardson, and D. W. Stinson. 1999. *Washington State Recovery Plan for the Western Pond Turtle*. August. Olympia, WA: Washington Department of Fish and Wildlife. Available: <http://www.wdfw.wa.gov/wlm/diversty/soc/recovery/pondturt/wptfinal.pdf>.

Healey, M. C. 1991. *Life History of Chinook Salmon* (Oncorhynchus tshawytscha). Pages 311–394 in C. Groot, L. Margolis (eds.), *Pacific Salmon Life Histories*. Vancouver, B.C.: University of British Columbia Press.

Hedgecock, D., V. K. Rashbrook, and P. W. Hedrick. 2000. Effective Population Size of Winter-Run Chinook Salmon Based on Microsatellite Analysis of Returning Spawners. *Canadian Journal of Fisheries and Aquatic Science* 57:2368–2373.

Hedrick, P. W., D. Hedgecock, and S. Hamelberg. 1995. Effective Population Size in Winter-Run Chinook Salmon. *Conservation Biology* 9(3):615–624.

Heim, W. A., M. Stephenson, A. Bonnema, A. Byington, A. Newman, D. Feliz, L. Sousa, and K. Coale. In Press. *Methylmercury Concentrations and Exports from Seasonal Wetlands in the Yolo Wildlife Area, California*. Final Report.

Henneberry Y. K., T. E. Kraus, J. A. Fleck, D. P. Krabbenhoft, P. M. Bachand, W. R. Horwath. 2011. Removal of Inorganic Mercury and Methylmercury from Surface Waters following Coagulation of Dissolved Organic Matter with Metal-Based Salts. *The Science of Total Environment* 409(3):631–7. Available: <http://www.ncbi.nlm.nih.gov/pubmed/21075424>.

Henneberry, Y. K., T. E. C. Kraus, P. S. Nico, W. R. Horwath. In Press. Structural Stability of Coprecipitated Natural Organic Matter and Ferric Iron under Reducing Conditions. *Organic Geochemistry* 48:81–89. Available: <http://dx.doi.org/10.1016/j.orggeochem.2012.04.005>.

Herren, J. R., and S. S. Kawasaki. 2001. Inventory of Water Diversions in Four Geographic Areas in California's Central Valley. *California Department of Fish and Game Fish Bulletin* 179(2): 343–355.

Hestir, E. L. 2010. Trends in Estuarine Water Quality and Submerged Aquatic Vegetation Invasion. Ph.D dissertation, University of California, Davis. As cited in Baxter, R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solgar, T. Sommer, and K. Souza. 2010. *2010 Pelagic Organism Decline Work Plan and Synthesis of Results*. Interagency Ecological Program for the San Francisco Estuary, Sacramento, CA.

Hestir, E. L., D. H. Schoellhamer, J. A. Greenberg, T. Morgan, and S. L. Ustin. 2010. Interactions between Submerged Vegetation, Turbidity, and Water Movement in a Tidal River Delta. *Water Resources Research,* in review.

Hilty, J. A., W. Z. Lidicker, Jr. and A. M. Merenlender. 2006. Corridor Ecology, The Science and Practice of Linking Landscapes for Biodiversity Conservation. Washington, D.C.: Island Press.

Hobbs, J. A., W. A. Bennett, and J. E. Burton. 2006. Assessing Nursery Habitat Quality for Native Smelts (*Osmeridae*) in the Low-Salinity Zone of the San Francisco Estuary. *Journal of Fish Biology* 69:907–922.

Hoffman Black, S., M. Shepard, M. Vaughan, C. LaBar, and N. Hodges. 2009. *Yolo Natural Heritage Program (HCP/NCCP) Pollinator Conservation Strategy*. November. The Xerces Society for Invertebrate Conservation, Sacramento, CA.

Holbrook, C. M., R. W., Perry, and N. S. Adams. 2009. *Distribution and Joint Fish-Tag Survival of Juvenile Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta, 2008*. U.S. Department of the Interior, U.S. Geological Survey. Biological Resources Discipline Report to San Joaquin River Group Authority. Cook, WA.

Holomuzki, J. R., J. W. Feminella, and M. E. Power. 2010. Biotic Interactions in Freshwater Benthic Habitats. *Journal of the North American Benthological Society* 29:220–244.

Hosea, R. C., K. Z. Bjurstrom, and E. E. Littrell. 2004. *Acute Oral and Dermal Toxicity of Aquatic Herbicides and a Surfactant to Garter Snakes.* Administrative Report 2004-01 February 23. State of California The Resources Agency Department of Fish and Game, Office of Spill Prevention and Response, Rancho Cordova, CA.

Howitt, R., D. MacEwan, C. Garnache, J. M. Azuara, P. Marchand, Doug Brown, J. Six, and J. Lee. 2013. *Agricultural and Economic Impacts of Yolo Bypass Fish Habitat Proposals*. Prepared for Yolo County.

Huenemann, T. W., E. D. Dibble, and J. P. Fleming. 2012. Influence of Turbidity on the Foraging of Largemouth Bass. *Transactions of the American Fisheries Society* 141:107–111.

ICF International. 2010a. *Final Report: Stockton Deep Water Ship Channel Demonstration Dissolved Oxygen Aeration Facility Project*. Prepared for California Department of Water Resources.

ICF International. 2010b. *Biological Assessment of the 2011 Georgiana Slough Nonphysical Barrier Study for USFWS-Managed Species*. November. (ICF 00754.10.) Sacramento, CA. Prepared for California Department of Water Resources, Sacramento, CA.

Independent Scientific Review Panel. 2011. *Retrospective Report 2011*. Prepared for the Northwest Power and Conservation Council. ISRP 2011-25.

Interagency Ecological Program. 2008a. *Interagency Ecological Program 2008 Work Plan to Evaluate the Decline of Pelagic Species in the Upper San Francisco Estuary*. Interagency Ecological Program for the San Francisco Estuary, Sacramento, CA.

Ingebritsen, S. E., M. E. Ikehara, D. L. Galloway, and D. R. Jones. 2000. *Delta Subsidence in California—The Sinking Heart of the State: U.S. Geological Survey Fact Sheet*. Available: <http://pubs.usgs.gov/fs/2000/fs00500>.

Interagency Ecological Program. 2008b. *Pelagic Organism Decline Progress Report: 2007 Synthesis of Results*. January. Available: <http://www.fws.gov/sacramento /es/documents/POD_report_2007.pdf>.

Israel, J. A., K. M. Fisch, T. F. Turner, and R. S. Waples. 2011. Conservation of Native Fishes of the San Francisco Estuary: Considerations for Artificial Propagation of Chinook Salmon, Delta Smelt, and Green Sturgeon. *San Francisco Estuary and Watershed Science* 9(1):1–20.

Israel, J. A. and A. P. Klimley. 2008. *Life History Conceptual Model for North American Green Sturgeon* (Acipenser medirostris). Final. California Department of Fish and Game Delta Regional Ecosystem Restoration and Implementation Program.

Israel, J. A. and B. May. 2010. Characterization and Evaluation of Polymorphic Microsatellite Markers in the Anadromous Fish *Spirinchus thaleichthys*. *Conservation Genetics Resources* 2:227–230.

Israel, J. A, M. J. Thomas, A. P. Klimley, B. P. May. 2009. *Sacramento River Green Sturgeon Migration and Population Assessment.* Annual Program Performance Report to Bureau of Reclamation. Draft. May.

Ivey, G. L., B. E. Dugger, C. P. Herziger, M. L. Casazza, and J. P. Fleskes. In prep. *Characteristics of Sandhill Crane Roosts in the Sacramento-San Joaquin Delta of California*. Submitted to North American Crane Working Group Proceedings.

Jassby, A. D., and J. E. Cloern. 2000. Organic Matter Sources and Rehabilitation of the Sacramento-San Joaquin Delta (California, USA). *Aquatic Conservation: Marine and Freshwater Ecosystems*. 10:323–352.

Jassby, A. D., J. E. Cloern, and B. E. Cole. 2002. Annual Primary Production: Patterns and Mechanisms of Change in a Nutrient-Rich Tidal Ecosystem. *Limnology and Oceanography* 47:698–712. As cited in: Nobriga, M. F., and B. Herbold. 2009. *The Little Fish in California's Water Supply: a Literature Review and Life-History Conceptual Model for Delta Smelt* (Hypomesus transpacificus) *for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP)*.

Jassby, A., and E. E. Van Nieuwenhuyse. 2005. Low Dissolved Oxygen in an Estuarine Channel (San Joaquin River, California): Mechanisms and Models based on Long-Term Time Series. *San Francisco Estuary and Watershed Science*. 3(2).

Jeffres, C. A., J. J. Opperman, and P. E. Moyle. 2008. Ephemeral Floodplain Habitats Provide Best Growth Conditions for juvenile Chinook Salmon in a California River. *Environmental Biology of Fishes* 83(4):44–458.

Jones & Stokes. 2002. *City of Stockton Year 2001 Field Sampling Program Data Summary Report for San Joaquin River Dissolved Oxygen TMDL CALFED 2001 Grant*. Prepared for the City of Stockton Department of Municipal Utilities.

Jones & Stokes. 2007. *California Department of Water Resources Deep Water Shipping Channel Aeration Demonstration Project Biological Assessment for Operations*. Sacramento, CA.

Jones & Stokes Associates, Inc. 1989. *Results of Biological Resource Inventories and Habitat Evaluations in the Kellogg Creek Watershed*. February. (JSA 87-031.) Sacramento, CA. Prepared for James M. Montgomery, Consulting Engineers, Inc., and the Contra Costa Water District.

Katz, J. 2012. *The Knaggs Ranch Experimental Agricultural Floodplain Pilot Study 2011-2012 Year One Overview*. Cooperative project of the UC Davis Center for Watershed Sciences, California Department of Water Resources. Sacramento, CA.

Keeley, J. E. 1993. Assessing Suitable Sites for Grassland Restoration. Pages 277–281 in J. E. Keeley (ed.), *Interface Between Ecology and Land Development in California*. Los Angeles, CA: Southern California Academy of Sciences.

Kimmerer, W. J. 2002. Effects of Freshwater Flow on Abundance of Estuarine Organisms: Physical Effects or Trophic Linkages? *Marine Ecology Progress Series* 243:39–55. As cited in: Nobriga, M. F., and B. Herbold. 2009. *The Little Fish in California's Water Supply: a Literature Review and Life-History Conceptual Model for Delta Smelt (*Hypomesus Transpacificus*) for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP)*.

Kimmerer, W. J. 2004. Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses. *San Francisco Estuary and Watershed Science* 2(1):Article 1. Available: <http://escholarship.org/uc/item/9bp499mv>.

Kimmerer, W. J. 2006. Response of Anchovies Dampens Effects of the Invasive Bivalve Corbula Amurensis on the San Francisco Estuary Foodweb. *Marine Ecology Progress Series* 324:207–218. Cited in Nobriga, M. F., and B. Herbold. 2009. *The Little Fish in California's Water Supply: a Literature Review and Life-History Conceptual Model for delta smelt (*Hypomesus transpacificus*) for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP).*

Kimmerer, W. J. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento–San Joaquin Delta. *San Francisco Estuary and Watershed Science* 6(2):Article 2. Available: <http://escholarship.org/uc/item/7v92h6fs>.

Kimmerer, W. J., J. H. Cowan Jr., L. W. Miller, and K. A. Rose. 2000. Analysis of an Estuarine Striped Bass (Morone Saxatilis) Population: Influence of Density-Dependent Mortality between Metamorphosis and Recruitment. *Canadian Journal of Fisheries and Aquatic Sciences* 57:478–486.

Kimmerer, W. J., J. H. Cowan Jr., L. W. Miller, and K. A. Rose. 2001. Analysis of an Estuarine Striped Bass Population: Effects of Environmental Conditions during Early Life. *Estuaries* 24:557–575.

Kitchell, J. F., E. A. Eby, X. He, D. E. Schindler, and R. M. Wright. 1994. Predator-Prey Dynamics in an Ecosystem Context. *Journal of Fish Biology* 45(Supplement A):209–226.

Kitchell, J. F., D. E. Schindler, R. Ogutu-Ohwayo, and P. N. Reinthal. 1997. The Nile Perch in Lake Victoria: Interactions between Predation and Fisheries. *Ecological Applications* 7(2):653–664.

Kjelson, M. A. and P. Brandes. 1989. The Use of Smolt Survival Estimates to Quantify the Effects of Habitat Changes on Salmonid Stocks in the Sacramento-San Joaquin Rivers, California. In: Levings, C., L. Holtby, and M. Henderson (eds.). Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. *Canadian Special Publication of Fisheries and Aquatic Sciences* 105:100–115.

Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1982. Life History of Fall-Run Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin Estuary, California. Pages 393–411 in V. S. Kennedy (ed.), *Estuarine Comparisons*. New York: Academic Press.

Knowles, N., and D. Cayan. 2002. Potential Effects of Global Warming on the Sacramento/San Joaquin Watershed and the San Francisco Estuary. *Geophysical Research Letters* 29:38-1–38-4.

Kowalski, R. K., P. Hliwa, A. Andronowska, J. Król, G. J. Dietrich, M. Wojtczak, R. Stabiński, and A. Ciereszko. 2006. Semen Biology and Stimulation of Milt Production in the European Smelt (*Osmerus eperlanus* L.). *Aquaculture* 261(2006):760–770.

Kratville, D. 2008. *Sacramento–San Joaquin Delta Regional Ecosystem Restoration Implementation Plan, Semi-final Species Life History Conceptual Model: Sacramento Splittail* (Pogonichthys macrolepidotus). Sacramento, CA: California Department of Fish and Game.

Kurth, R., and M. Nobriga. 2001. Food Habits of Larval Splittail. *Interagency Ecological Program Newsletter* 14(3):40–42.

Kus, B. E., and M. J. Whitfield. 2005. Parasitism, Productivity, and Population Growth: Response of Least Bell's Vireos (*Vireo bellii pusillus*) and Southwestern Willow Flycatchers (*Empidonax traillii extimus*) to Cowbird (*Molothrus* spp.) Control. *Ornithological Monographs* 2005(57)16–27.

Kyle, K. 2011. *Tricolored Blackbird Habitat on California Department of Fish and Game Properties: An Assessment of Existing and Potential Habitat and Recommendations for Habitat Improvement and Maintenance*. California Department of Fish and Game, Nongame Wildlife Program Report 2011-07. Sacramento, CA.

Lake County Invasive Mussel Prevention Program. 2011. Resident Screening. <http://www.nomussels.com/resident.htm>. Accessed: June 27, 2012.

Lande, R. 1988. Genetics and Demography in Biological Conservation. *Science* 241:1455–1460.

Laughlin, J. 2007. *California Department of Fish and Game, Enforcement Branch, Delta-Bay Enhanced Enforcement Project (DBEEP) Annual Report July 2006–June 2007*. Sacramento, CA.

Laymon, S. A., P. L. Williams, and M. D. Halterman. 1997. *Breeding Status of the Yellow-billed Cuckoo in the South Fork Kern River Valley, Kern County, California: Summary Report 1985–1996.*

Administrative Report, U.S. Department of Agriculture Forest Service, Sequoia National Forest, Cannell Meadow Ranger District, Challenge Cost-Share Grant #92-5-13.

Lehman, P. W., G. Boyer, M. Satchwell, and S. Waller. 2008. The Influence of Environmental Conditions on the Seasonal Variation of *Microcystis* Cell Density and Microcystins Concentration in San Francisco Estuary. *Hydrobiologia* 600:187–204.

Lehman, P. W., S. Mayr, L. Mecum, and C. Enright. 2010. The Freshwater Tidal Wetland Liberty Island, CA was both a Source and Sink of Inorganic and Organic Material to the San Francisco Estuary. *Aquatic Ecology* 44:359–372.

Lindley, S. T., and M. S. Mohr. 2003. Modeling the Effect of Striped Bass (*Morone saxatilis*) on the Population Viability of Sacramento River Winter-Run Chinook Salmon (*Oncorhynchus tshawytscha*). *Fish Bulletin* 101:321–331.

Link, J. S. 2004. A General Model of Selectivity for Fish Feeding: A Rank Proportion Algorithm. *Transactions of the American Fisheries Society* 133:655–673.

Livingston, R. J., X. Niu, F. G. Lewis III, and G. C. Woodsum. 1997. Freshwater Input to a Gulf Estuary: Long-Term Control of Trophic Organization. *Ecological Applications* 277–299.

Loboschefsky, E., G. Benigno, T. Sommer, K. Rose, T. Ginn, A. Massoudieh, and F. Loge. 2012. Individual-Level and Population-Level Historical Prey Demand of San Francisco Estuary Striped Bass Using a Bioenergetics Model. *San Francisco Estuary and Watershed Science* 10(1).

Lopez, C. B., J. E. Cloern, T. S. Schraga, A. J. Little, L. V. Lucas, J. K. Thompson, and J. R. Burau. 2006. Ecological Values of Shallow-Water Habitats: Implications for the Restoration of Disturbed Ecosystems. *Ecosystems* 9:422–440.

Lott, J. 1998. Feeding Habits of Juvenile and Adult Delta Smelt from the Sacramento–San Joaquin River Estuary. *Interagency Ecological Program Newsletter* 11(1):14–19. Available: <nrm.dfg.ca.gov/FileHandler.ashx?documentversionid=77171>.

Lucas, L. V., and J. K. Thompson. 2012. Changing Restoration Rules: Exotic Bivalves Interact with Resident Time and Depth to Control Phytoplankton Productivity. *Ecosphere* 3(12):117. Available: <http://dx.doi.org/10.1890/ES12-00251.1>.

Lund, J., E. Hanak, W. Fleenor, W. Bennett, R. Howitt, J. Mount, and P. Moyle. 2008. *Comparing Futures for the Sacramento-San Joaquin Delta*. Public Policy Institute of California. Available: <http://www.ppic.org/main/publication.asp?i=810>.

Lund, J., E. Hanak, W. Fleenor, R. Howitt, J. Mount, and P. Moyle. 2007. *Envisioning Futures for the Sacramento-San Joaquin Delta*. Public Policy Institute of California (PPIC). February.

Manly, B. F. J. 2008. *Review of the Report an Evaluation of Four Sacramento-San Joaquin River Delta Juvenile Salmon Survival Studies by K. B. Newman*. July 16. Western EcoSystems Technology Inc.

Marine, K. R., and J. J. Cech. 2004. Effects of High Water Temperature on Growth, Smoltification and Predator Avoidance in Juvenile Sacramento River Chinook Salmon. *North American Journal of Fisheries Management* 24:198–210.

Marty, J. T. 2005. Effects of Cattle Grazing on Diversity in Ephemeral Wetlands. *Conservation Biology* 19:1626–1632.

Matern, S. A., P. B. Moyle, and L. C. Pierce. 2002. Native and Alien Fishes in a California Estuarine Marsh: Twenty-One Years of Changing Assemblages. *Transactions of the American Fisheries Society* 131:797–816.

Matica, Z., and M. L. Nobriga. 2005. Modifications to an Agricultural Water Diversion to Permit Fish Entrainment Sampling. California Department of Fish and Game 91(1):53–56.

McEwan, D. 2001. Central Valley Steelhead. Pages 1–43 in R. L. Brown (ed.). *Contributions to the Biology of Central Valley Salmonids*. California Department of Fish and Game.

McLain, J. S., and C. G. Castillo. 2009. Nearshore Areas Used by Chinook Salmon Fry, *Oncorhynchus tshawytscha*, in the Northwestern Sacramento–San Joaquin Delta, California. *San Francisco Estuary and Watershed Science* 7(2):1–12. Available: <http://escholarship.org/us/item/4f4582tb>. Accessed: December 15, 2011.

Meffe, G. K. 1984. Effects of Abiotic Disturbance on Coexistence of Predator-Prey Fish Species. *Ecology* 65:1525–1534.

Meng, L., and S. A. Matern. 2001. Native and Introduced Fishes of Suisun Marsh, California: The Effects of Freshwater Flow. *Transactions of the American Fisheries Society* 130:750–765.

Meng, L., P. B. Moyle, and B. Herbold. 1994. Changes in Abundance and Distribution of Native and Introduced Fishes in Suisun Marsh. *Transactions of the American Fisheries Society* 123:498–507.

Menke, J. W. 1992. Grazing and fire management for native perennial grass restoration in California grasslands. *Fremontia* 20(2):22–25

Merenlender A. M., and J. Crawford. 1998. *Vineyards in an Oak Landscape: Exploring the Physical, Biological, and Social Benefits of Maintaining and Restoring Native Vegetation in and around the Vineyard*. Vol. 21577. University of California Division of Agriculture and Natural Resources Publication.

Mesick, C. F. 2001. *Factors that Potentially Limit the Population of Fall-Run Chinook in the San Joaquin River Tributaries*. Unpublished manuscript. El Dorado, CA: Carl Mesick Consultants.

Miller, W. J. 2007. Testimony before the Subcommittee on Water and Power. Presented at: Extinction Is Not a Sustainable Water Policy: The Bay-Delta Crisis and the Implications for California Water Management. July 2.

Miller, N. L., K. E. Bashford, and E. Strem. 2003. Potential Impacts of Climate Change on California Hydrology. *Journal of the American Water Resources Association* 39:771–784.

Mills, C. E., and F. Sommer. 1995. Invertebrate Introductions in Marine Habitats: Two Species of Hydromedusae (Cnidaria) Native to the Black Sea, Maeotias inexspectata and Blackfordia virginica, invade San Francisco Bay. *Marine Biology* 122:279–288.

Miller R. L., and R. Fujii. 2011. Re-establishing Marshes Can Turn a Current Carbon Source into a Carbon Sink in the Sacramento-San Joaquin Delta of California, USA. Pages 1–34 in D. A. Contreras (ed.), *River Deltas: Types, Structures and Ecology*. Nova Science Publishers, Inc.

Miranda, J., R. Padilla, J. Morinaka, J. DuBois, and M. Horn. 2010. *Release Site Predation Study*. California Department of Water Resources. Available: <http://baydeltaoffice.water.ca.gov/announcement/Element2FinalReport5-2010.pdf>.

Mitsch, W. J., and J. G. Gosselink. 2000. *Wetlands*. 3rd edition. New York: Wiley & Sons Inc.

Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. Declining Mountain Snowpack in Western North America. *Bulletin of the American Meteorological Society* 86(1):39–49.

Moyle, P. B. 2002. *Inland Fishes of California, Revised and Expanded*. Berkeley, CA: University of California Press.

Moyle, P. B. 2008. The Future of Fish in Response to Large-Scale Change in the San Francisco Estuary, California. *American Fisheries Society Symposium* 64:1–18.

Moyle, P. B., R. D. Baxter, T. Sommer, T. C. Foin, and S. A. Matern. 2004. Biology and Population Dynamics of the Sacramento Splittail (*Pogonichthys macrolepidotus*) in the San Francisco Estuary: A Review. *San Francisco Estuary and Watershed Science* 2(2):Article 4.

Moyle, P. B., W. A. Bennett, W. E. Fleenor, and J. R. Lund. 2010. Habitat Variability and Complexity in the Upper San Francisco Estuary. *San Francisco Estuary and Watershed Science* 8(3).

Moyle, P. B., P. K. Crain, and K. Whitener. 2007. Patterns of Use of a Restored California Floodplain by Native and Alien Fishes. *San Francisco and Estuary Watershed Science* 5(3).

Moyle, P. B., J. A. Israel, and S. E. Purdy. 2008. *Salmon, Steelhead, and Trout in California: Status of an Emblematic Fauna*. Report for the Center for Watershed Sciences, University of California, Davis, CA.

Moyle, P. B., P. K. Crain, K. Whitener, and J. F. Mount. 2003. Alien Fishes in Natural Streams: Fish Distribution, Assemblage Structure, and Conservation in the Cosumnes River, California, U.S.A. *Environmental Biology of Fishes* 68 (2):143–162.

Moyle, P. B. and J. A. Israel. 2005. Untested Assumptions: Effectiveness of Screening Diversions for Conservation of Fish Populations. *Fisheries* 30(5):20–28.

Moyle, P. B., and D. White. 2002. *Effects of Screening Diversions on Fish Populations in the Central Valley: What Do We Know*? Report for the Science Board, CALFED Ecosystem Restoration Program. January.

Mueller, G. 2005. Predatory Fish Removal and Native Fish Recovery in the Colorado River Mainstem: What Have We Learned? *Fisheries* 30(9):10–19. Available: <http://www.fort.usgs.gov/Products/Publications/21228/21228.pdf>. Accessed: December 15, 2011.

Müeller-Solger, A. B., A. D. Jassby, and D. C. Müeller-Navarra. 2002. Nutritional Quality of Food Resources for Zooplankton (Daphnia) in a Tidal Freshwater System (Sacramento-San Joaquin River Delta). *Limnology and Oceanography* 47:1468–1476.

Muir, W. D., G. T. McCabe, Jr., M. J. Parsley, and S. A. Hinton. 2000. Diet of First Feeding Larval and Young-of-the-Year White Sturgeon in the Lower Columbia River. *Northwest Science* 74:25–33.

Nakano, S., and M. Murakami. 2001. Reciprocal Subsidies: Dynamic Interdependence between Terrestrial and Aquatic Food Webs. *Proceedings of the National Academy of Sciences of the United States of America* 98:166–170.

National Invasive Species Council. 2003. *General Guidelines for the Establishment and Evaluation of Invasive Species Early Detection and Rapid Response Systems*. National Biological Information Infrastructure Invasive Species Information Node.

National Marine Fisheries Service. 1996. Factors for Decline: A Supplement to the Notice of Determination for West Coast Steelhead under the Endangered Species Act. Portland, OR, and Long Beach, CA: Protected Resource Division.

National Marine Fisheries Service. 2006. *Biological and Conference Opinion; Stockton Deep Water Ship Channel Maintenance Dredging and Levee Stabilization Project*. Southwest Region, NMFS

National Marine Fisheries Service. 2007. *Biological Opinion for the Egeria Densa Control Program (2007 to 2011).* Long Beach, CA.

National Marine Fisheries Service. 2009a. *Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project*. Southwest Region. June 4.

National Marine Fisheries Service. 2009b. *Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead*. Sacramento, CA.

National Marine Fisheries Service. 2010. *Environmental Assessment for the Proposed Application of Protective Regulations under Section 4(d) of the Endangered Species Act for the Threatened Southern Distinct Population Segment of North American Green Sturgeon*. Long Beach, CA.

National Marine Fisheries Service. 2011. *2011 Amendments to the NMFS OCAP RPA*. April 7. Available: <http://swr.nmfs.noaa.gov/ocap.htm>. Southwest Region, Long Beach, CA. Nielsen, L. A., and D. L. Johnson (eds.) 1983. *Fisheries Techniques.* American Fisheries Society, Bethesda, MD.

Newman, K. B. 2008. *An Evaluation of Four Sacramento-San Joaquin River Delta Juvenile Salmon Survival Studies*. Stockton, CA: U.S. Fish and Wildlife Service. Available: <http://www.science.calwater.ca.gov/pdf/psp/PSP_2004_final/PSP_CalFed_FWS_salmon_studies_final_033108.pdf>.

Nilo, P., S. Tremblay, A. Bolon, J. Dodson, P. Dumont, and R. Fortin. 2006. Feeding Ecology of Juvenile Lake Sturgeon in the St. Lawrence River System. *Transactions American Fisheries Society* 135:1044–1055.

Nobriga, M. and P. Cadrett. 2001. Differences Among Hatchery and Wild Steelhead: Evidence from Delta Fish Monitoring Programs. *Interagency Ecological Program Newsletter* 14(3):30–38.

Nobriga, M. L., and F. Feyrer. 2007. Shallow-Water Piscivore-Prey Dynamics in the Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science* 5(2):Article 4.

Nobriga, M. L., and F. Feyrer. 2008. Diet Composition in San Francisco Estuary Striped Bass: Does Trophic Adaptability Have Its Limits? *Environmental Biology of Fishes* 83(4):495–503.

Nobriga, M. L., F. Feyrer, and R. D. Baxter. 2006. Aspects of Sacramento Pikeminnow Biology in Nearshore Habitats of the Sacramento-San Joaquin Delta, California. *Western North American Naturalist* 66(1):106–114.

Nobriga, M. L., F. Feyrer, R. Baxter, and M. Chotkowski. 2005. Fish Community Ecology in an Altered River Delta: Spatial Patterns in Species Composition, Life History Strategies, and Biomass. *Estuaries and Coasts* 28:776–785.

Nobriga, M., and B. Herbold. 2008. *Conceptual Model for Delta Smelt (Hypomesus Transpacificus) for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP).* Prepared by California Department of Fish and Game, Sacramento, CA, and U.S. Environmental Protection Agency, Washington, D.C.

Nobriga, M., and B. Herbold. 2009. *The Little Fish in California's Water Supply: A Literature Review and Life-History Conceptual Model for Delta Smelt (*Hypomesus transpacificus*) for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP).*

Nobriga, M. L., Z. Matica, and Z. P. Hymanson. 2004. Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: a Comparison among Open-Water Fishes. *American Fisheries Society Symposium* 39:281–295.

North America Weed Management Association. 2002. *North America Invasive Plant Mapping Standards*. May 7. Available: <http://www.nawma.org/Mapping/MappingMain.pdf>.

Noss, R. F., E. T. LaRoe, J. M. Scott. 1995. *Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation*. Biological Report 28. Washington, DC: U.S. Geological Survey. Available: <http://biology.usgs.gov/pubs/ecosys.htm>.

Pacific States Marine Fisheries Commission. 2008. *Don't Move a Mussel*. Available: <http://100thmeridian.org/video.asp>. Accessed: May 14, 2012.

Parsley, M. J., P. J. Anders, A. I. Miller, L. G. Beckman, and G. T. McCabe, Jr. 2002. Recovery of White Sturgeon Populations through Natural Production: Understanding the Influence of Biotic and Biotic Factors on Spawning and Subsequent Recruitment. Pages 55–66 in *Biology, Management, and Protection of North American Sturgeon, American Fisheries Society*. American Fisheries Society Symposium 28.

Peckarsky, B. L. 1983. Biotic Interactions or Abiotic Limitations? A Model of Lotic Community Structure. Pages 303–323 in T. D. Fontaine III and S. M. Bartell (eds.). Dynamics of Lotic Ecosystems. Ann Arbor Science, Ann Arbor, MI.

Pennington, T., and M. D. Sytsma. 2009. Seasonal Changes in Carbohydrate and Nitrogen Content of *Egeria Densa* from Populations in Oregon and California. *Invasive Plant Science and Management* 2:120–129.

Perry, L. G., D. C. Anderson, L. V. Reynolds, S. M. Nelson, and P. B. Shafroth. 2012. Vulnerability of Riparian Ecosystems to Elevated CO_2 and Climate Change in Arid and Semiarid Western North America. *Global Change Biology* 18:821–841.

Perry, R. W., P. L. Brandes, P. T. Sandstrom, A. P. Klimley, A. Ammann, and B. MacFarlane. 2009. Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento-San Joaquin River Delta. *North American Journal of Fisheries Management* 30:142–156.

Perry, R. W., and J. R. Skalski. 2008. *Migration and Survival of Juvenile Chinook Salmon through the Sacramento-San Joaquin River Delta during the Winter of 2006-2007*. Technical report. September. Submitted to U.S. Fish and Wildlife Service, Stockton, CA.

Perry, R. W., and J. R. Skalski. 2009. *Survival and Route Migration Probabilities of Juvenile Chinook Salmon in the Sacramento-San Joaquin River Delta during the Winter of 2007-2008*. Final report. July 15. Submitted to U.S. Fish and Wildlife Service, Stockton, CA.

Perry, R. W., J. R. Skalski, P. L. Brandes, P. T. Sandstrom, A. P. Klimley, A. Amman, and B. MacFarlane. 2010. Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento – San Joaquin River Delta. *North American Journal of Fisheries Management* 30:142–156.

Peterson, M. S. 2003. A Conceptual View of Environment-Habitat Production Linkages in Tidal River Estuaries. *Reviews in Fisheries Science* 11(4):291–313.

Pine, W. E., III, S. J. D. Martell, C. J. Walters, and J. F. Kitchell. 2009. Counterintuitive Responses of Fish Populations to Management Actions: Some Common Causes and Implications for Predictions Based on Ecosystem Modeling. *Fisheries* 34:165–180.

Pistori, R., A. Camargo, and G. Henry-Silva. 2004. Relative Growth Rate and Doubling Time of the Submerged Aquatic Macrophyte *Egeria densa* Planch. *Acta Limnológica Brasileira* 16:77–84.

Poff, N. L., and J. V. Ward. 1989. Implications of Streamflow Variability and Predictability for Lotic Community Structure: A Regional Analysis of Streamflow Patterns. Canadian Journal of Fisheries and Aquatic Sciences. 46:1805–1818.

Polis, G. A., C. A. Myers, R. D. Holt. 1989. The Ecology and Evolution of Intraguild Predation: Potential Competitors That Eat Each Other. *Annual Review of Ecology and Systematics* 20:297–330.

Porter, R. 2010. *Report on the Predation Index, Predator Control Fisheries, and Program Evaluation for the Columbia River Basin Experimental Northern Pikeminnow Management Program.* Annual Report. Prepared by Pacific States Marine Fisheries Commission, Portland, OR.

Porter, R. 2011. *Report on the Predation Index, Predator Control Fisheries, and Program Evaluation for the Columbia River Basin Experimental Northern Pikeminnow Management Program.* Annual Report. Prepared by Pacific States Marine Fisheries Commission, Portland, OR.

Power, M. E., R. J. Stout, C. E. Cushing, P. P. Harper, F. R. Hauer, W. J. Matthews, P. B. Moyle, B. Statzner, and I. R. Wais de Badgen. 1988. Biotic and Abiotic Controls in River and Stream Communities. *Journal of the North American Benthological Society* 7:456– 479.

Purchase, C. F., D. J. Hasselman, and L. K. Weir. 2007. Relationship between Fertilization Success and the Number of Milt Donors in Rainbow Smelt *Osmerus mordax* (Mitchell): Implications for Population Growth Rates. *Journal of Fish Biology.* 70(3):934–946.

Quinn, T. P. 2005. *The Behavior and Ecology of Pacific Salmon and Trout.* Seattle, WA: University of Washington Press.

Reichard, N. 1989. *Restoring and Maintaining Riparian Habitat on Private Pastureland*. USDA Forest Service Gen. Tech. Rep. PSW-110.

Ribeiro F., P. K. Crain, and P. B. Moyle. 2004. Variation in Condition Factor and Growth in Young-of-the-Year Fishes in Floodplain and Riverine Habitats of the Cosumnes River, California. *Hydrobiologia* 527:77–84.

Rice, P. M. 2005. *Fire as a Tool for Controlling Nonnative Invasive Plants.* Available: <http://www.weedcenter.org/management/control.html>. Accessed: December 28, 2011.

Richards, J. M., M. J. Hansen, C. R. Bronte, and S. P. Sitar. 2004. Recruitment Dynamics of the 1971–1991 Year Classes of Lake Trout in Michigan Waters of Lake Superior. *North American Journal of Fish Management* 24:475–489.

Riley, F., and S. Finlayson. 2004a. *Chronic Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Neonate Cladoceran and Larval Fathead Minnow.* Administrative Report 04-004. June 8. Aquatic Toxicology Laboratory, California Department of Fish and Game, Elk Grove, CA. Prepared for Office of Spill Prevention and Response, California Department of Fish and Game.

Riley, F., and S. Finlayson. 2004b. *Acute Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Larval Delta Smelt and Sacramento Splittail.* Administrative Report 04-003. June 8. Aquatic Toxicology Laboratory, California Department of Fish and Game, Elk Grove, CA. Prepared for Office of Spill Prevention and Response, California Department of Fish and Game. Elk Grove, CA. Available: <http://www.cdpr.ca.gov/docs/emon/surfwtr/hazasm/hazasm04_03.pdf>.

Riparian Habitat Joint Venture. 2004. *The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian-associated Birds in California.* Version 2.0. California Partners in Flight. Available: <http://www.prbo.org/calpif/pdfs/riparian.v-2.pdf>.

Riparian Habitat Joint Venture 2009. *California Riparian Restoration Handbook*. 2nd edition. July. Available: <http://www.riverpartners.org/documents/Restoration_Handbook_Final_Dec09.pdf>.

Rodriguez, M. A., and W. M. Lewis, Jr. 1994. Regulation and Stability in Fish Assemblages of Neotropical Floodplain Lakes. *Oecologia* 99:166–180.

Rosenfield, J. A. 2010. *Life History Conceptual Model and Sub-Models for Longfin Smelt, San Francisco Estuary Population for the Delta Regional Ecosystem Restoration Implementation Plan*.

Rosenfield, J. A., and R. D. Baxter. 2007. Population Dynamics and Distribution Patterns of Longfin Smelt in the San Francisco Estuary. *Transactions of the American Fisheries Society* 136:1577–1592.

Rubissow Okamoto, Ariel. 2012. Submerged Surprise in Suisun. *Estuary News: Bay-Delta News and Views from the San Francisco Estuary Partnership* 21(1):1. Available: <http://www.sfestuary.org/PDF/newsletters/Estuary_02_12_7FINAL_for%20web.pdf>.

Ruch, S. A., and Aquatic Weed Unit, California Department of Boating and Waterways. 2006. *Utilizing Differential Quantitative Mapping Technologies and Traditional Botanical Knowledge to Assist Brazilian Waterweed Management in the Sacramento-San Hoaquin Delta: An Example from Frank's Tract*. Berkeley and Sacramento, CA.

San Joaquin River Group Authority. 2006. *2005 Annual Technical Report on the Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan*. January.

Santos, M. J., L. W. Anderson, and S. L. Ustin. 2011. Effects of Invasive Species on Plant Communities: an Example Using Submersed Aquatic Plants at the Regional Scale. *Biological Invasions* 13:433–457.

Santos, M. J., S. Khanna, E. L. Hestir, M. E. Andrew, S. S. Rajapakse, J. A. Greenberg, L. W. J. Anderson, and S. L. Ustin. 2009. Use of Hyperspectral Remote Sensing to Evaluate Efficacy of Aquatic Plant Management in the Sacramento-San Joaquin River Delta, California. *Invasive Plant Science and Management* 2:216–229.

Sawyer, J. O., T. Keeler-Wolf, and J. M. Evens. 2009. *A Manual of California Vegetation*. 2nd Edition. Sacramento, CA: California Native Plant Society.

Schaffter, R. G. and D. W. Kohlhorst. 1999. Status of White Sturgeon in the Sacramento-San Joaquin Estuary. *California Fish and Game* 85(1):37–41.

Schemel, L. E., S. W. Hagar, and D. Childers. 1996. The Supply and Carbon Content of Suspended Sediment from the Sacramento River to San Francisco Bay. Pages 237–260 in J. T. Hollibaugh (ed.), *San Francisco Bay: The Ecosystem*. San Francisco, CA: Pacific Division of the American Association for the Advancement of Science.

Seabloom, E. W., E. T. Borer, V. L. Boucher, R. S. Burton, K. L. Cottingham, L. Goldwasser, W. K. Gram, B. E. Kendall, and F. Micheli. 2002. Competition, Seed Limitation, Disturbance, and Reestablishment of California Native Annual Forbs. *Ecological Applications* 13:575–592.

Sharp, B. L., and B. E. Kus. Factors Influencing the Incidence of Cowbird Parasitism of Least Bell's Vireo. *Journal of Wildlife Management* 70(3):682–690.

Shreffler, D. K., C. A. Simenstad, and R. M. Thom. 1990. Temporary Residence by Juvenile Salmon in a Restored Estuarine Wetland. *Canadian Journal of Fisheries and Aquatic Sciences* 47:2079–2084.

Siegel, S. W. 2007. *Starting the Discussion: Foundation Concepts and Some Initial Activities to Restore Ecosystem Functions to the California Delta*. Technical report prepared for the Delta Vision Blue Ribbon Task Force. December 14. Available: < <http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v4c05a03_cwp2009.pdf>. Accessed: August 15, 2012.>.

Simenstad C. A., J. R. Cordell, J. A. Miller, W. G. Wood, R. M. Thom. 1993. Ecological Status of a Created Estuarine Slough in the Chehalis River Estuary: Assessment of Created and Natural Estuarine Sloughs, January-December 1992. Fisheries Research Institute, University of Washington, School of Fisheries, Seattle, WA. As cited in Brown, L. R. 2003. Will tidal wetland restoration enhance populations of native fishes? *San Francisco Estuary and Watershed Science*: 1(1):Article 2. Available: <http://escholarship.org/uc/item/2cp4d8wk>.

Singer, G. P., A. R. Hearn, E. D. Chapman, M. L. Peterson, P. E. LaCivita, W. N. Brostoff, A. Bremner, A. P. Klimley. 2012. Interannual Variation of Reach Specific Migratory Success for Sacramento River Hatchery Yearling Late-Fall Run Chinook Salmon (Oncorhynchus Tshawytscha) and Steelhead Trout (Oncorhynchus Mykiss). *Environmental Biology of Fishes.* 96(2-3)363–379.

Singleton, P., H. Gaines, L. William, and J. F. Lehmkuhl. 2002. Landscape Permeability for Large Carnivores in Washington: a Geographic Information System Weighted-Distance and Least-Cost Corridor Assessment. Res. Pap. PNW-RP-549. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Skurka Darin, G. M., S. Schoenig, J. N. Barney, F. D. Panetta, and J. M. DiTomaso. 2011. WHIPPET: A novel tool for prioritizing invasive plant populations for regional eradication. *Journal of Environmental Management* 92(1):131–139.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Müller -Solger, M. Nobriga, and K. Souza. 2007b. The Collapse of Pelagic Fishes in the Upper San Francisco Estuary. *Fisheries* 32:270–277.

Sommer, T., R. Baxter, and B. Herbold. 1997. Resilience of Splittail in the Sacramento–San Joaquin Estuary. *Transactions of the American Fisheries Society* 126:961–976.

Sommer, T. R., R. D. Baxter, and F. Feyrer. 2007a. Splittail "Delisting": A Review of Recent Population Trends and Restoration Activities. *American Fisheries Society Symposium* 53:25–38

Sommer, T., L. Conrad, G. O'Leary, F. Feyrer, and W. Harrell. 2002. Spawning and Rearing of Splittail in a Model Floodplain Wetland. *Transactions of the American Fisheries Society* 131:966–974.

Sommer, T. R., W. C. Harrell, R. Kurth, F. Feyrer, S. C. Zeug, and G. O'Leary. 2004. Ecological patterns of early life stages of fishes in a river-floodplain of the San Francisco Estuary. Pages 111–123 in F. Feyrer, L. R. Brown, R. L. Brown, J. J. Orsi (eds.), *Early Life History of Fishes in the San Francisco Estuary and Watershed*. American Fisheries Society, Symposium 39, Bethesda, Maryland.

Sommer, T. R., W. C. Harrell, Z. Manteca, and F. Feyrer. 2008. Habitat Associations and Behavior of Adult and Juvenile Splittail *(Cyprinidae: Pogonichthys macrolepidotus)* in a Managed Seasonal Floodplain Wetland. *San Francisco Estuary and Watershed Science* 6(2):1–16.

Sommer, T. R., W. C. Harrell, M. Nobriga. 2005. Habitat Use and Stranding Risk of Juvenile Chinook Salmon on a Seasonal Floodplain. *North American Journal of Fisheries Management* 25:1493–1504.

Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001b. California's Yolo Bypass: Evidence that Flood Control Can Be Compatible with Fisheries, Wetlands, Wildlife, and Agriculture. *Fisheries* 26(8):6–16.

Sommer, T. R., W. C. Harrell, M. L. Nobriga, and R. Kurth. 2003. Floodplain as Habitat for Native Fish: Lessons from California's Yolo Bypass. Pages 81–87 in P. M. Faber (ed.), *California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration*. 2001 Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, CA.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham and W. J. Kimmerer. 2001a. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58(2):325–333.

Sorensen, P. W. 1998. Hormonally Derived Sex Pheromones in Goldfish: A Model for Understanding the Evolution of Sex Pheromone Systems in Fish. *Biological Bulletin* 183:173–177.

Sotoyome Resource Conservation District. 2007. *Grazing Handbook: a Guide for Resource Managers in Coastal California.* September. Santa Rosa, CA.

Stanley, S. E., P. B. Moyle, and H. B. Shaffer. 1995. Allozyme Analysis of Delta Smelt, *Hypomesus Transpacificus*, and Longfin Smelt, *Spriinchus Thaleichthys*, in the Sacramento-San Francisco Estuary. *Copeia* 1995:390–396.

State Water Resources Control Board. 1995. *Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary*. 95-1WR. May. Available: <http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/1995wqcp/1995_plan.shtml>.

State Water Resources Control Board. 1999. *Final EIR for Implementation of the 1995 Water Quality Control Plan*. November. Available: <http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/eirs/eir1999/index.shtml>.

Stephenson, M., C. Foe, G. Gill, and K. H. Coale. 2007. *Transport, Cycling, and Fate of Mercury and Monomethyl Mercury in the San Francisco Delta and Tributaries: An Integrated Mass Balance Assessment and Approach*. Calfed Mercury Project Annual Report.

Stevens, D. E. 1963. *Food Habits of Striped Bass, Roccus saxatilis (Walbaum), in the Sacramento–Rio Vista Area of the Sacramento River.* Berkeley, CA: University of California.

Stevens, D. E. 1966. Food Habits of Striped Bass (*Roccus saxatilis*) in the Sacramento-San Joaquin Delta. *California Department of Fish and Game Fish Bulletin* 136(2):68–96.

Stromberg, M. R., J. Corbin, and C. D'Antonio. 2007. California Grasslands: Ecology and Management. University of California Press, Berkeley, CA. 390 pp.

Stromberg, M., and J. R. Griffin. 1996. Long-Term Patterns in Coastal California Grasslands in Relation to Cultivation, Gophers, and Grazing. *Ecological Applications* 6:1189–1211.

Stromberg, M. R., and P. Kephart. 1996. Restoring Native Grasses in California Old Fields. *Restoration and Management Notes* 14:102-111.

Suisun Resource Conservation District. 1998. *Individual Ownership Adaptive Management Plan*. DWR-30, Appendix L. California Department of Fish and Game.

Sustaita, D., P. F. Quickert, L. Patterson, L. Barthman-Thompson, and S. Estrella. 2011. Salt Marsh Harvest Mouse Demography and Habitat Use in the Suisun Marsh, California. *Journal of Wildlife Management* 75:1498–1507.

Sveinsson, T., and T. J. Hara. 1995. Mature Males of Arctic Charr, *Salvvelinus alpinus*, Release F-Type Prostaglandins to Attract Conspecific Mature Female and Stimulate Their Spawning Behavior. *Environmental Biology of Fishes* 42(3):253–266.

Sweitzer, R. A., and R. E. Loggins. 2001. *Wild Pig Management Plan for Henry W. Coe State Park.* Submitted to California Department of Parks and Recreation, Four Rivers District.

Swenson R. O., K. Whitener and M. Eaton. 2003. Restoring Floods to Floodplains: Riparian and Floodplain Restoration at the Cosumnes River Preserve. Pages 224–229 in P. M. Faber (ed.), *California Riparian Systems: Processes and Floodplain Management, Ecology and Restoration*. 2001 Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, CA. Available: <http://www.sjrdotmdl.org/concept_model/phys-chem_model/documents/300001823.pdf>.

Tanner, C. D., J. R. Cordell, J. Rubey, and L. M. Tear. 2002. Restoration of Freshwater Intertidal Habitat Functions at Spencer Island, Everett, Washington. *Restoration Ecology* 10(3)564–576.

Teh, S. J., D. F. Deng, I, Werner, F. C. Teh, S. S. O. Hung. 2005. Sublethal Toxicity of Orchard Stormwater Runoff Contaminated with Esfenvalerate and Diazinon in Sacramento Splittail (Pogonichthys macrolepidotus) Larvae. *Marine Environmental Research* 59:203–216.

Temple, R., K. Daily, T. Shrader, and B. Hooton. 1998. *Predation Issues: Introduced Fishes*. Draft Review. June 17. Salem, OR: Oregon Department of Fish and Wildlife.

The Bay Institute. 1998. *From the Sierra to the Sea: The Ecological History of the San Francisco Bay-Delta Watershed*. July. Novato, CA. Available: <http://www.bay.org/publications/from-the-sierra-to-the-sea-the-ecological-history-of-the-san-francisco-bay-delta-waters>.

The Nature Conservancy. 1998. *Ecoregional Assessment Status Tool (EAST)*. Version 2.01.04. Available: <http://east.tnc.org>.

Thomas, J. L. 1967. The Diet of Juvenile and Adult Striped Bass (*Roccus saxatilis*), in the Sacramento–San Joaquin River System. *California Fish and Game* 53:49–62.

Thompson, K. 1961. Riparian Forests of the Sacramento Valley, California. *Annals of the Association of American Geographers* 51:294–315.

Toft, J. D. 2000. *Community Effects of the Non-Indigenous Aquatic Plant Water Hyacinth (Eichhornia crassipes) in the Sacramento/San Joaquin Delta, California.* Master's thesis. University of Washington, Seattle.

Toft, J. D., C. A. Simenstad, J. R. Cordell, and L. F. Grimaldo. 2003. The Effects of Introduced Water Hyacinth on Habitat Structure, Invertebrate Assemblages, and Fish Diets. *Estuaries* 26(3):746–758.

Trenham, P. C. 1998. Radio Tracking Information. Unpublished manuscript.

Turesson, H., and C. Bronmark. 2007. Predator-Prey Encounter Rates in Freshwater Piscivores: Effects of Prey Density and Water Transparency. *Oecologia* 153(2):281–290.

Turner, T. F., T. E Dowling, P. C. Marsh, B. R. Kesner, and A. T. Kelsen. 2007. Effective Size, Census Size, and Genetic Monitoring of the Endangered Razorback Sucker, *Xyrauchen texanus*. *Conservation Genetics* 8:417–425.

Turner, T., and M. Osborne. 2008. Management of Genetic Resources in the Federally Endangered Rio Grande Silvery Minnow, *Hybognathus amarus*. *CALFED Science Program Workshop—The Use of Artificial Propagation as a Tool for Central Valley Salmonid and Delta Smelt Conservation*. July 24, 2008.

Ulrich, P. D. 2011. *Methylmercury Production in Tidal Salt Marsh Sediments and Potential Control Using Iron Amendments*. UC San Diego, California Sea Grant College Program. Available: <http://escholarship.org/uc/item/9ms4z5hz>.

Underwood, E., M. Mulitsch, J. Greenberg, M. Whiting, S. Ustin, and S. Kefauver. 2006. Mapping Invasive Aquatic Vegetation in the Sacramento–San Joaquin Delta Using Hyperspectral Imagery. *Environmental Monitoring and Assessment* 121:47−64.

U.S. Army Corps of Engineers. 2012. *Fact Sheet: Acoustic Fish Deterrents*. Issued by the Great Lakes and Mississippi River Interbasin Study. April. Available: <http://www.glmris.anl.gov/documents/docs/anscontrol/AcousticFishDeterrents.pdf>.

U.S. Census Bureau. 2012. State and County QuickFacts. Available: <http://quickfacts.census.gov/qfd/states/06000.html>. Accessed: May 22, 2012.

U.S. Environmental Protection Agency. 2007. *TMDL Review Checklist for Stockton Deep Water Ship Channel Dissolved Oxygen and Approval Letter*. February 27. San Francisco, CA.

U.S. Environmental Protection Agency. 2008. *National Menu of Stormwater Best Management Practices*. Available: < http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm>.

U.S. Environmental Protection Agency. 2012. *State Stormwater BMP Manuals*. Available: <http://yosemite.epa.gov/R10/WATER.NSF/0/17090627a929f2a488256bdc007d8dee?OpenDocument>.

U.S. Fish and Wildlife Service. 1994. *Wetlands Policy and Action Plan.* 660 FW 1, FWM#157. Division of Habitat Conservation.

U.S. Fish and Wildlife Service. 1999. *Draft Recovery Plan for the Giant Garter Snake* (Thamnophis gigas). Portland, OR.

U.S. Fish and Wildlife Service. 2002a. *Appendix F, Cowbird Parasitism and the Southwestern Willow Flycatcher: Impacts and Recommendations for Management. In Final Recovery Plan, Southwestern Willow Flycatcher* (Empidonax traillii extimus*)*. Albequerque, NM.

U.S. Fish and Wildlife Service. 2002b. *Recovery Plan for the California Red-Legged Frog.* Portland, OR.

U.S. Fish and Wildlife Service. 2004. *Impacts of Riprapping to Aquatic Organisms and River Functioning, Lower Sacramento River, California*. 2nd edition. Available: <www.fws.gov/sacramento/es/animal_spp_account/acctfish.htm>.

U.S. Fish and Wildlife Service. 2005. *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon*. Available: <http://www.fws.gov/sacramento/es/recovery_plans/vp_recovery_plan_links.htm>.

U.S. Fish and Wildlife Service. 2008. *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP).* December 15.

U. S. Fish and Wildlife Service. 2010. *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*. Sacramento, CA.

Ustin, S. L. 2008. *Mapping Invasive Plant Species in the Sacramento-San Joaquin River Delta Using Hyperspectral Imagery*. Final report. June. Center for Spatial Technologies and Remote Sensing (CSTARS), University of California, Davis. Submitted to Aquatic Weed Control, California Department of Boating and Waterways, Sacramento, CA.

Vander Zanden, M. J., J. D. Olden, and C. Gratton. 2006. Food Web Approaches in Restoration Ecology. Pages 165–189 in D. Falk M. Palmer J. Zedler (eds.), *Foundations of Restoration Ecology*. Island Press.

Vogel, D. A. 2008. *Biological Evaluations of the Fish Screens at the Glenn-Colusa Irrigation District's Sacramento River Pump Station, 2002–2007*. April. Prepared by Natural Resources Scientists, Inc., Red Bluff, CA.

Vogel, D. A. 2011. *Insights into the Problems, Progress, and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration*. Prepared for Northern California Water Association and Sacramento Valley Water Users by Natural Resources Scientists, Inc., Red Bluff, CA.

Vogel, D. A., K. R. Marine, and J. G. Smith. 1988. *Fish Passage Action Program for Red Bluff Diversion Dam: Final Report on Fishery Investigations*. Report No. FR1/FAO-88-19. October. Prepared by U.S. Fish and Wildlife Service, Sacramento, CA.

Wang, J. C. S. 1986. *Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: a Guide to the Early Life Histories*. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, Tech. Rep. 9. Stockton, CA.

Wanner, G. A., D. A. Shuman, and D. W. Willis. 2007. Food Habits of Juvenile Pallid Sturgeon and Adult Shovel Nose Sturgeon in the Missouri River Downstream of Fort Randall Dam, South Dakota. *Journal of Freshwater Ecology* 22:81–92.

Webber, J. D., S. N. Chun, T. R. MacColl, L. T. Mirise, A. Kawabata, E. K. Anderson, T. S. Cheong, L. Kavvas, M. M. Rotondo, K. L. Hochgraf, R. Churchwell, J. J. Cech, Jr. 2007. Upstream Swimming Performance of Adult White Sturgeon: Effects of Partial Baffles and a Ramp. *Transactions of the American Fisheries Society* 136:402–408.

Welton, J. S., W. R. C. Beaumont, and R. T. Clarke. 2002. The Efficacy of Air, Sound and Acoustic Bubble Screens in Deflecting Atlantic Salmon, *Salmo salar* L., Smolts in the River Frome, UK. *Fisheries Management and Ecology.* 9:11–18.

Werner, I., S. Anderson, S. Larsen, and J. Oram. 2008. *Chemical Stressors in the Sacramento-San Joaquin Delta Conceptual Model. Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan.*

Weston, D. P., R. W. Holmes, J. You, and M. J. Lydy. 2005. Aquatic Toxicity Due to Residential Use of Pyrethroid Insecticides. *Environmental Science and Technology* 39:9778–9784.

Weston, D. P. and M. J. Lydy. 2010. Urban and Agricultural Sources of Pyrethroid Insecticides to the Sacramento-San Joaquin Delta of California. *Environmental Science and Technology* 44:1833–1840.

Whipple A. A., R. M. Grossinger, D. Rankin, B. Stanford, R. A. Askevold. 2012. *Sacramento-San Joaquin Delta Historic Ecology Investigation: Exploring Pattern and Process*. August. A Report of San Francisco Estuary Institute Aquatic Science Center's Historical Ecology Program, Publication #672, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA. Prepared for the California Department of Fish and Game and Ecosystem Restoration Program.

Wiese, F. K., J. K. Parrish, C. W. Thompson, and C. Maranto. Ecosystem-Based Management of Predator-Prey Relationships: Piscivorous Birds and Salmonids. *Ecological Applications* 18(3):681–700.

Williams, J. G. 2006. Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. *San Francisco Estuary and Watershed Science* 4(3):Article 2.

Williams, J. G. 2010. *Life History Conceptual Model for Chinook Salmon and Steelhead*. DRERIP Delta Conceptual Model. Sacramento, CA: Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). Available: <http://www.dfg.ca.gov/ERP/drerip_conceptual_models.asp>.

Williams, P., and P. M. Faber. 2004. *Design Guidelines for Tidal Wetland Restoration in San Francisco Bay*. December 29. Prepared for The Bay Institute.

Williams, D. F., P. A. Kelly, and L. P. Hamilton. 2002. *Controlled Propagation and Reintroduction Plan for the Riparian Brush Rabbit*. Turlock, CA: Endangered Species Recovery Program, California State University. Available: <http://esrp.csustan.edu/publications/pdf/rbr_prop_plan_final.pdf>.

Williams, D. F., P. A. Kelly, L. P. Hamilton, M. R. Lloyd, E. A. Williams, and J. J. Youngblom. 2008. Recovering the Endangered Riparian Brush Rabbit (*Sylvilagus bachmani riparius*): Reproduction and Growth in Confinement and Survival after Translocation. In P. C. Alves, N. Ferrand, and K. Hacklander (eds.), *Lagomorph Biology: Evolution, Ecology, and Conservation.* Proceedings of the Second World Lagomorph Conference, Vairao, Portugal, July 2004. Berlin/Heidelberg, Germany: Springer-Verlag. Pages 349–361.

Williams, A. E., S. O'Neil, E. Speith, and J. Rodgers. 2009. *Early Detection of Invasive Plant Species in the San Francisco Bay Area Network: A Volunteer-Based Approach*. Natural Resource Report NPS/SFAN/NRR—2009/136. National Park Service, Fort Collins, Colorado.

Windham-Myers, Lisamarie, M. Marvin-DiPasquale, J. Fleck, C. N. Alpers, J. Ackerman, C. Eagles-Smith, C. Stricker, M. Stephenson, D. Feliz, G. Gill, P. Bachand, A. Brice, and R. Kulakow. 2010. *Methylmercury Cycling, Bioaccumulation, and Export from Agricultural and Non-Agricultural Wetlands in the Yolo Bypass*. San Jose University Foundation and the California State Water Board.

Wood, M., C. Foe, J. Cooke, and L. Stephen. 2010. *Sacramento–San Joaquin Delta Estuary TMDL for Methylmercury*. California Regional Water Quality Control Board: Central Valley Region.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B Moyle. 1996. *Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. In Sierra Nevada Ecosystem Project, Final Report to Congress, Volume III, Assessments, Commissioned Reports, and Background Information*. University of California, Davis, Centers for Water and Wildland Resources.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2001. Historical and Present Distribution of Chinook Salmon in the Central Valley of California. *California Department of Fish and Game Fish Bulletin* 179:71–176.

Young P. S., and J. J. Cech, Jr. 1996. Environmental Tolerances and Requirements of Splittail. *Transactions of the American Fisheries Society* 125:664–678.

Zook, B. and S. Phillips. 2012. *Uniform Minimum Protocols and Standards for Watercraft Interception Programs for Dreissenid Mussels in the Western United States (UMPS II).* Portland, OR: Pacific States Marine Fisheries Commission. Available: <http://www.aquaticnuisance.org/wordpress/wp-content/uploads/2010/01/UMPS_II_doc2_APRIL_5_2012_FINAL_final_edits.pdf>. Accessed: May 14, 2012.

3.4.24.2 Personal Communications

Bowen, Mark. Fishery Biologist. Bureau of Reclamation, Denver, CO. October 12, 2010—conversation with Marin Greenwood, Aquatic Ecologist, ICF International, Sacramento, CA.

Burau, J. U.S. Geological Survey. August 20, 2008—discussion with BDCP Hood Bypass Sub-Group about Delta hydrology.

Burkhard, B. Incident Commander, California Department of Water Resources. July 22, 2010—telephone conversation with J-L Cartron, regarding functioning of Suisun Marsh salinity control gates and patterns of land use in Suisun Marsh.

Cavallo, Brad. Senior scientist. Cramer Fish Sciences, Auburn, CA. June 21 and 28, 2012—phone conversation with Ramona Swenson, Cardno ENTRIX, and email communication regarding fish removal techniques and experiments such as electrofishing, targeted predator fishing tournament, and orally delivered piscicide.

Chappell, S. Executive Director, Suisun Resource Conservation District. July 22, 2010—telephone conversation with J-L Cartron regarding functioning of salinity gates and patterns of land use at Suisun Marsh, and development and release of the Suisun Marsh Habitat Management, Preservation, and Restoration Plan.

Clarke, R. U.S. Fish and Wildlife Service. February 3, 2009—conversation with Alison Willy (USFWS) regarding delta smelt refugial hatchery population.

DeGeorge, J. RMA. May 28, 2008—presentation to the BDCP Conveyance Working Group on Hydrodynamic effects of restoration of tidal habitat in Suisun Marsh: initial evaluation.

Enright, C., Senior Engineer. California Department of Water Resources. August 26, 2008—telephone conversation with R. Wilder about methyl-mercury and low dissolved oxygen in effluent from managed seasonal wetlands in Suisun Marsh.

Fullerton, D. Principal Resource Specialist. MWD. November 27, 2007—CALFED Brown Bag Seminar: The Interaction among Turbidity, Salinity, and Smelt during Fall and Winter: a Work in Progress.

Griggs, Dr. Thomas. Senior Restoration Ecologist. River Partners, Chico, CA. June 1, 2009—telephone conversation with John Gerlach.

Hansen, Robert. President. Tulare Basin Wildlife Partners, Visalia, CA. June 1, 2009—telephone conversation with John Gerlach.

Hickey, Catherine, and David Shuford. July 1, 2013—E-mail to Rebecca Sloan regarding shorebird enhancement and management activities.

Holderman, M. Chief, Temporary Barriers Project and Lower San Joaquin. California Department of Water Resources. June 10, 2009—telephone conversation with R. Wilder regarding the 2009 DWR Head of Old River Non-Physical Barrier Test Project.

Hoover, Michael. U.S. Fish and Wildlife Service, Sacramento, CA. March 9, 2012—communication with Daniel Huang, Senior Staff Scientist, Cardno ENTRIX, Sacramento, CA.

Koopman, Tim. Range Manager. San Francisco Public Utility Commission, San Francisco, CA. July 7, 2003—conversation with Joel Gerwein, Jones and Stokes, Oakland, CA.

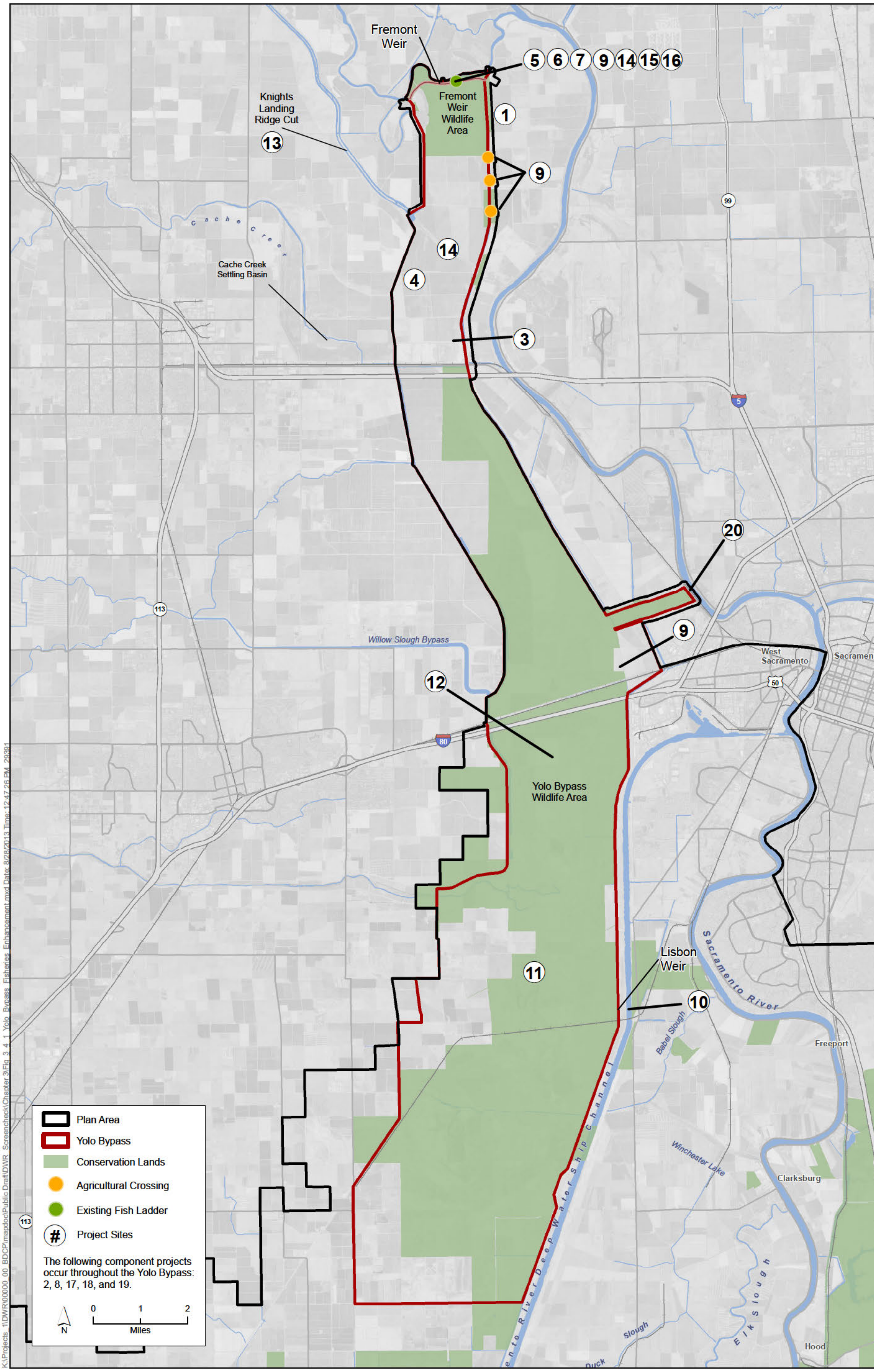
Lindberg, Joan. UC Davis Fish Conservation and Culture Lab, Byron, CA. March 15, 2012—communication with Daniel Huang, Senior Staff Scientist, Cardno ENTRIX, Sacramento, CA.

Munévar, Armin. Engineer. CH2M Hill. April 2009—technical memorandum to BDCP Integration Team regarding an evaluation of operations of the Fremont Weir to increase the frequency and duration of inundation of the Yolo Bypass.

Nobriga, M. L. Fish Habitat Biologist. U.S. Fish and Wildlife Service, Sacramento, CA. May 23 and June 7, 2012—email to Chris Earle, ICF International, and phone conversation with Ramona Swenson, Cardno ENTRIX, Sacramento, CA, regarding foodweb interactions in Delta fish community, potential for predator effects, and recommendations for revising CM15.

Roberts, Jason. Biologist. California Department of Fish and Game, Sacramento, CA. December 17, 2012—telephone and email communications.

Vendlinski, Tim. U.S. Environmental Protection Agency, San Francisco, CA. April 26, 2012—email containing scope of work for the Regional Applied Research Effort (RARE) and Regional Methods (RM) Proposal - Evaluating a water treatment method to prevent the formation and export of MeHg in restored wetlands and ricelands of the Sacramento-San Joaquin Delta (Delta).



GIS Data Source: Fremont Wier, DWR 2012; Lisbon Wier, DWR 2012; Fish Ladder, DWR 2012; Low Flow Crossing, DWR 2012.

Figure 3.4-1
Yolo Bypass Fisheries Enhancement

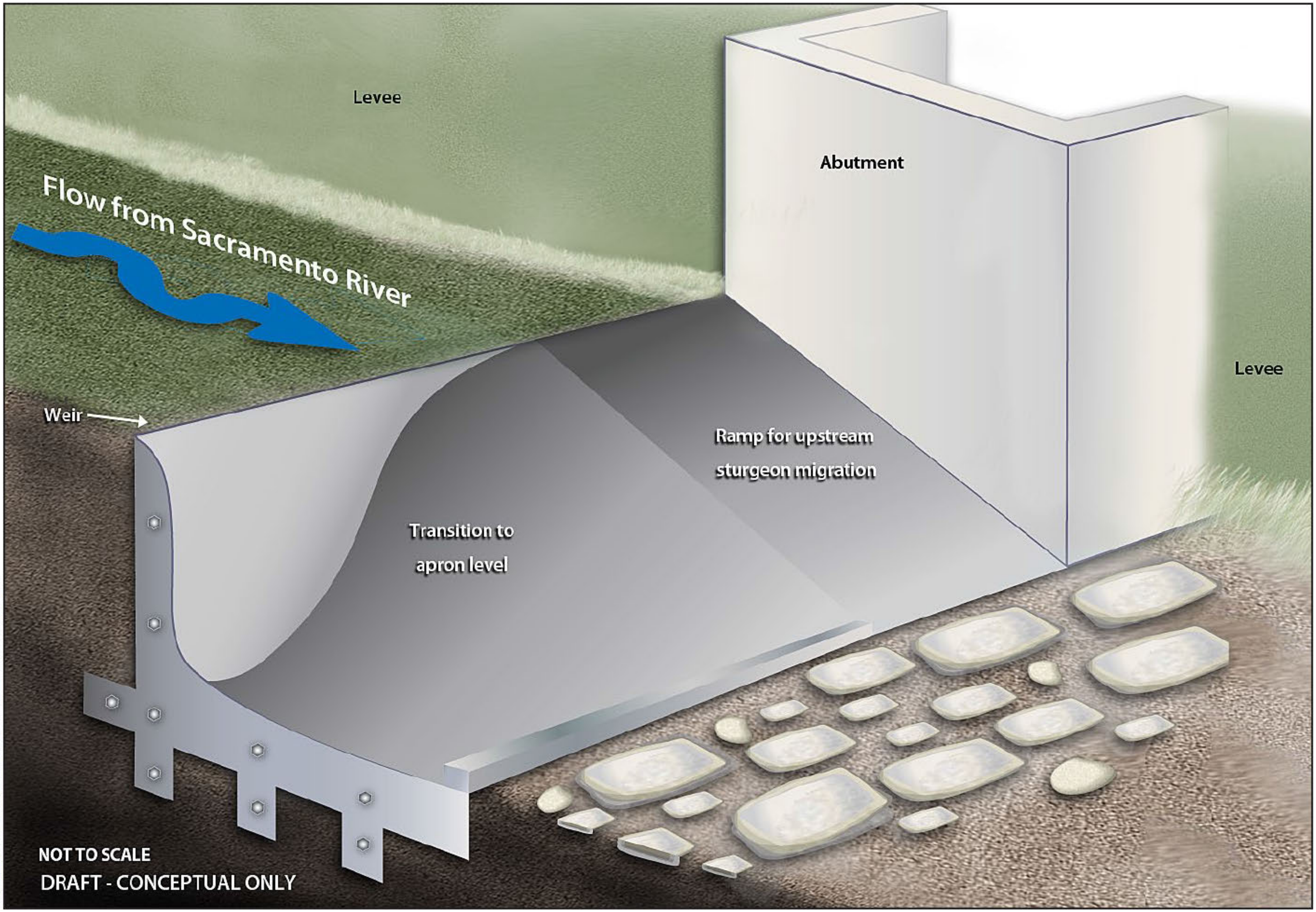
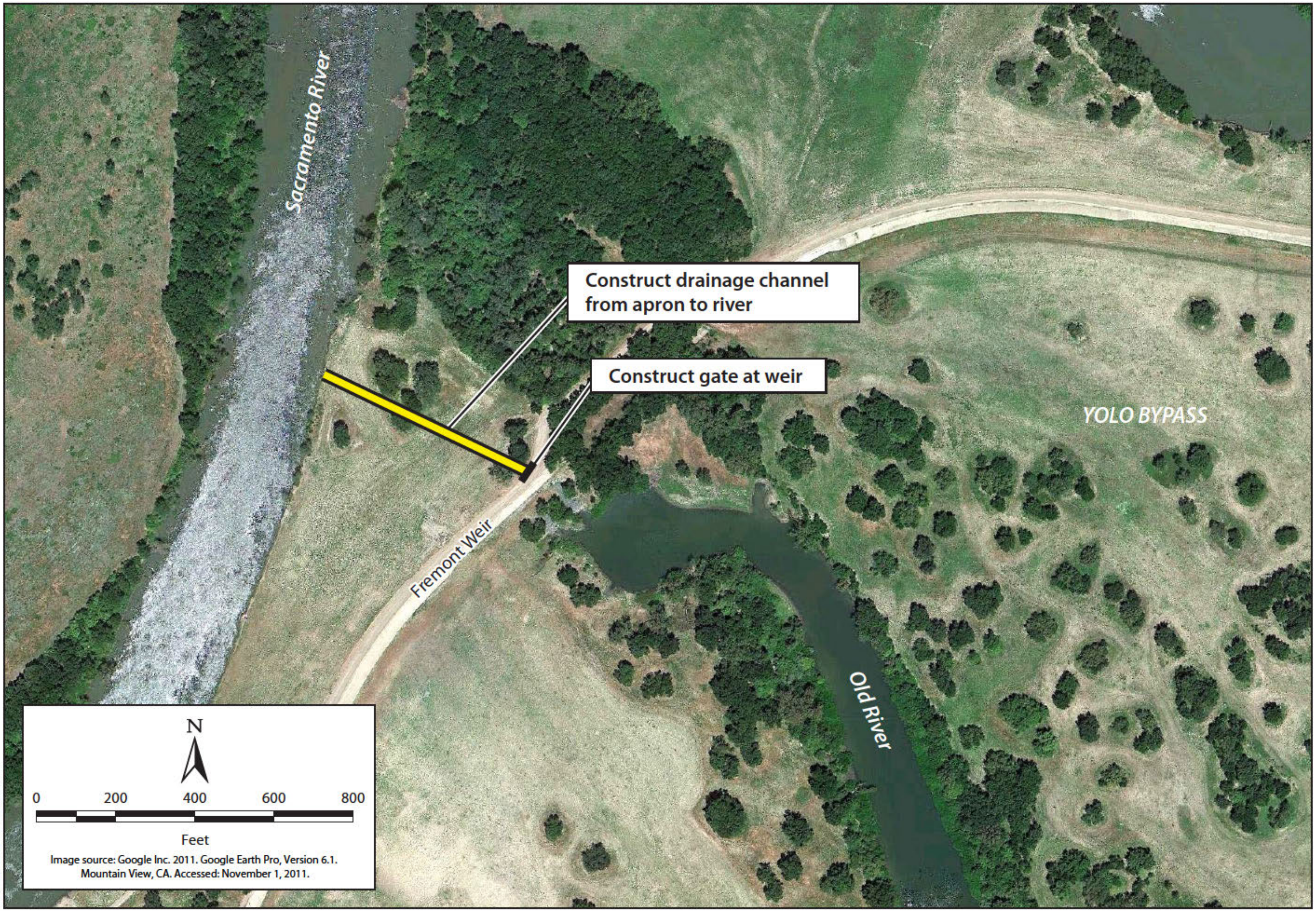


Figure 3.4-2
Conceptual Design for Experimental Sturgeon Ramp



Graphics...BDCP HCP (6-25-2012) TM

Figure 3.4-3
Concept for a Facility to Prevent Fish Stranding in the Western Length of Fremont Weir

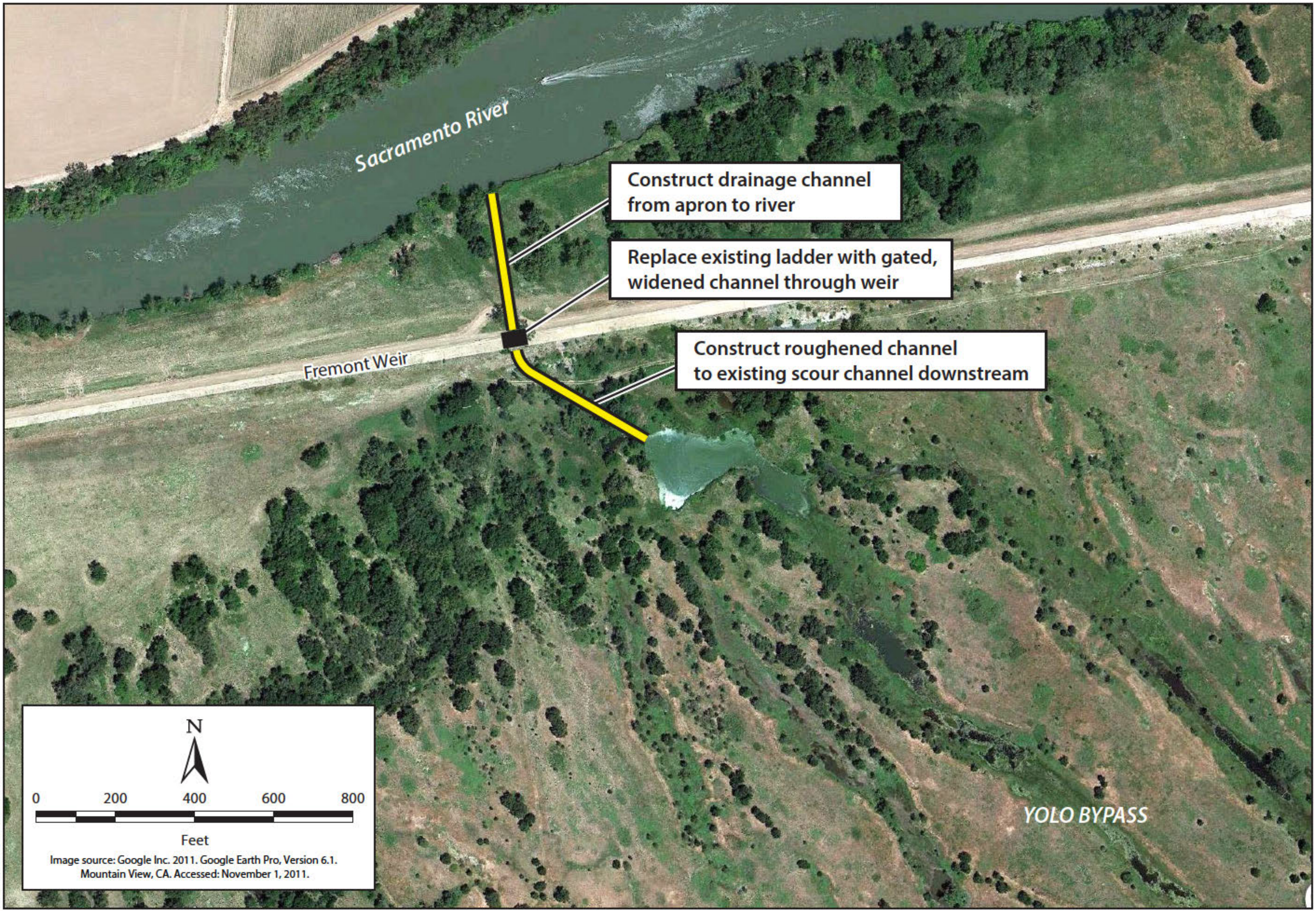


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Figure 3.4-4
Concept for Substantially Improving the Existing Fremont Weir Fish Ladder

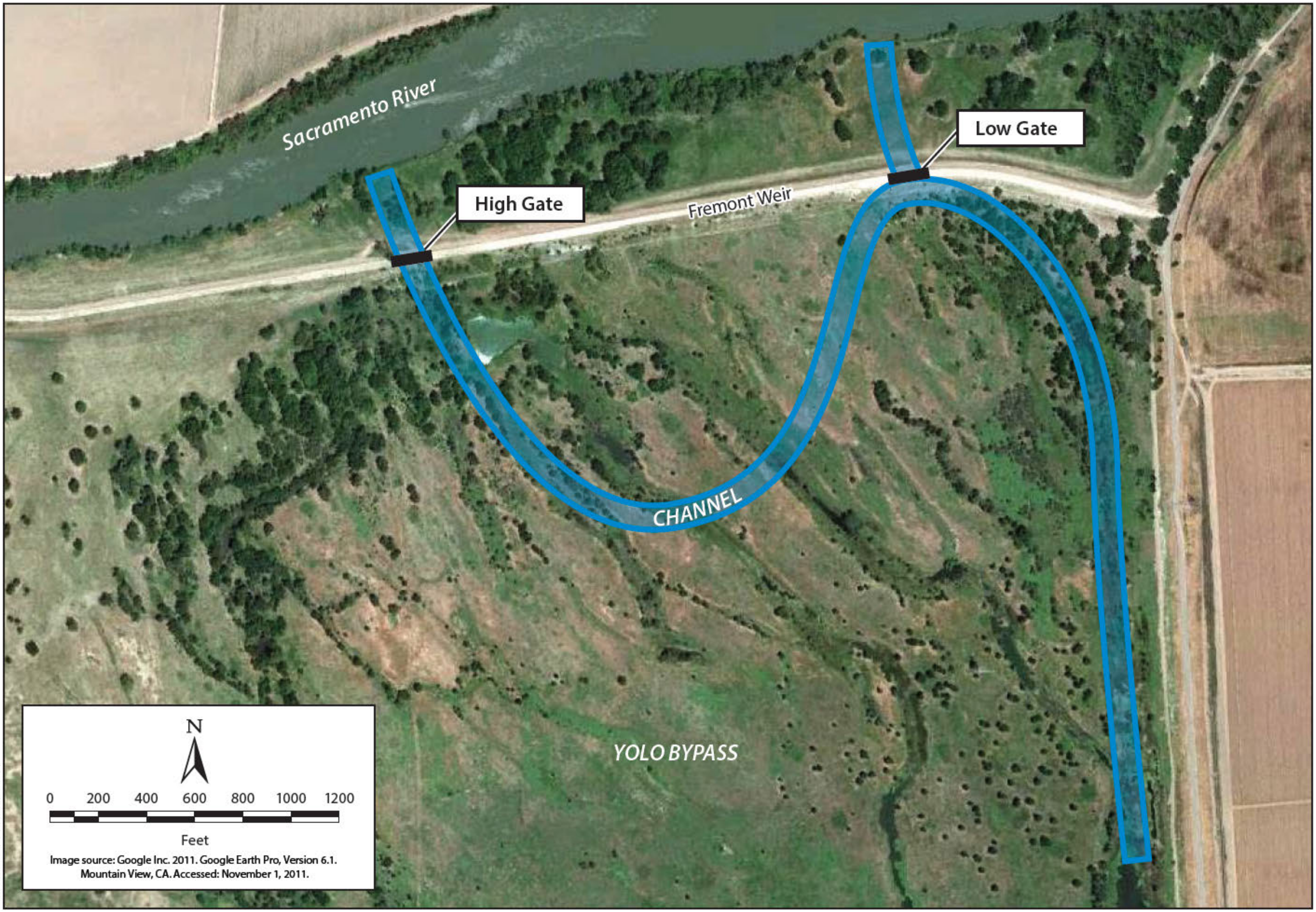

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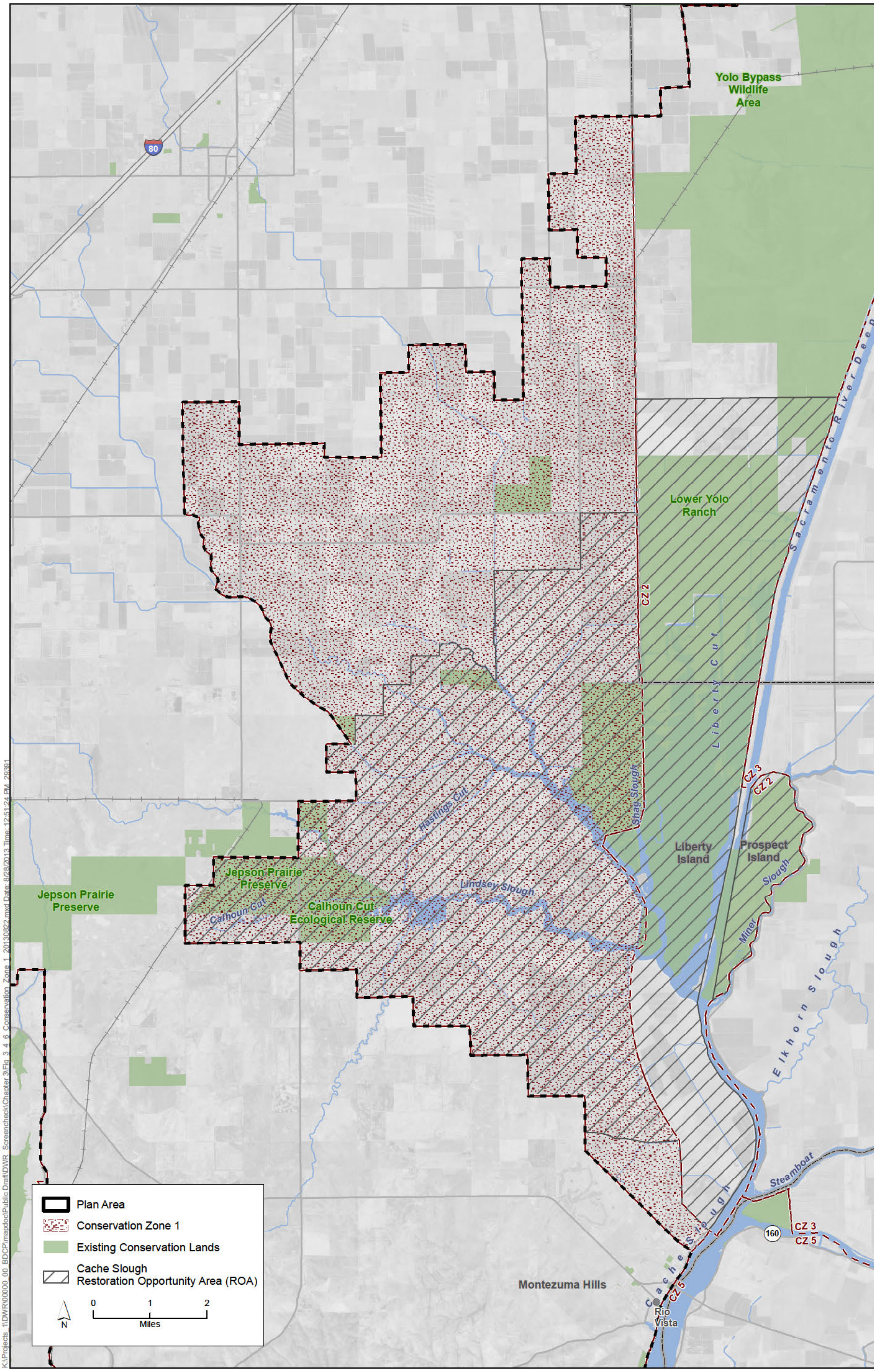
Figure 3.4-5
Concept for Providing Multistage, Multispecies Fish Passage at Fremont Weir



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GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011.

Figure 3.4-6
Conservation Zone 1

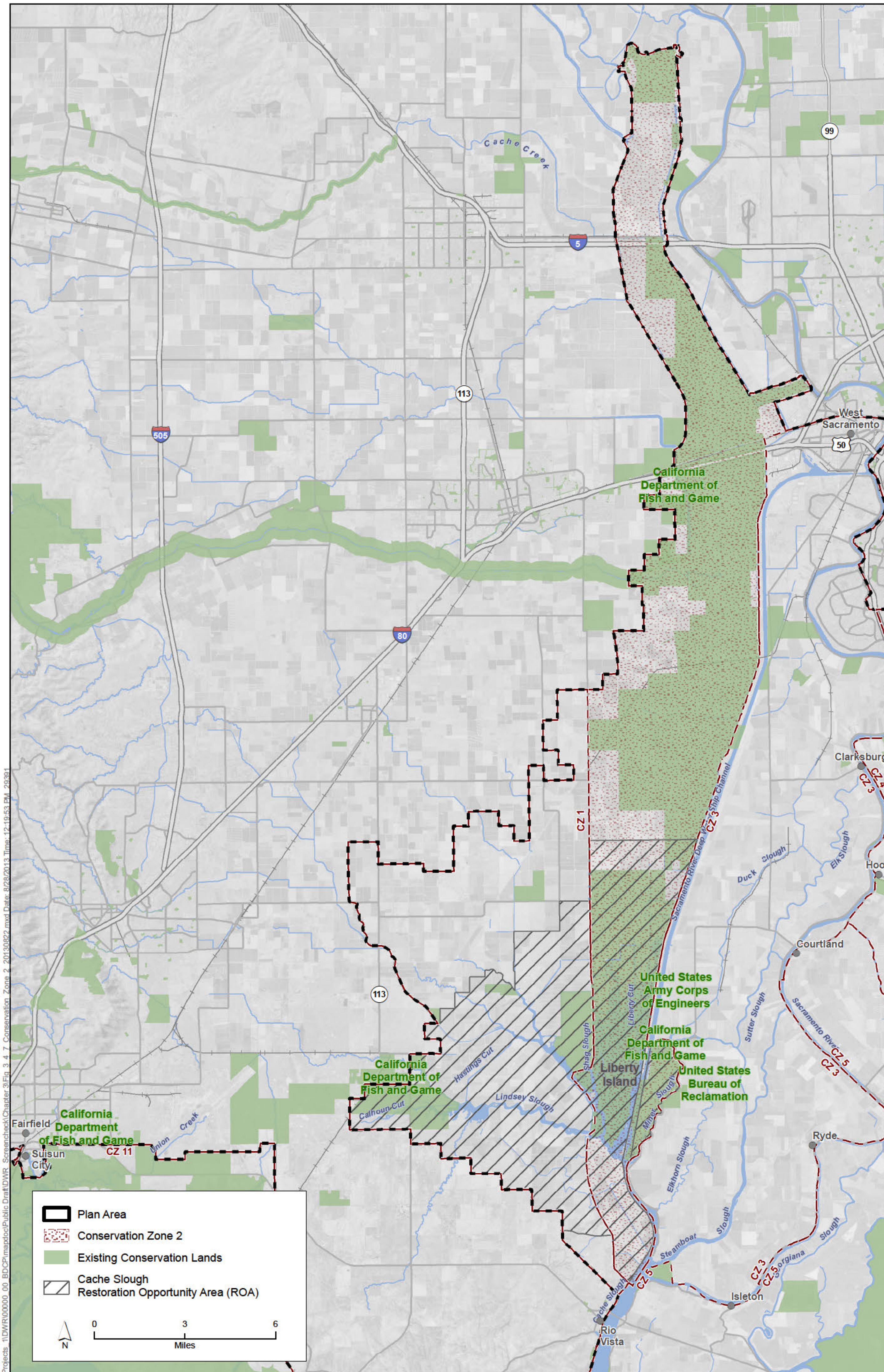

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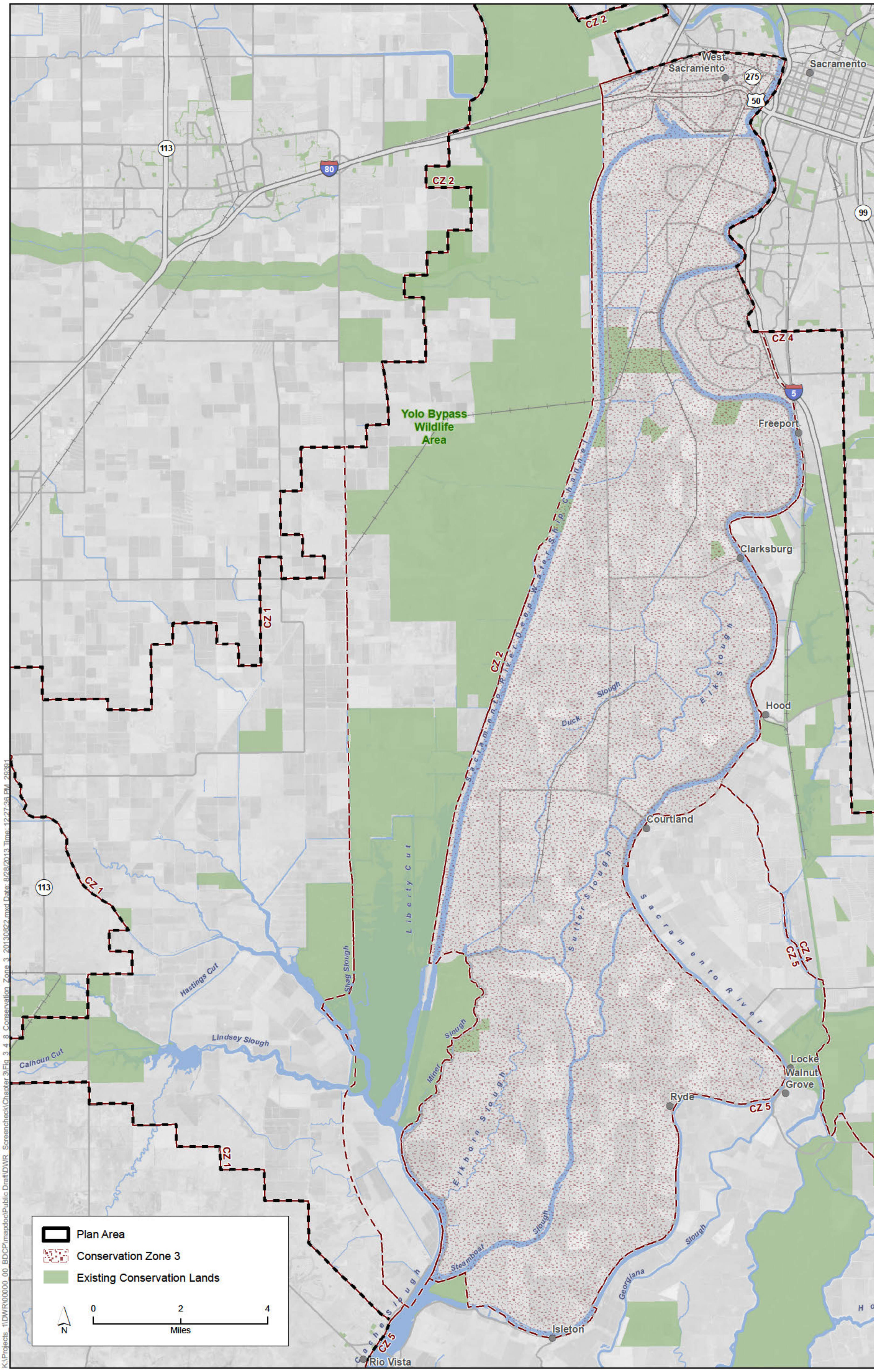
Figure 3.4-7
Conservation Zone 2



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GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011.

Figure 3.4-8
Conservation Zone 3

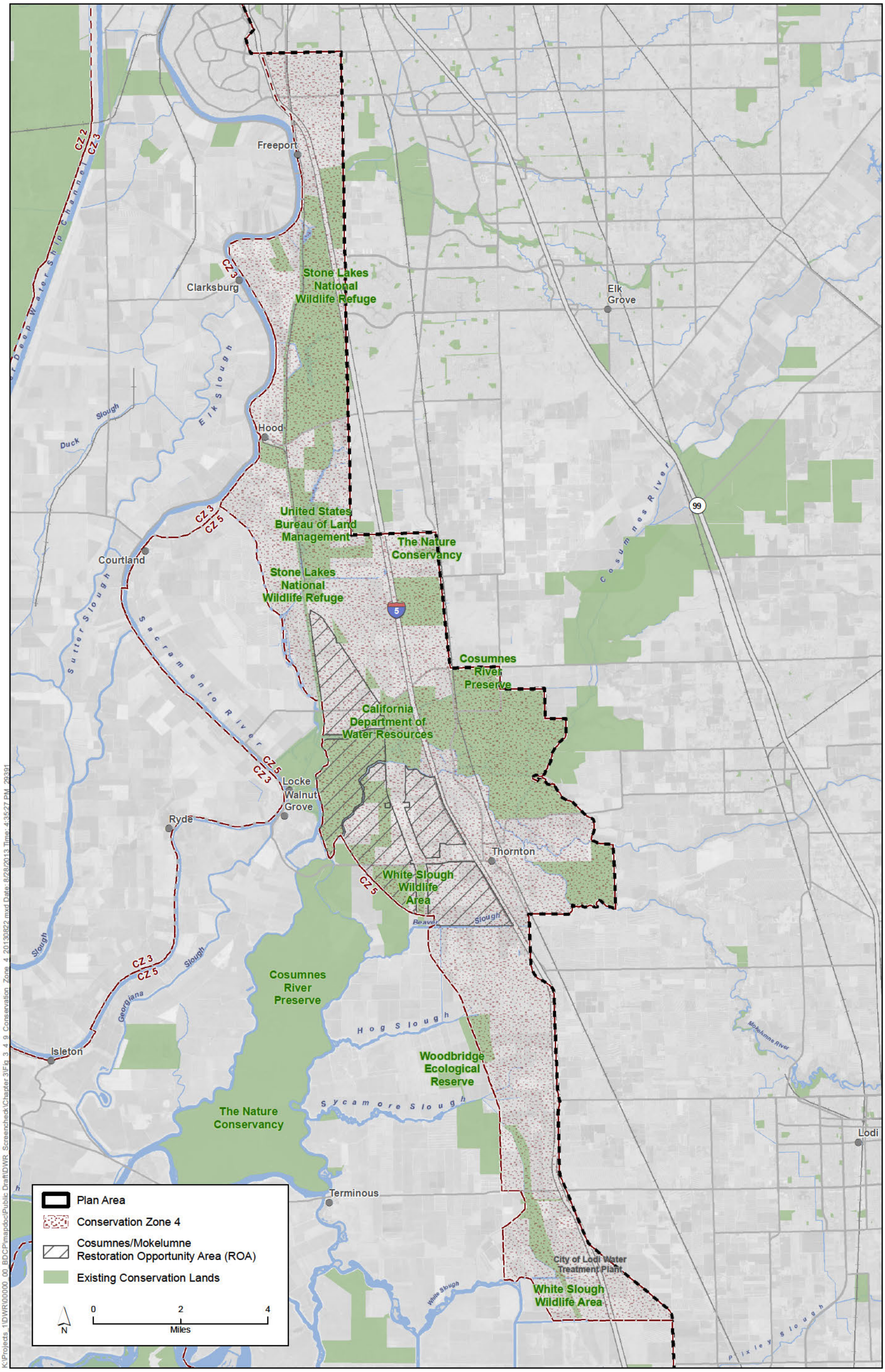

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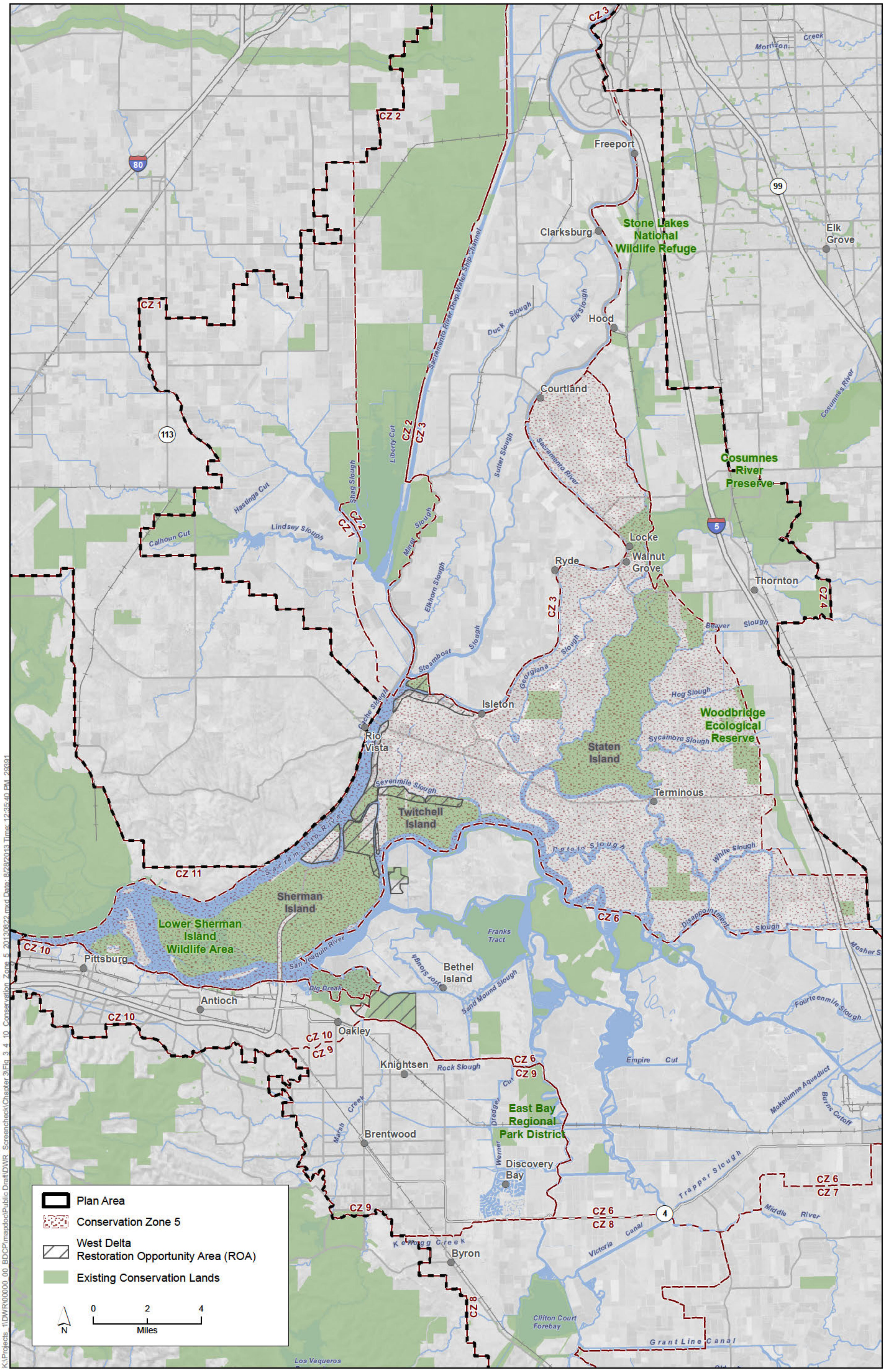
Figure 3.4-9
Conservation Zone 4



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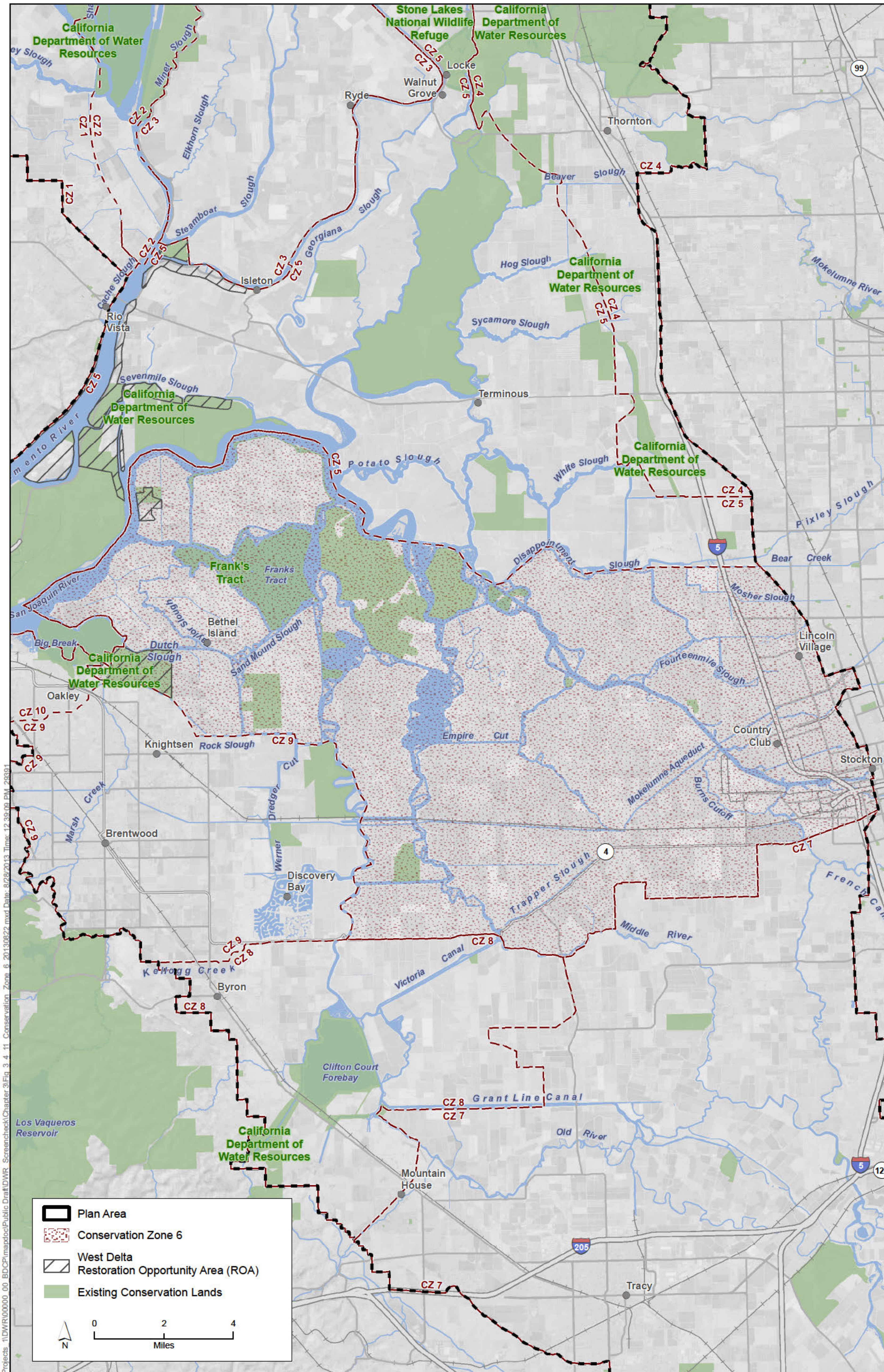
GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011.

Figure 3.4-10
Conservation Zone 5



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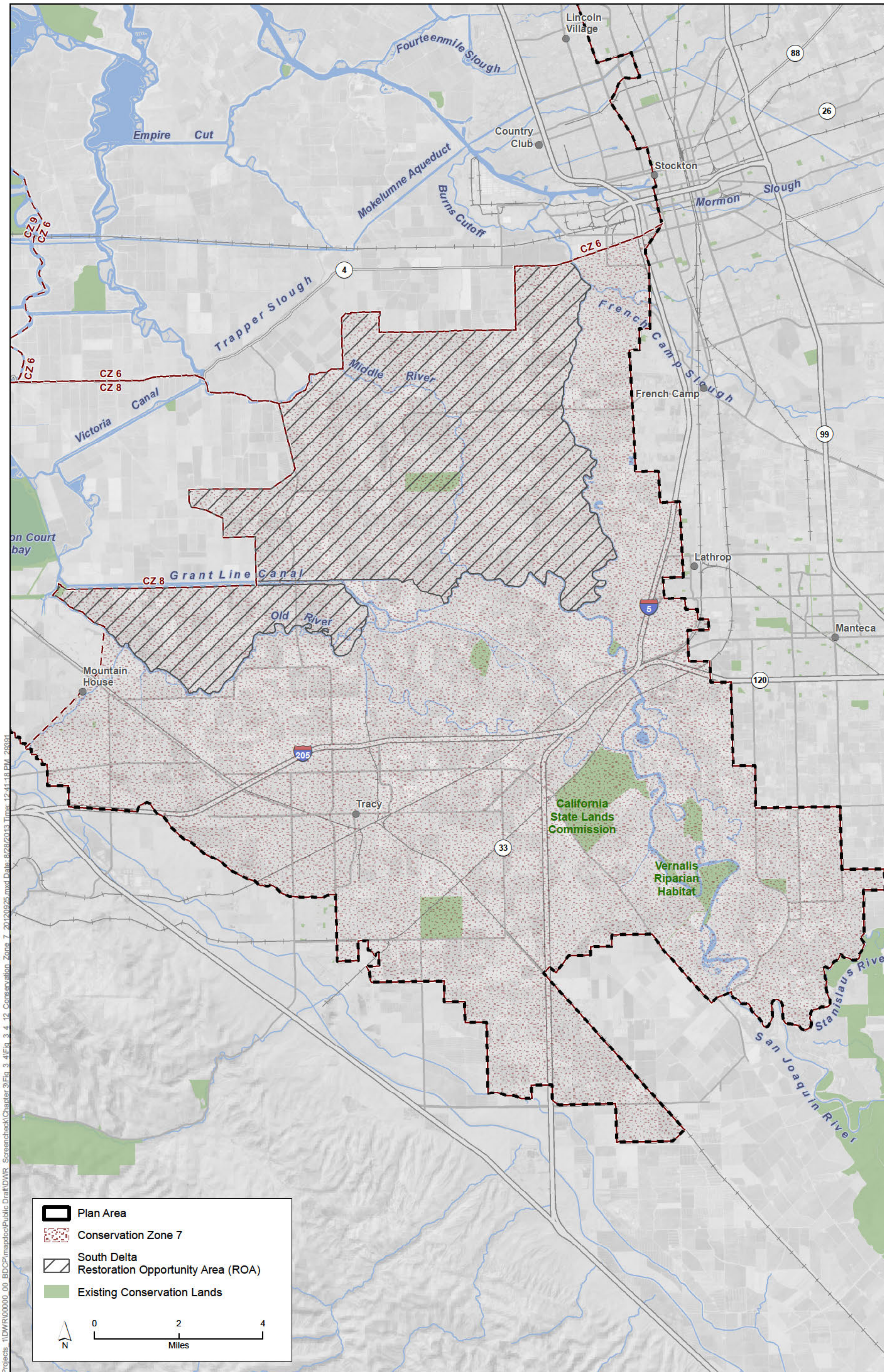
GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011.

Figure 3.4-11
Conservation Zone 6



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GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011.

Figure 3.4-12
Conservation Zone 7

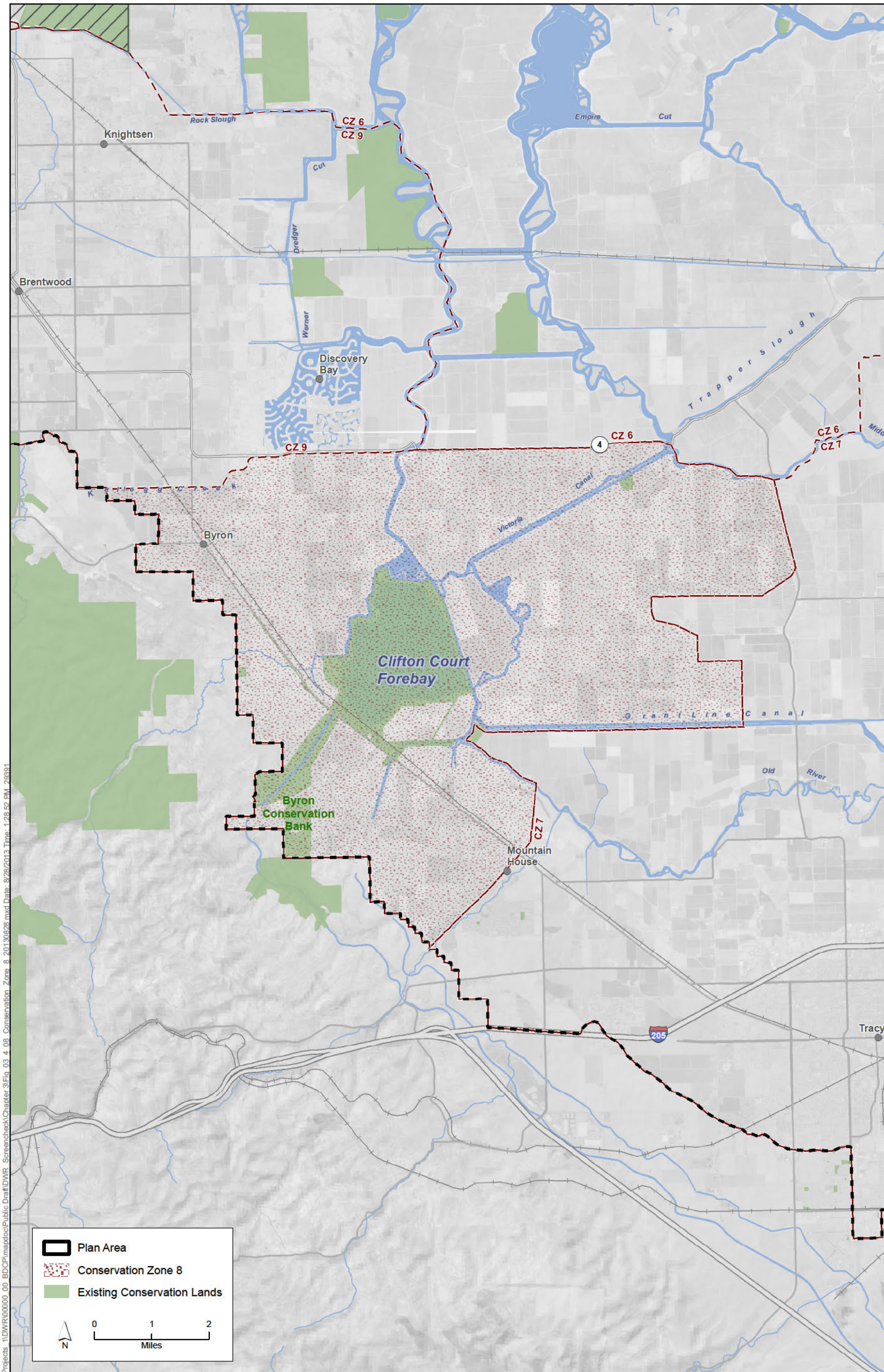

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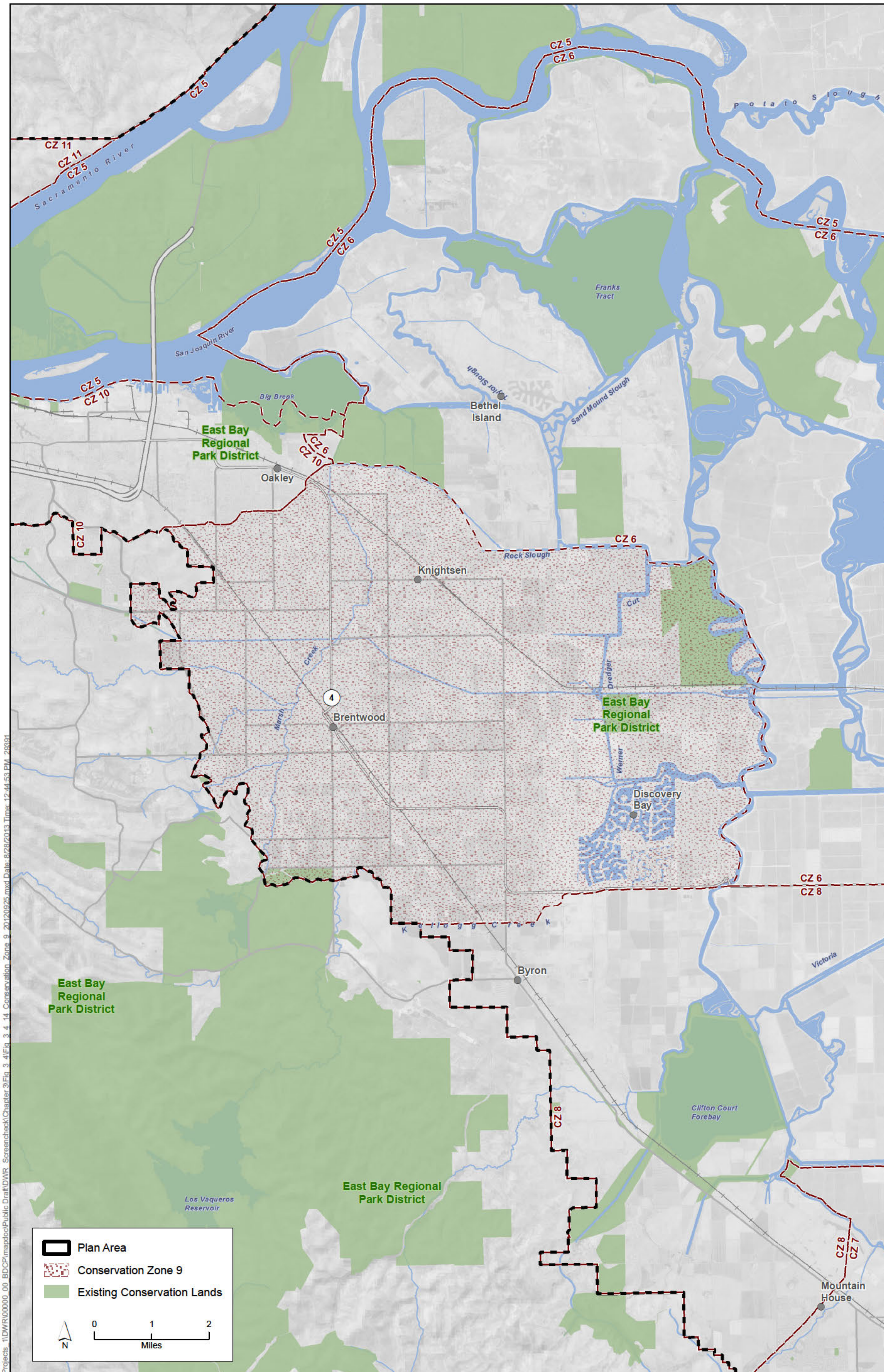
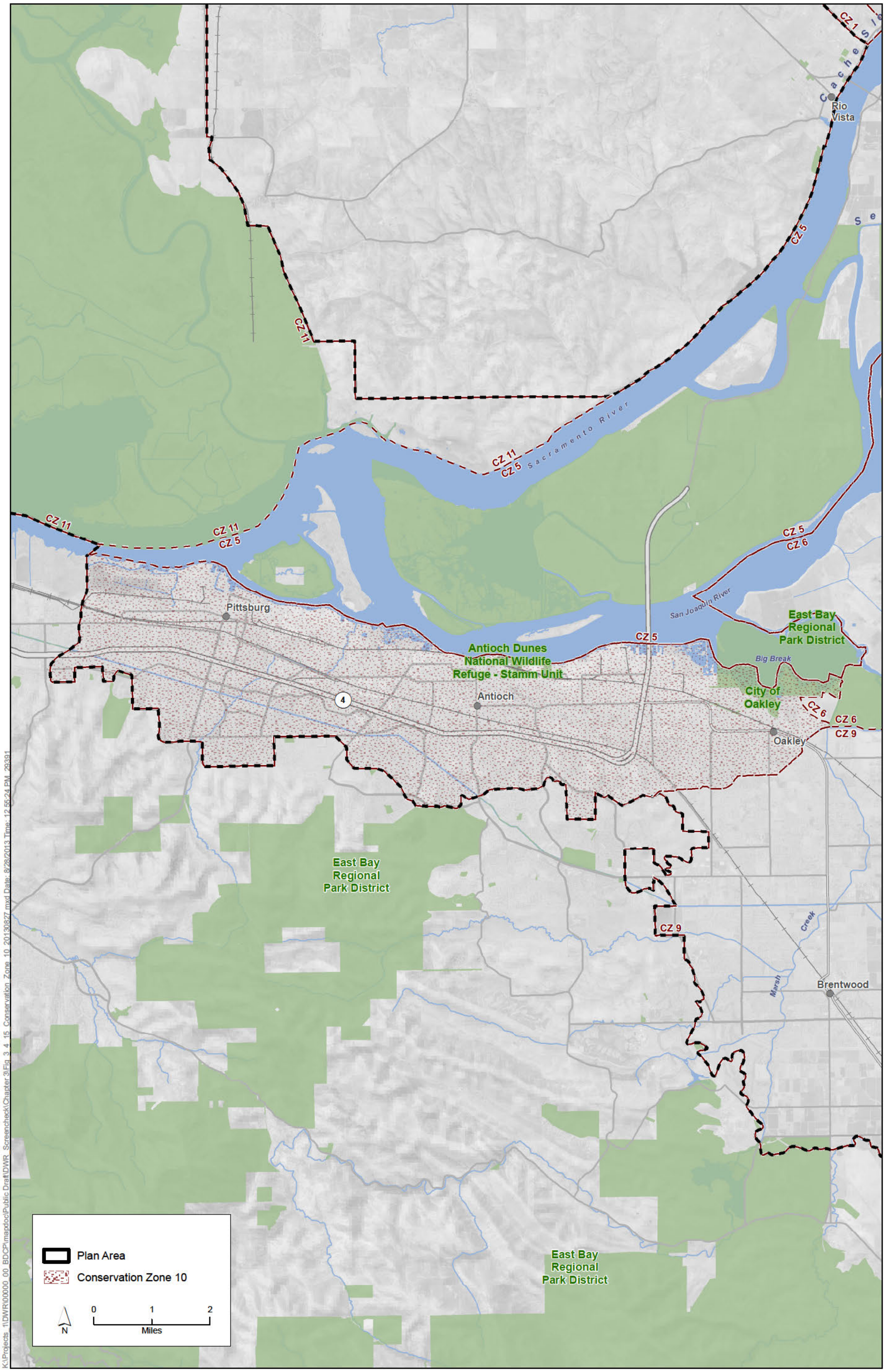
Figure 3.4-13
Conservation Zone 8



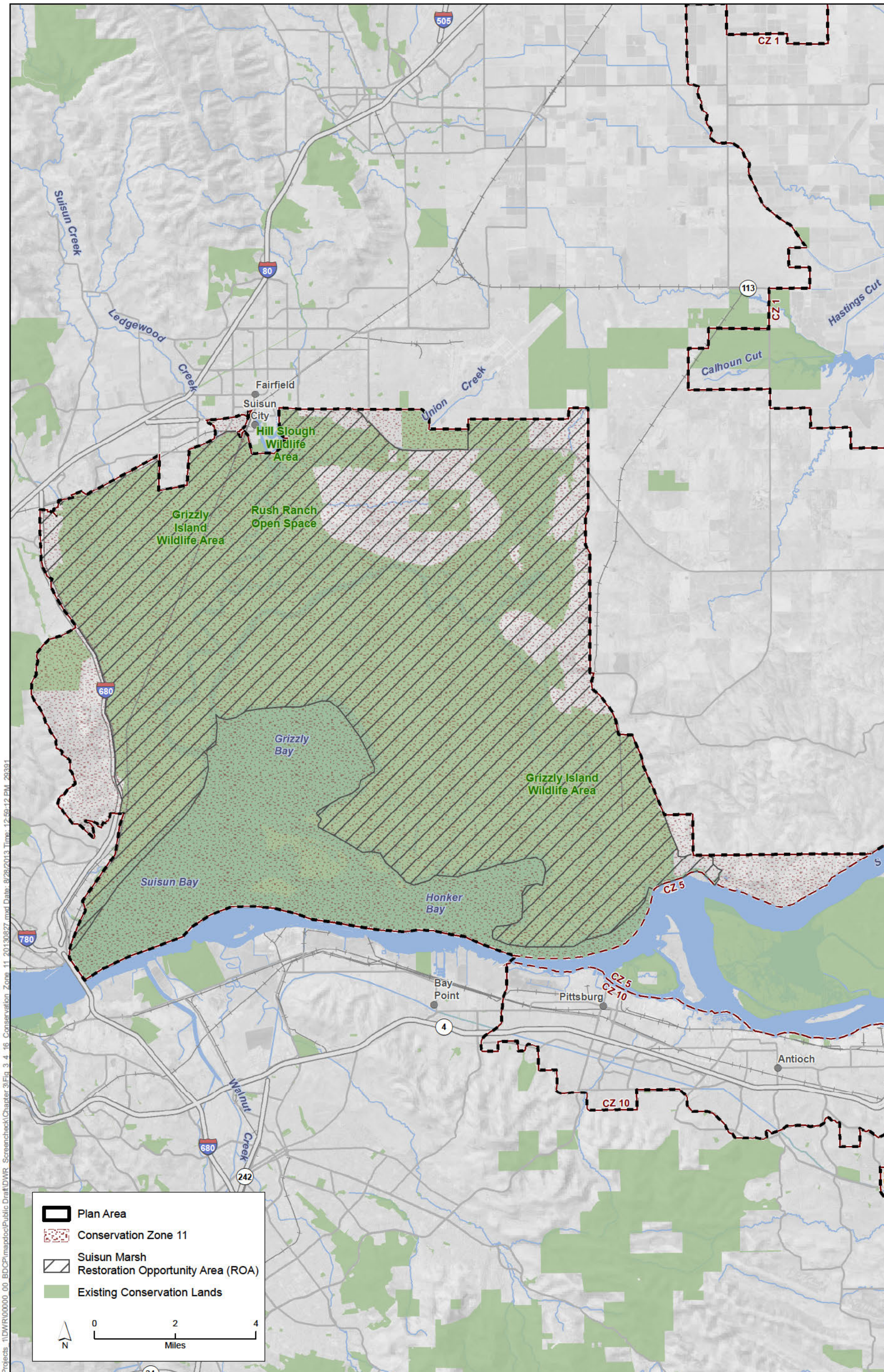
GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011.

Figure 3.4-14
Conservation Zone 9



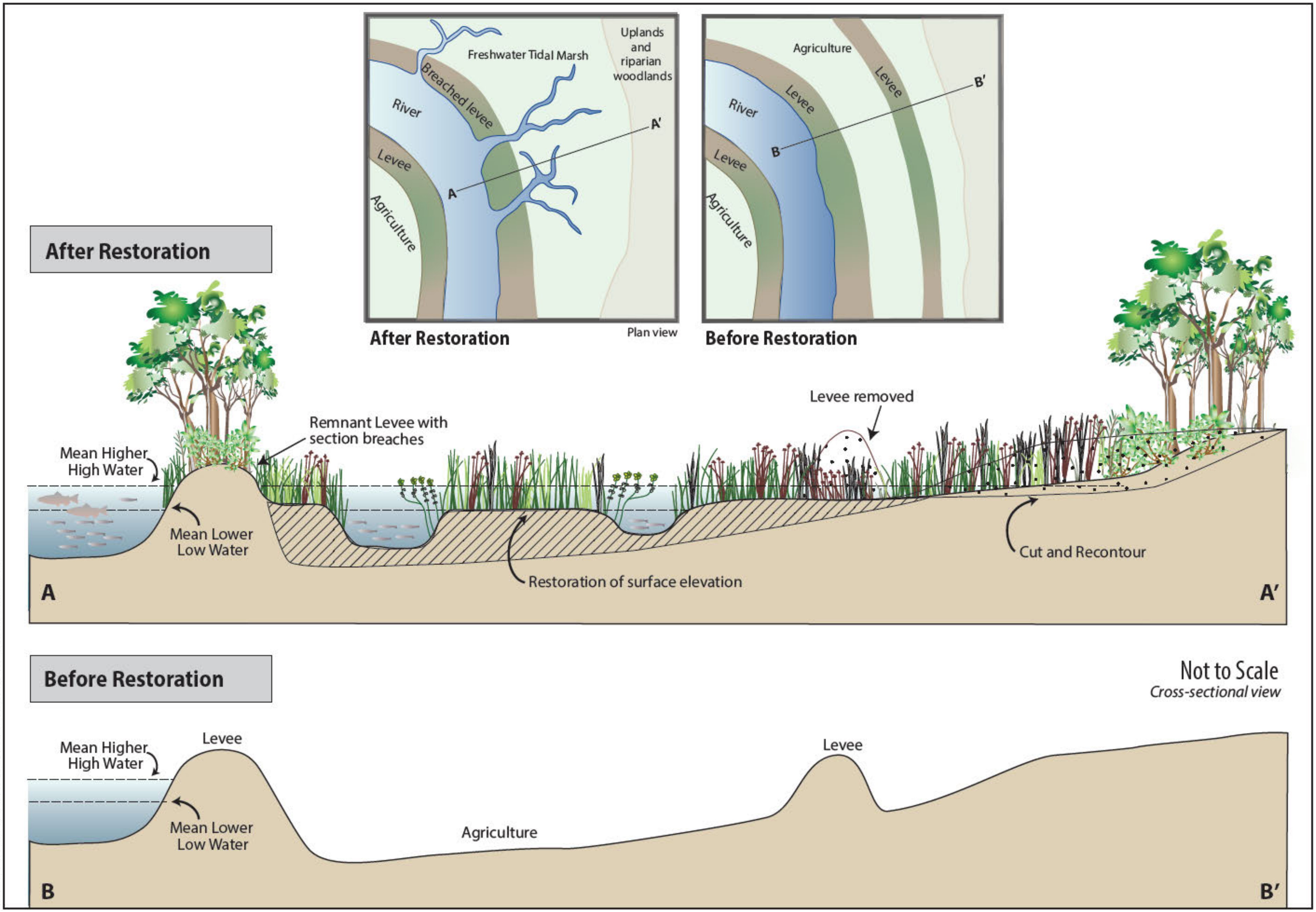
GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011.

Figure 3.4-15
Conservation Zone 10



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011.

Figure 3.4-16
Conservation Zone 11



Graphics/... BDCP Other Chapters/SAIC Nov 2010 (created: 11/09/10) (Rev. 11-9-2012 TM)

Figure 3.4-17
Conceptual Design for Restored Tidal Freshwater Emergent Wetland Natural Communities

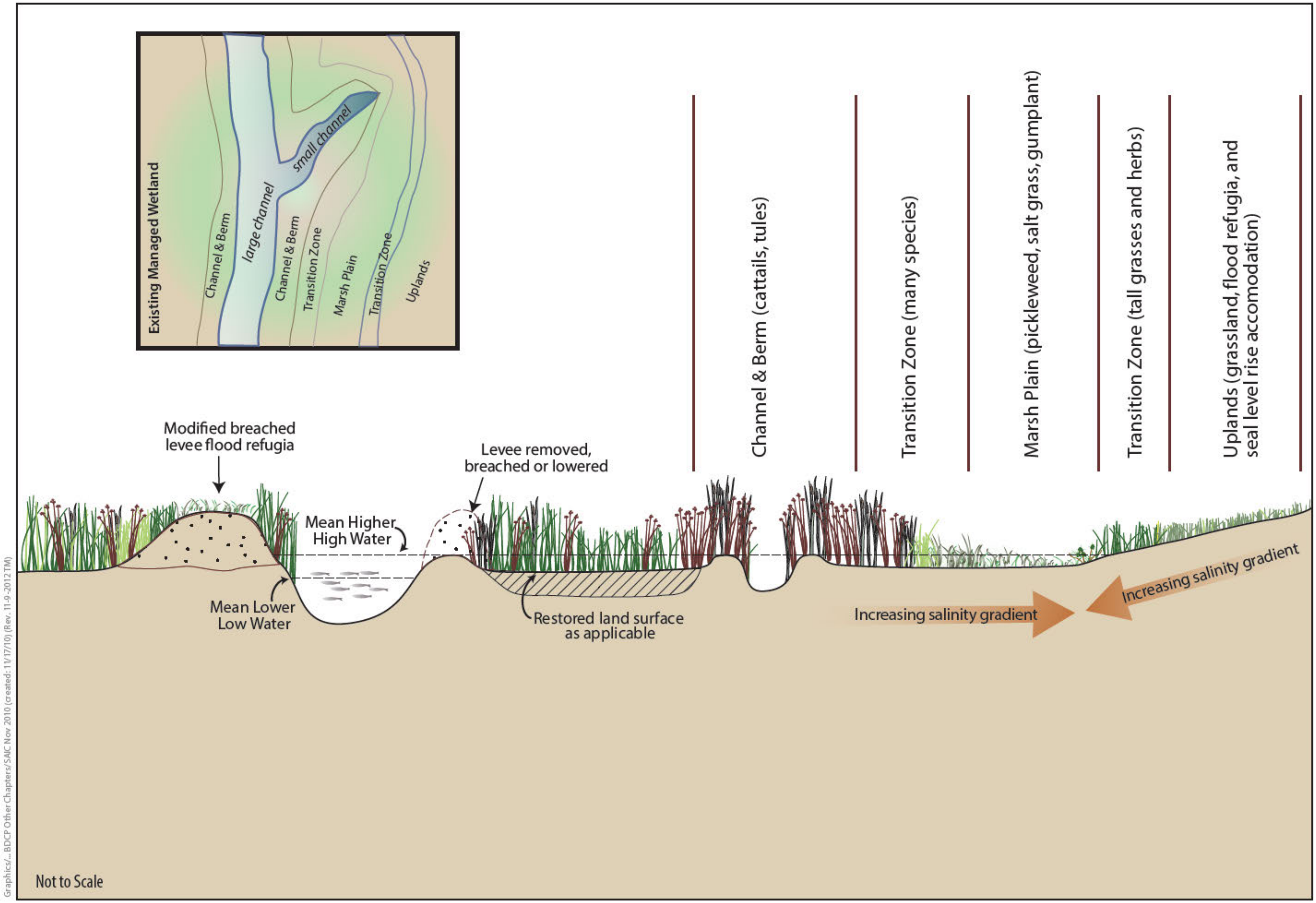


Figure 3.4-18
Conceptual Design for Restored Brackish Tidal Natural Communities (Suisun Marsh Restoration Opportunity Area)

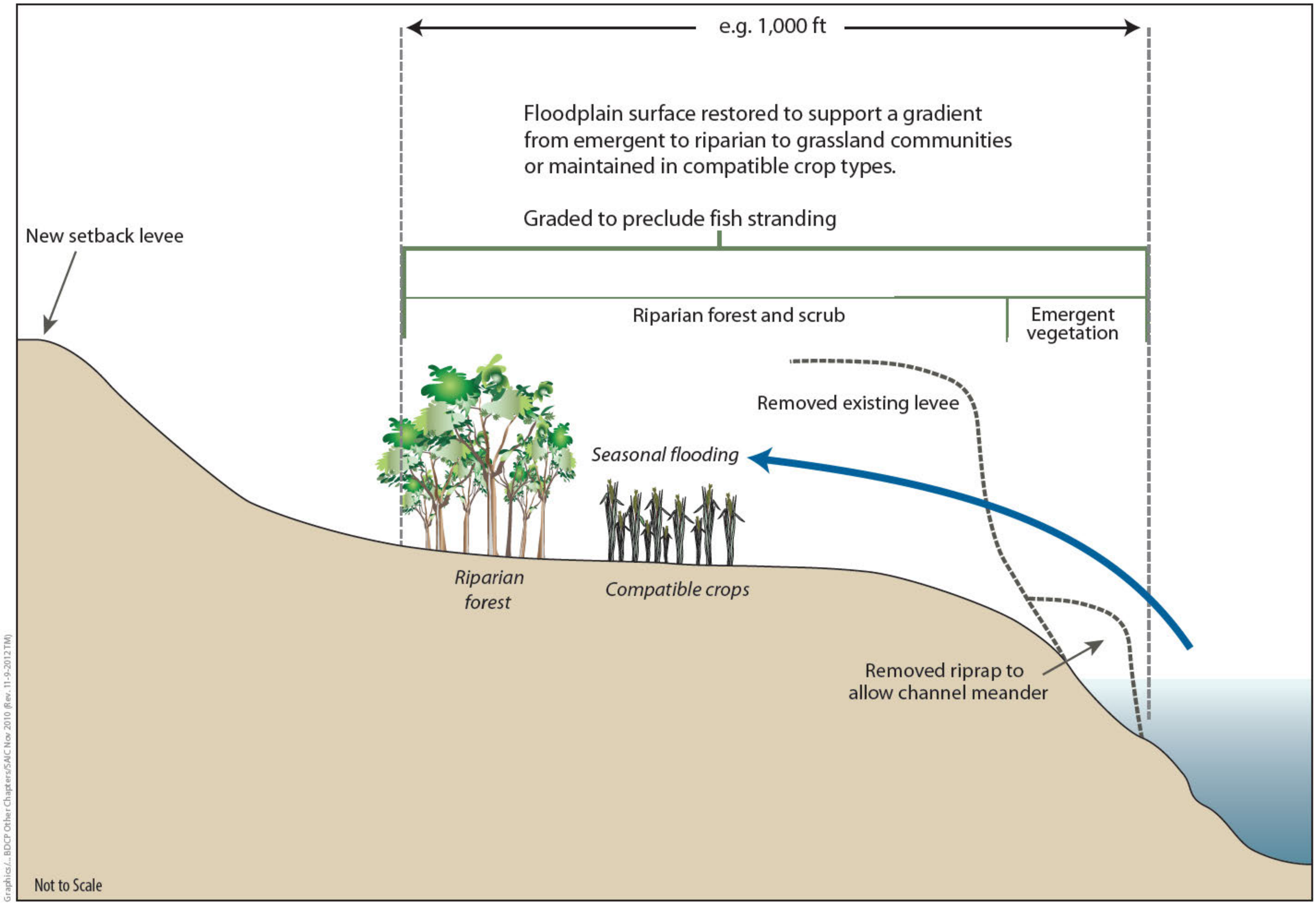
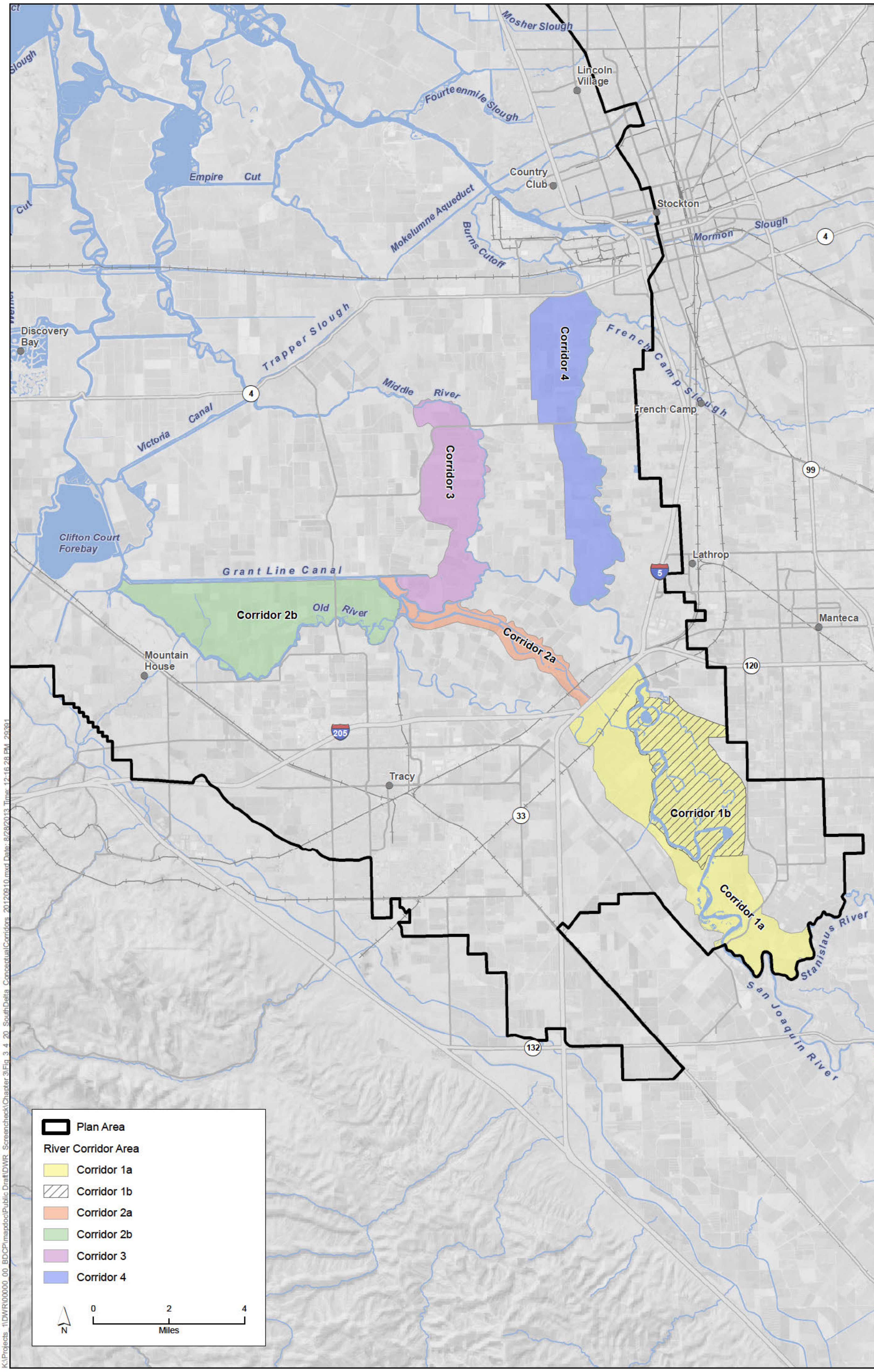


Figure 3.4-19
Conceptual Design for Restored Seasonally Inundated Floodplain



GIS Data Source:River Corridor Areas, ESA PWA 2011.

Figure 3.4-20
South Delta Conceptual Corridors (For Planning Purposes Only)

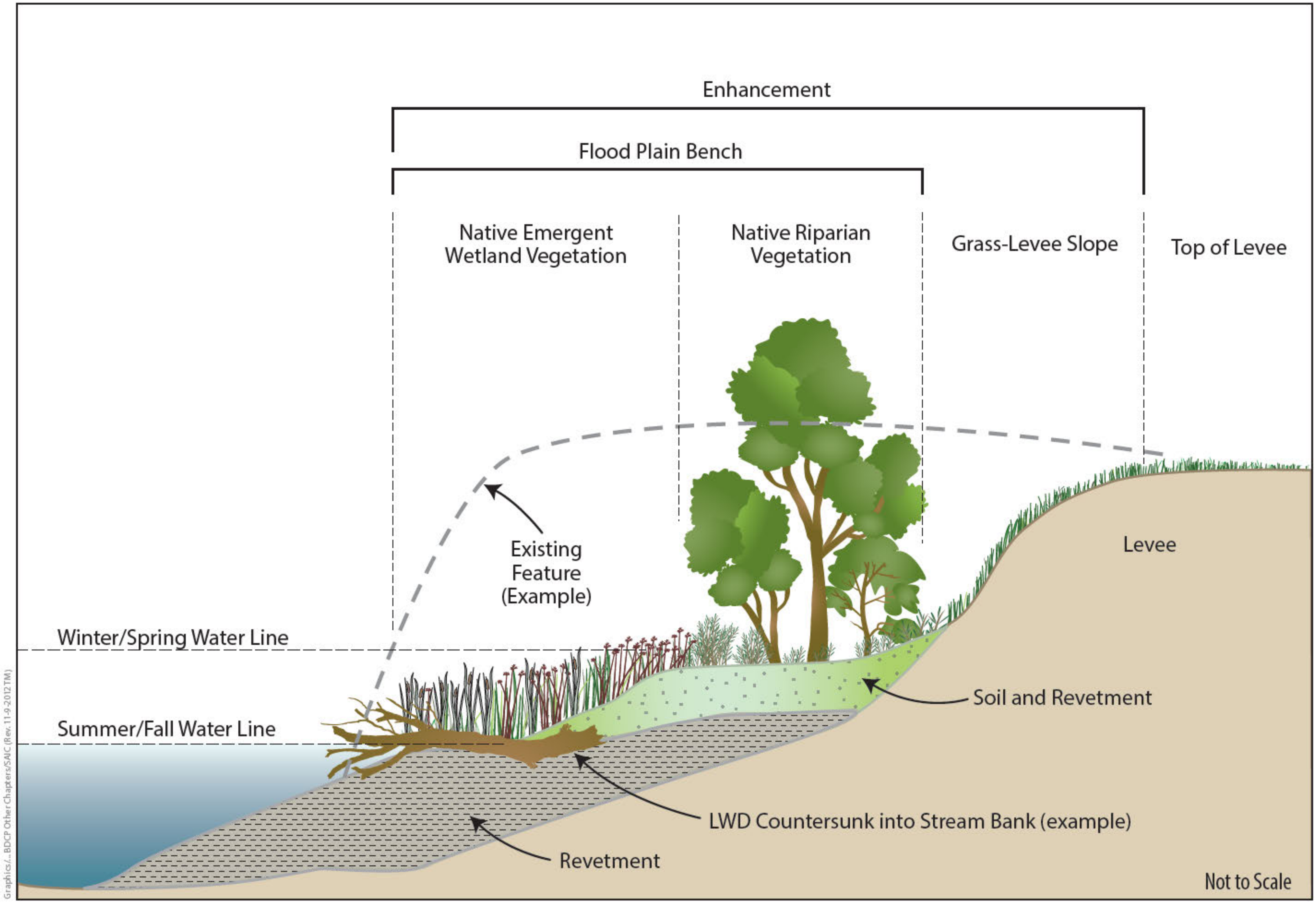


Figure 3.4-21
Cross-Section of Example Channel Margin Enhancements

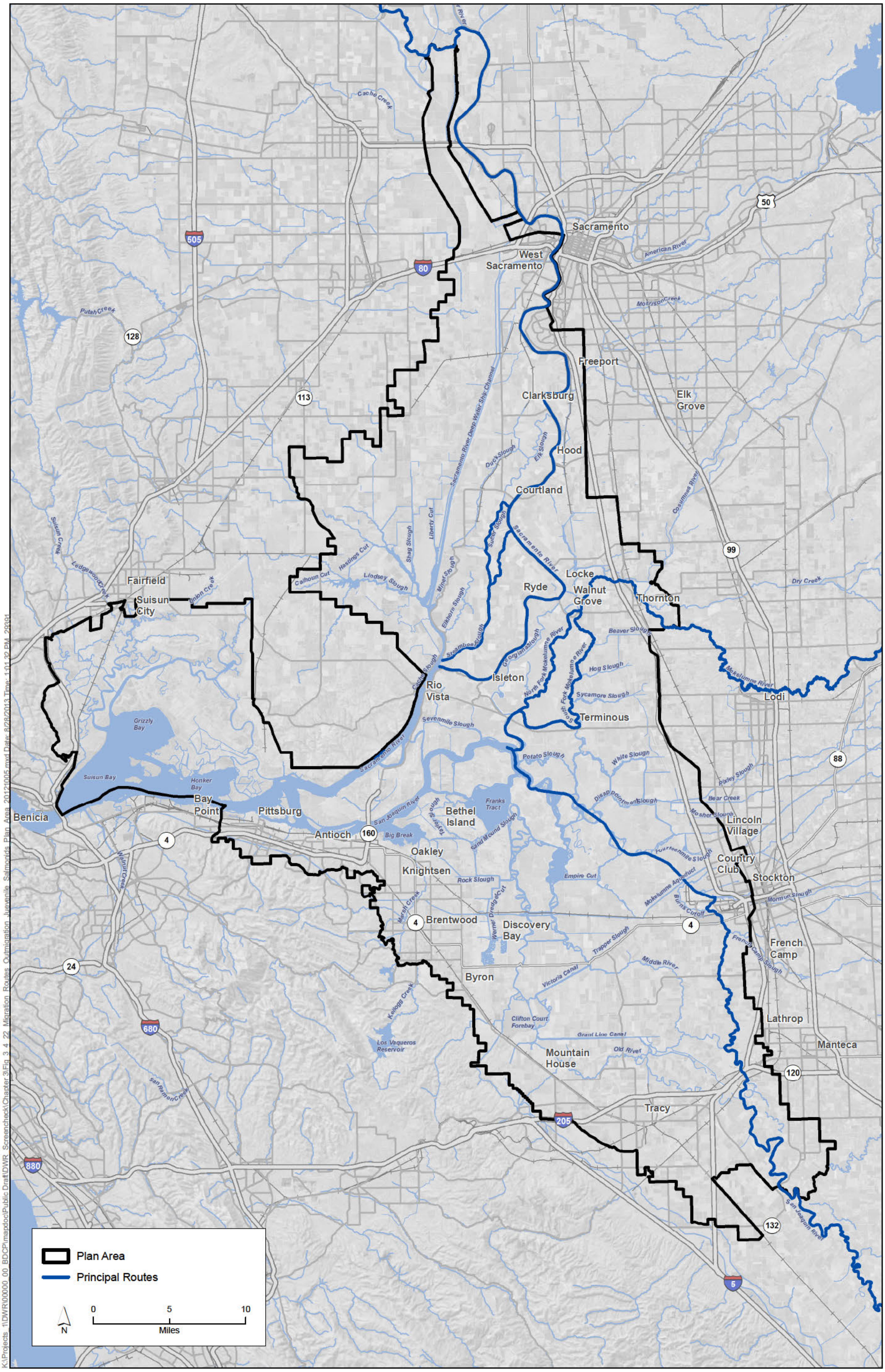


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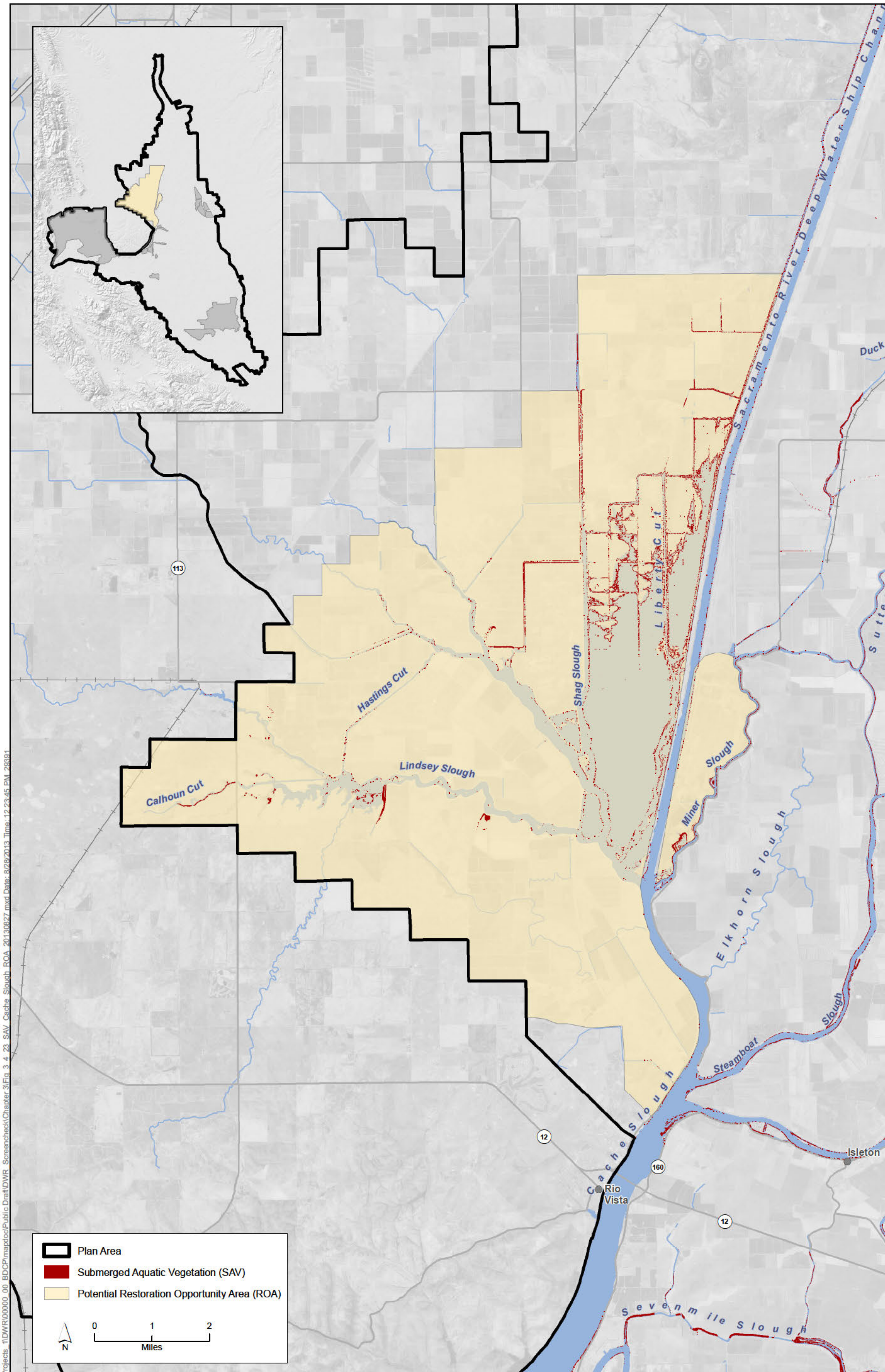
Figure 3.4-22
Principal Migration Routes of Rearing and Outmigrating Habitat for Juvenile Salmonids through the Plan Area



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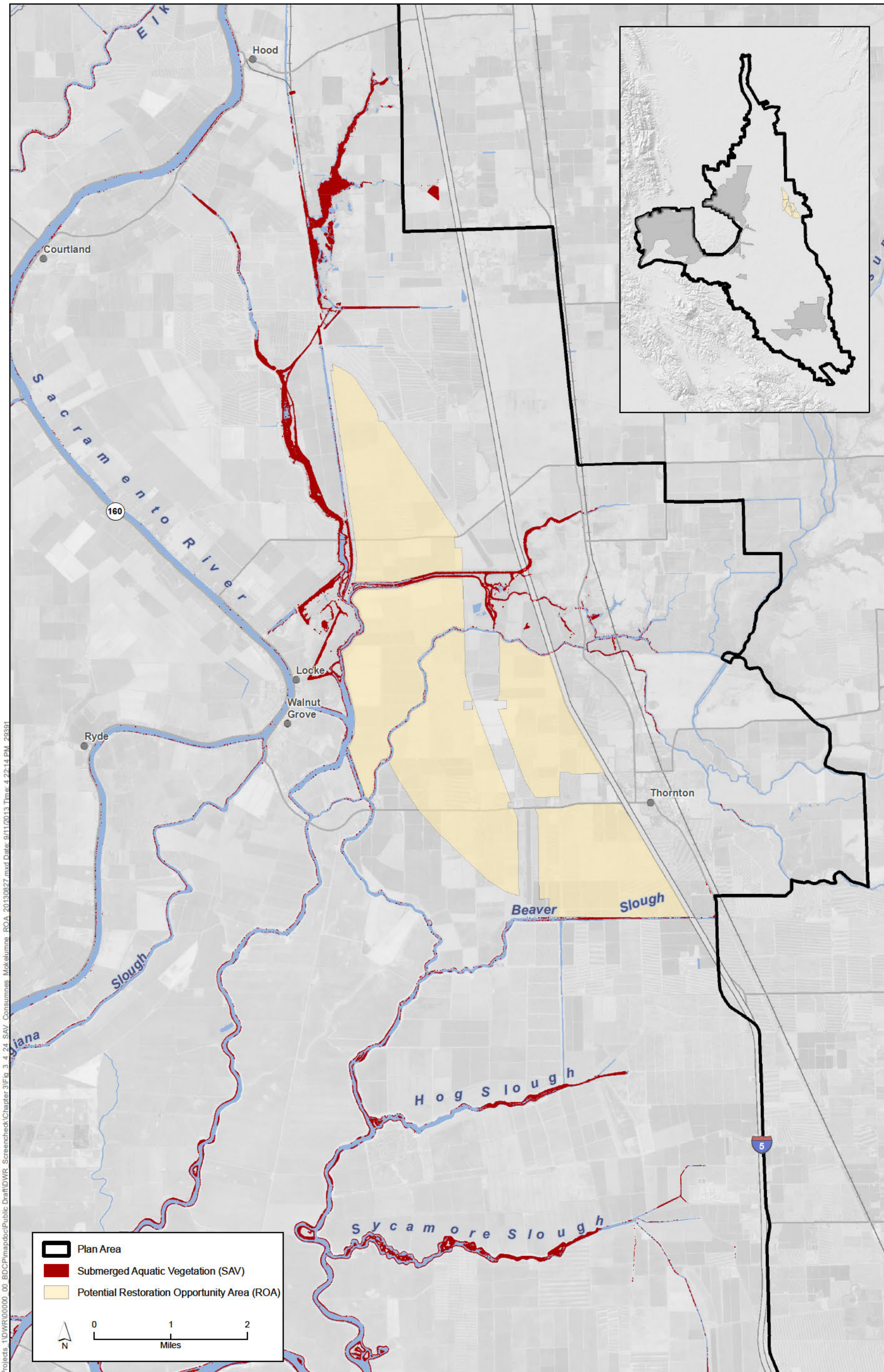
GIS Data Source: Restoration Opportunity Area, SAIC 2010; Submerged Aquatic Vegetation, UC Davis 2007.

Figure 3.4-23
Submerged Aquatic Vegetation in Cache Slough Restoration Opportunity Area



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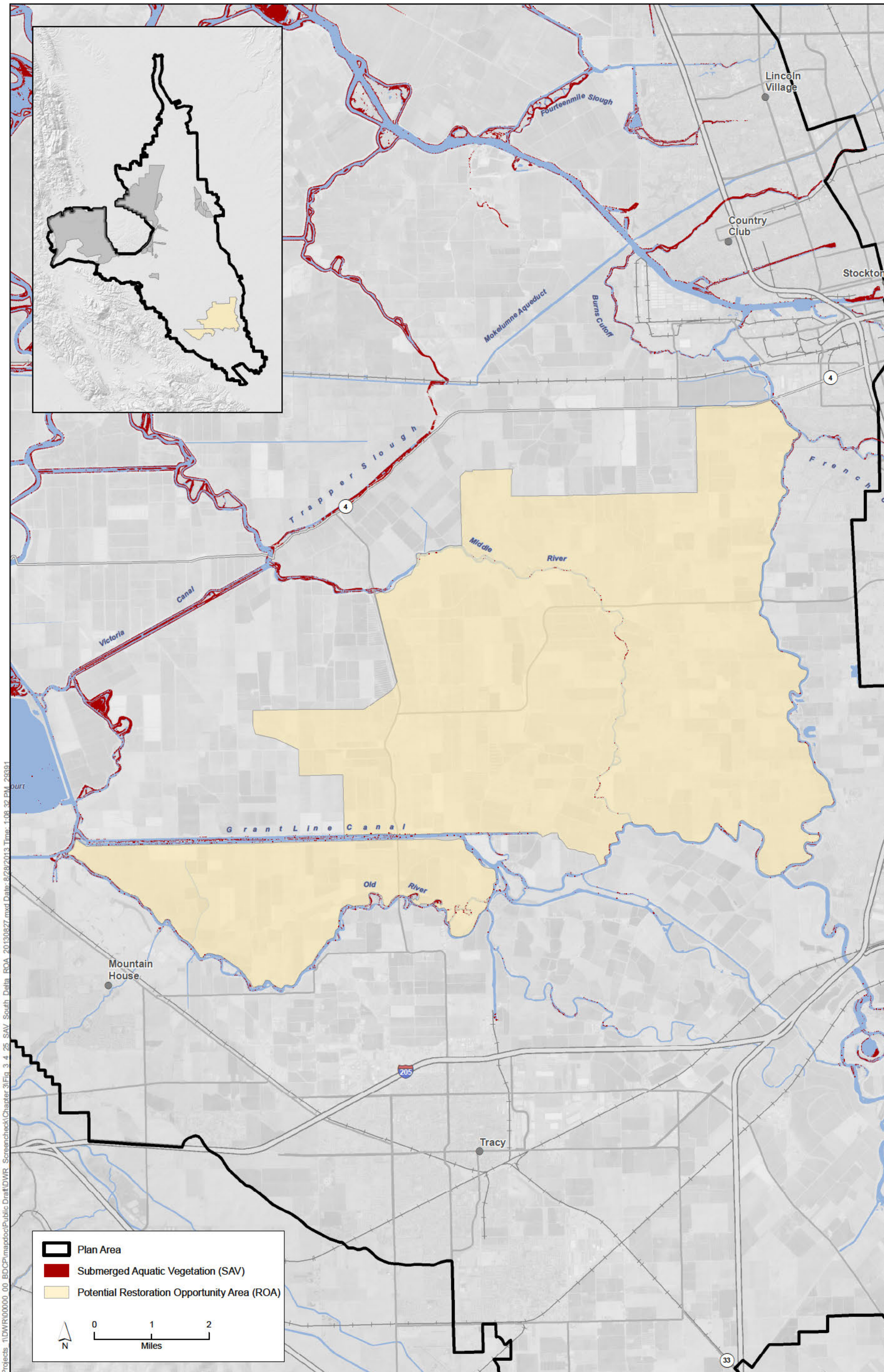
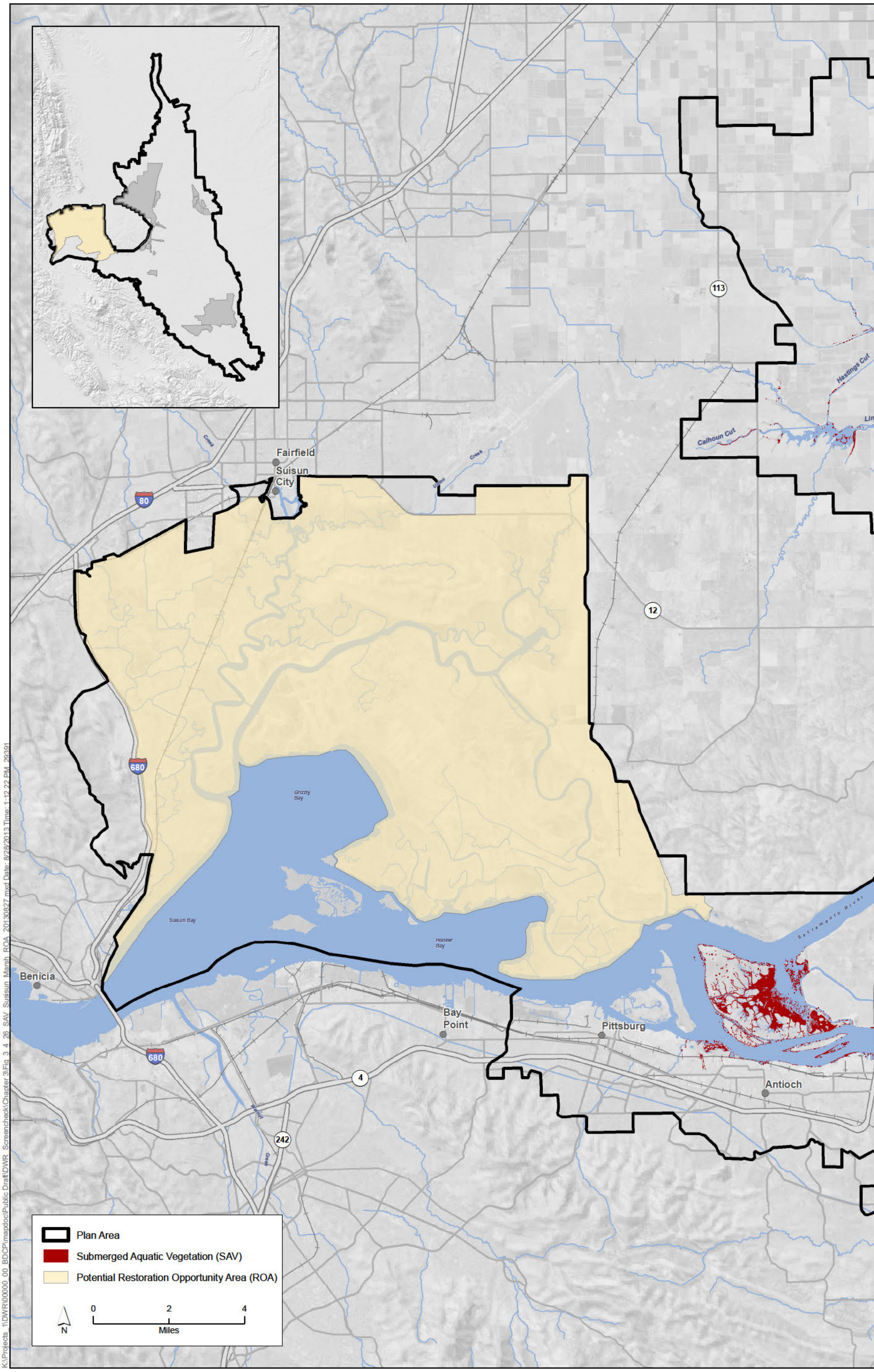
GIS Data Source: Restoration Opportunity Area, SAIC 2012; Submerged Aquatic Vegetation, UC Davis 2007.

Figure 3.4-24
Submerged Aquatic Vegetation in Cosumnes/Mokelumne Restoration Opportunity Area



GIS Data Source: Restoration Opportunity Area, SAIC 2012;
Submerged Aquatic Vegetation, UC Davis 2007.

Figure 3.4-25
Submerged Aquatic Vegetation in South Delta Restoration Opportunity Area



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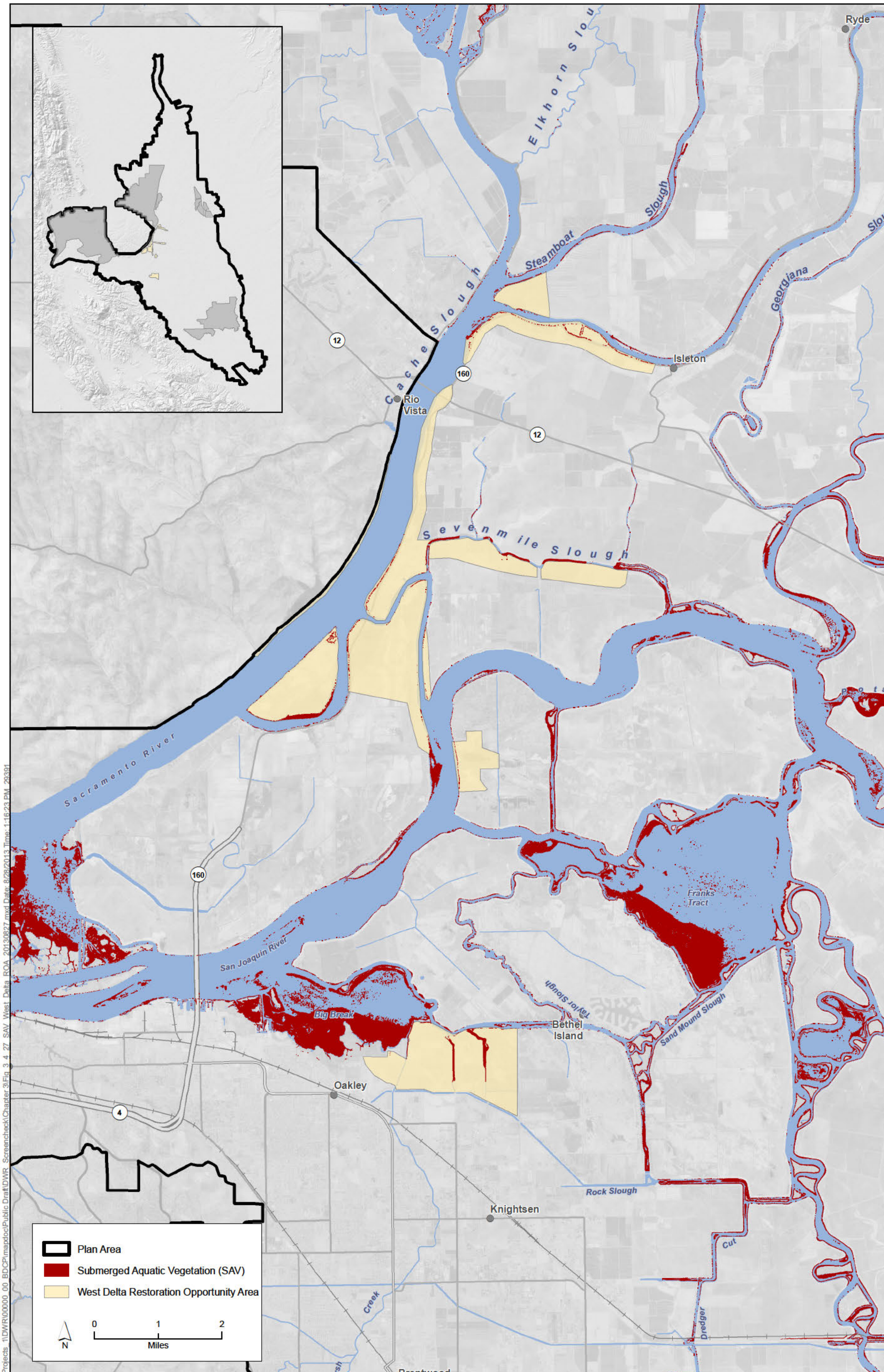
GIS Data Source: Restoration Opportunity Area, SAIC 2012;
Submerged Aquatic Vegetation, UC Davis 2007.

Figure 3.4-26
Submerged Aquatic Vegetation in Suisun Marsh Restoration Opportunity Area



GIS Data Source: Restoration Opportunity Area, SAIC 2012;
Submerged Aquatic Vegetation, UC Davis 2007.

Figure 3.4-27
Submerged Aquatic Vegetation in West Delta Restoration Opportunity Area

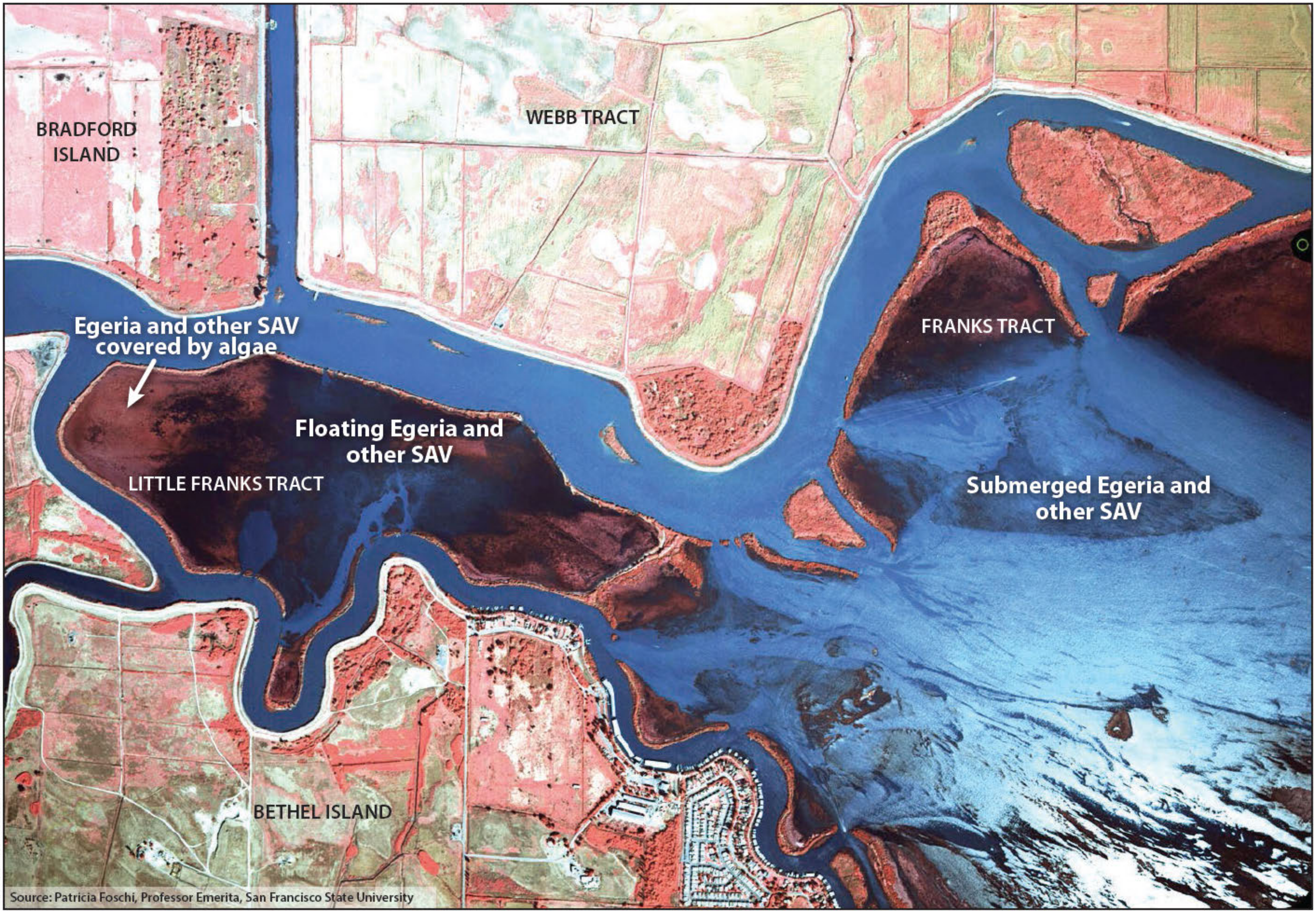


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Figure 3.4-28
Examples of Delta Areas with Submerged Aquatic Vegetation Infestations

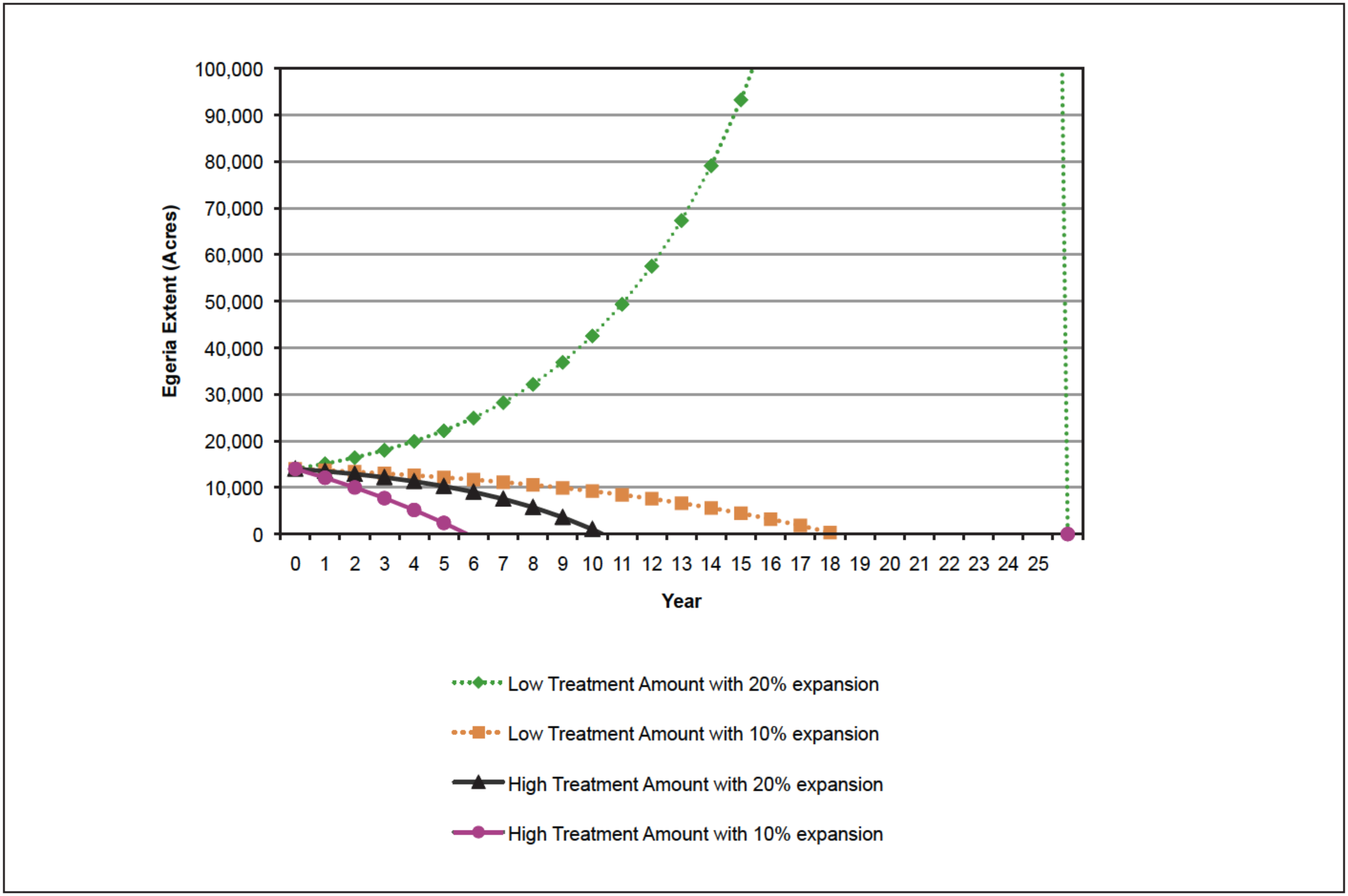

Figure 3.4-29
Projected Changes in Delta-Wide Extent of Egeria under Low and High Treatment Amounts and Two Different Projected Rates of Egeria Increase

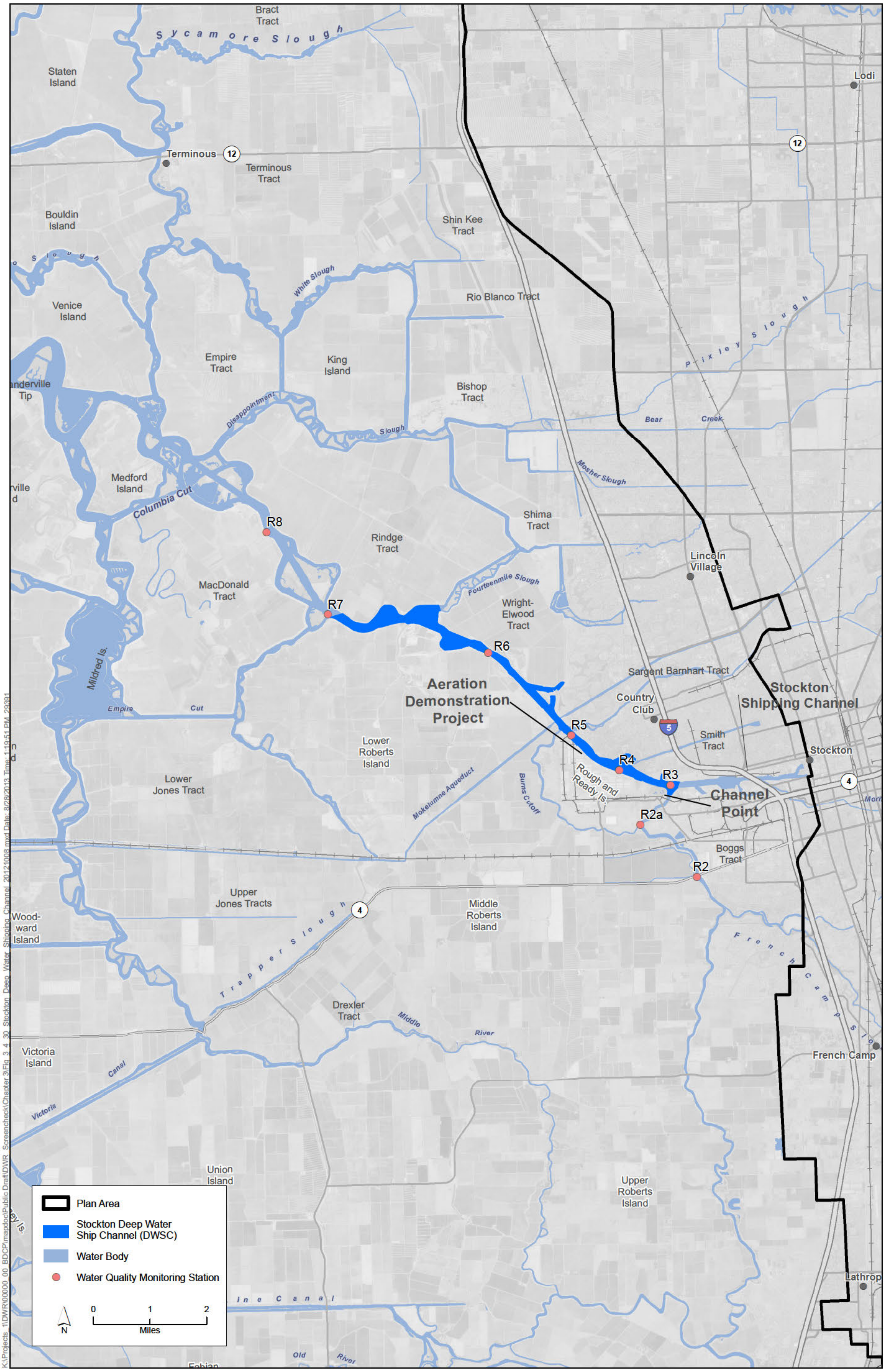

Figure 3.4-30
Stockton Deep Water Ship Channel, Aeration Facility, and Water Quality Monitoring Stations

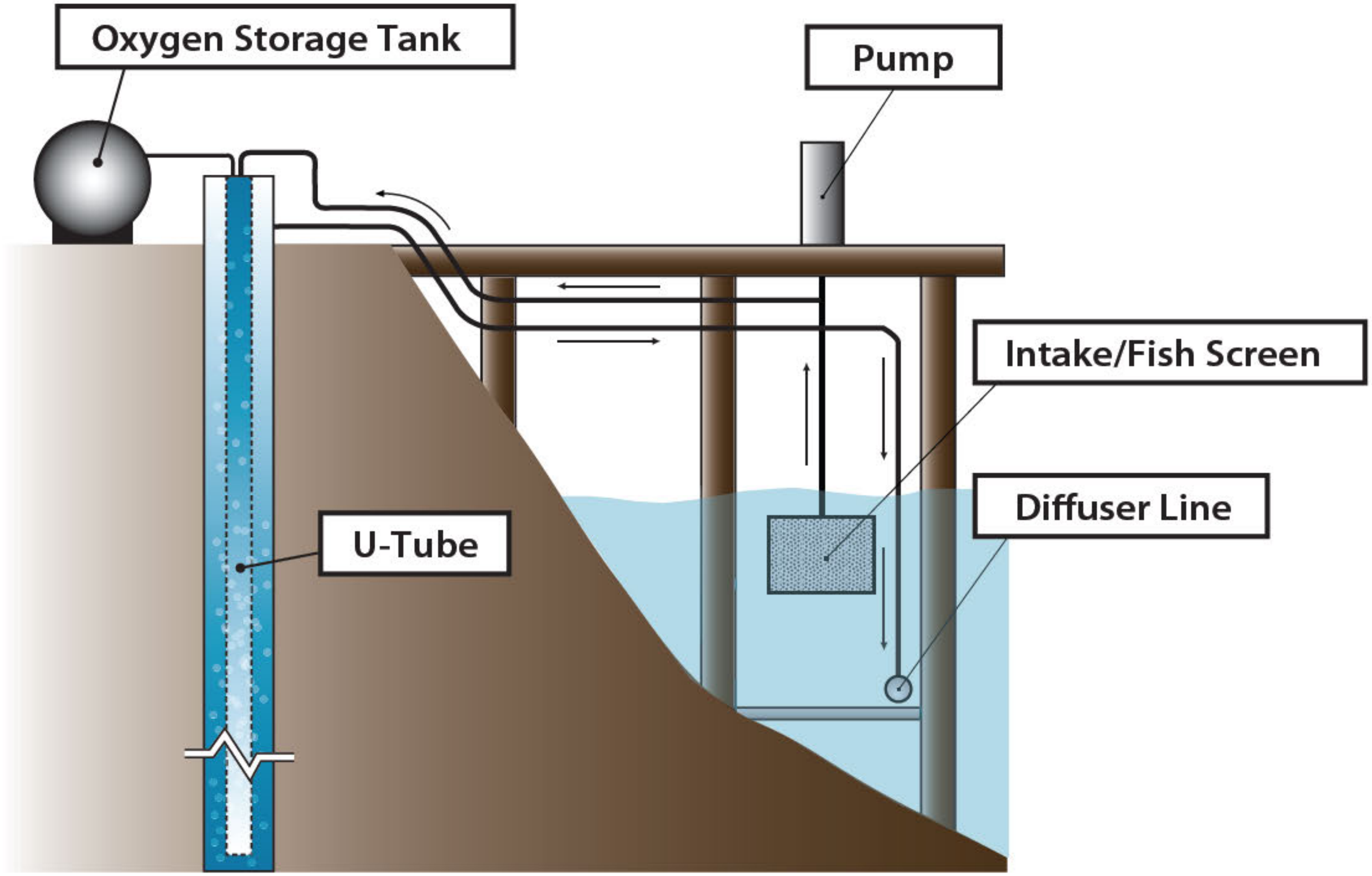

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Figure 3.4-31
Schematic of the Aeration Facility

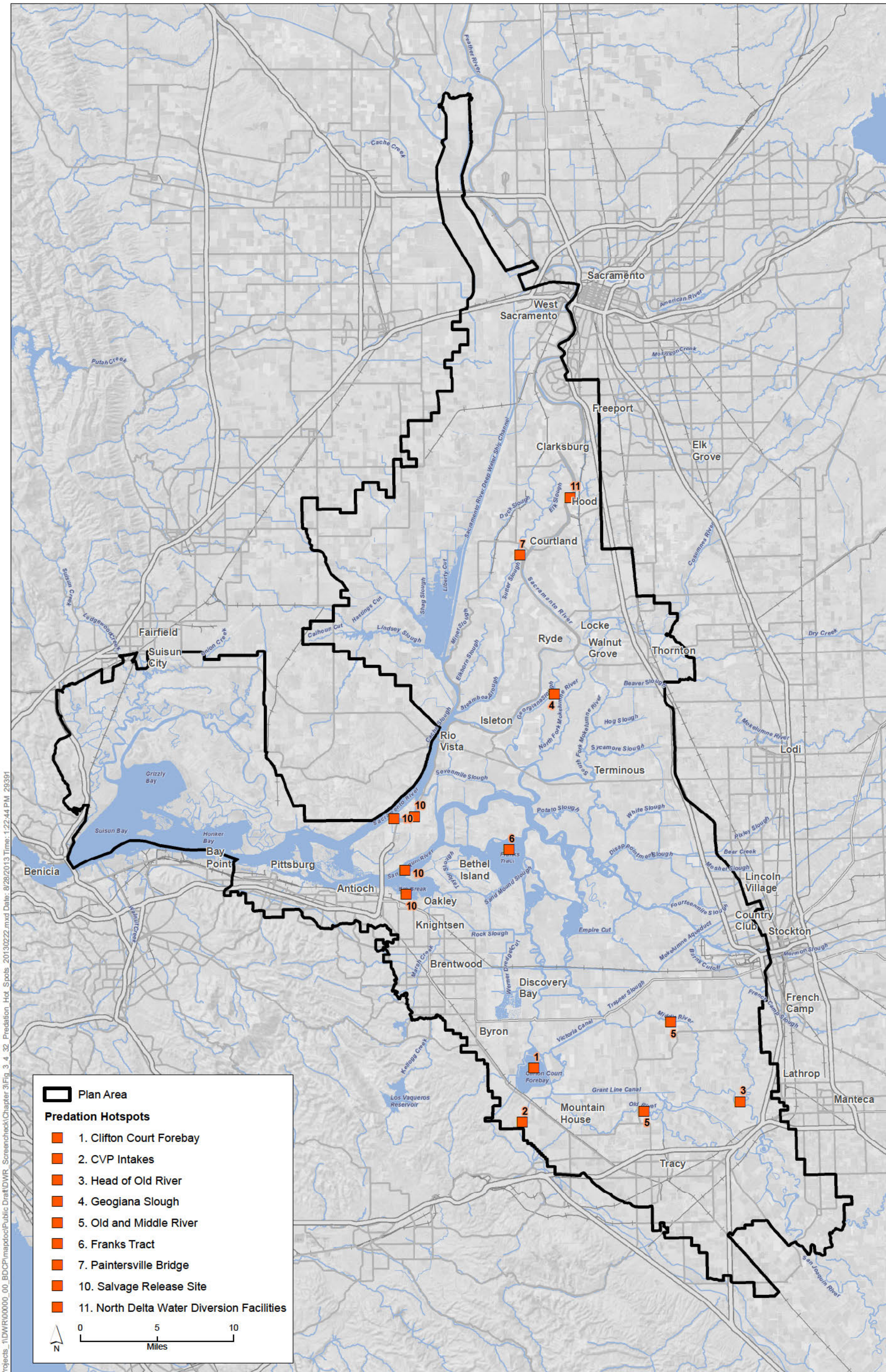

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Figure 3.4-32
Predation Hotspots in the Plan Area

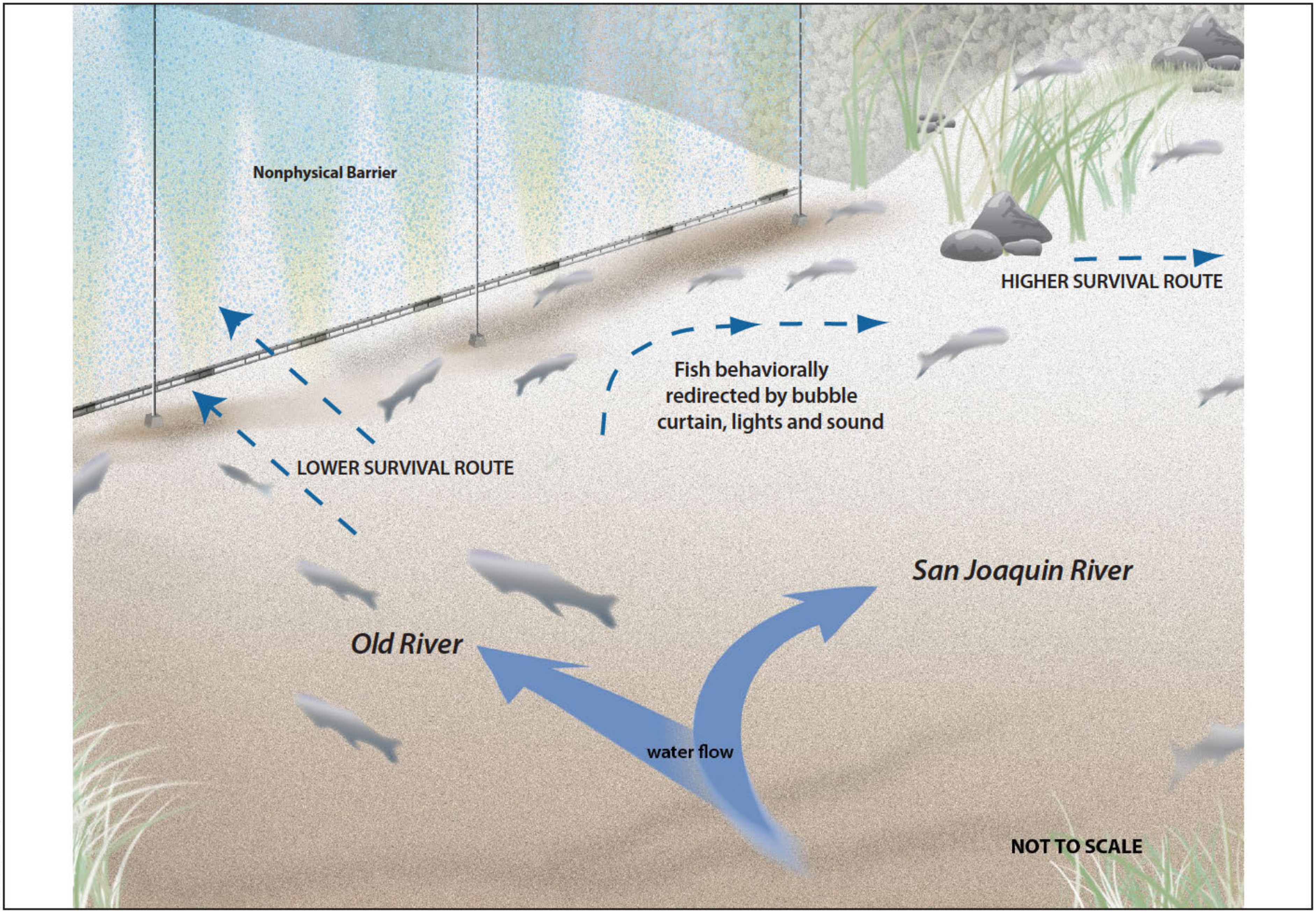
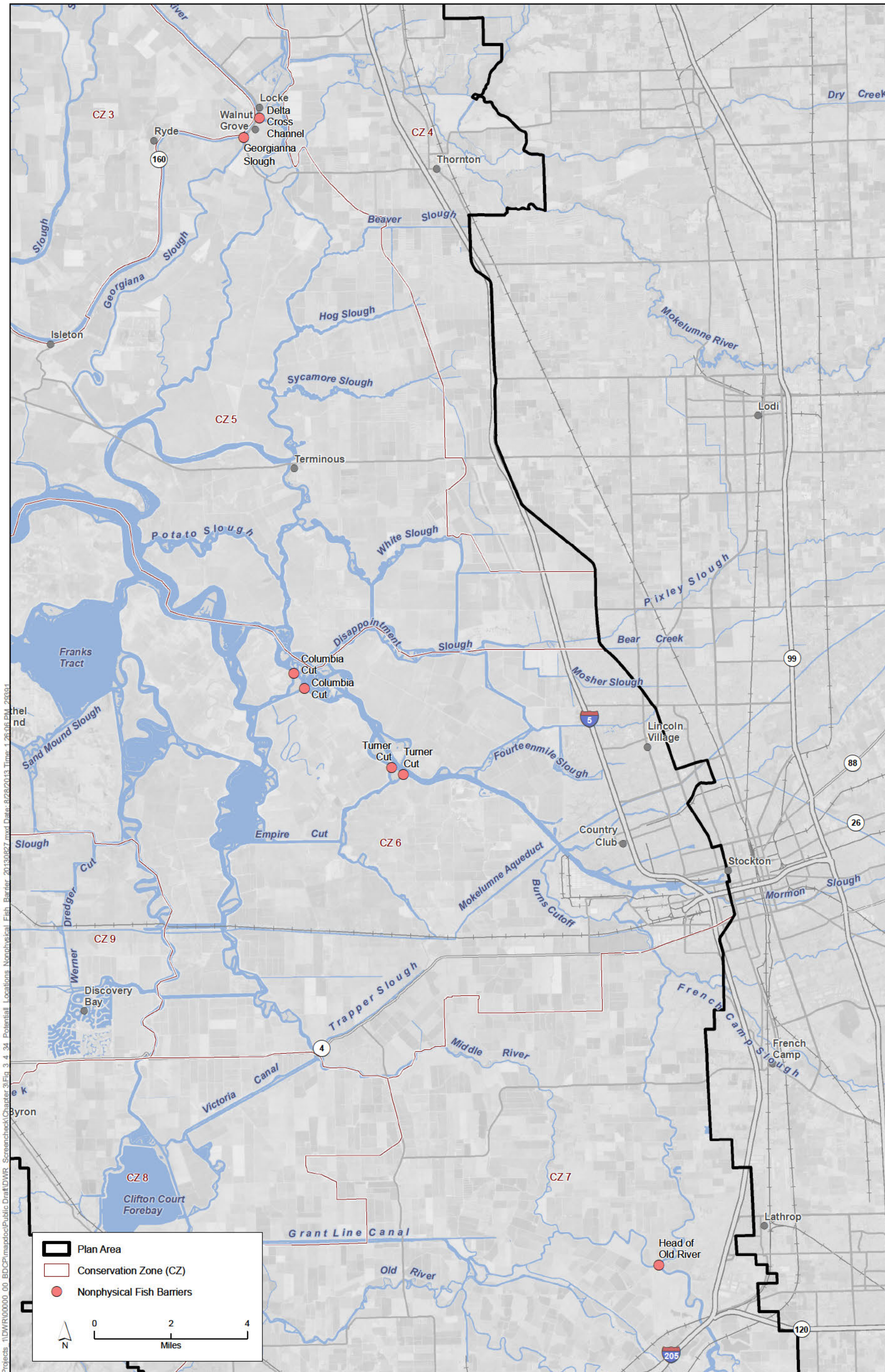
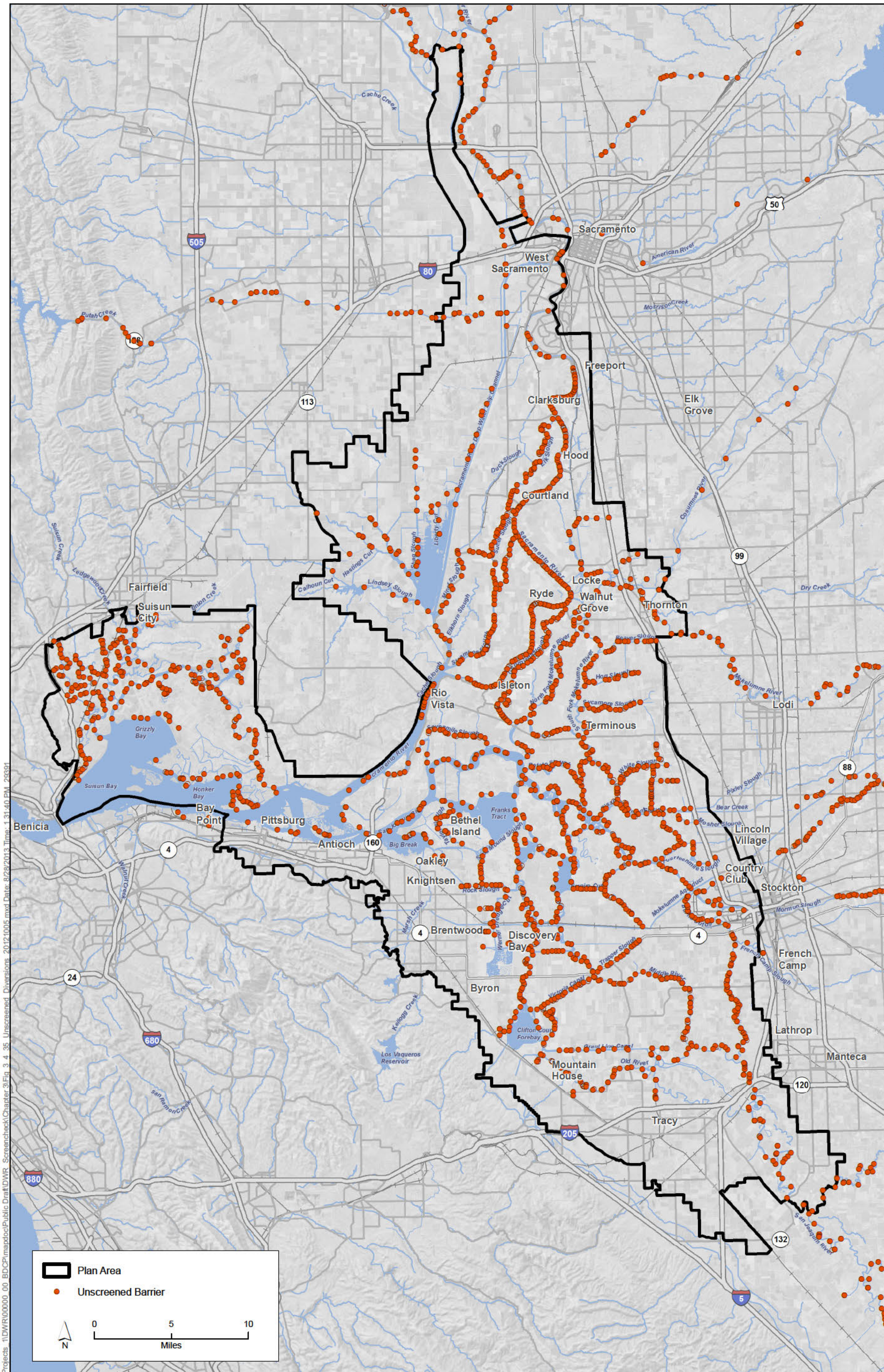


Figure 3.4-33
Schematic of Nonphysical Fish Barrier



GIS Data Source: Conservation Zones, SAIC 2012.

Figure 3.4-34
Potential Locations of Nonphysical Fish Barriers



GIS Data Source: Barriers, DFG 2011

Figure 3.4-35
Unscreened Nonproject Diversions in the Plan Area

3.5 Important Regional Actions

The conservation measures presented in the preceding section represent a suite of actions intended to minimize and mitigate the effect of covered activities on covered species and provide for the conservation and management of the species and natural communities in the Plan Area. However, these are not the only actions that are expected to influence ecosystem health in the Delta. In addition to actions taken pursuant to overlapping and adjacent regional conservation plans described in Chapter 1, Section 1.5, *Relationship to Other Plans in the Delta*, a number of other foreseeable actions, outside the scope of the BDCP and not within the control of the Authorized Entities, are likely to have a substantial influence on the health and recovery of the Delta natural communities and the associated species. This section describes the most important of these related actions: ammonia load reduction and hatchery genetic management plans.

3.5.1 Ammonia Load Reduction

3.5.1.1 Problem Statement

Ammonia is present in water in two forms: un-ionized ammonia (NH_3^+), sometimes referred to as free ammonia, and a positively charged ammonium ion (NH_4^+). These two forms are collectively referred to as total ammonia or ammonia plus ammonium. Generally, environmental un-ionized ammonia is more toxic to fish, and ammonium is taken up by plants and algae as a nutrient and can drive algae blooms and growth of invasive species (Jabusch 2011); however, in systems that are not nutrient-limited, such as the Bay-Delta, ammonium can inhibit primary production, and its presence does not result in the classic bloom/eutrophication cycle.

Recent research on the effects of elevated ammonium in the Delta strongly indicates that ammonium at low concentrations has resulted in subtle but important effects on Delta ecosystems and covered fish species (Foe et al. 2010; Glibert 2010; Glibert et al. 2011). Ammonium concentrations in Delta waters are not high enough to result in acute toxicity to fish species, but ammonium was identified as one of the potential causes of pelagic organism decline (Ballard et al. 2009). Ammonium has also been linked to effects on the foodweb, including covered fishes (Foe et al. 2010; Werner et al. 2008).

The primary source of total ammonia in the Delta is effluent discharged from wastewater treatment plants (WWTPs). The primary contributing facility is the Sacramento Regional WWTP, which discharges an average of 141 million gallons per day (mgd) and accounts for 1 to 2% of the river water volume (Foe et al. 2010). This facility produces 90% of the Sacramento River ammonia load (Jassby 2008). The Stockton Regional Wastewater Control Facility was formerly another important source of ammonia discharges via the San Joaquin River, but this facility has upgraded its treatment systems in recent years to remove most total ammonia from the effluent (City of Stockton 2011).

Total ammonia levels may affect covered fish species by inhibiting primary productivity (Ballard et al. 2009; Dugdale et al. 2007; Dugdale et al. 2012 in Parker et al. 2012; Glibert 2010; Glibert et al. 2011; Parker et al. 2012; Wilkerson et al. 2006), altering the phytoplankton species assemblage (Baxter et al. 2010; Glibert 2010), or altering the role of invasive species (Ballard 2009); each of these mechanisms is described below. The frequency, severity, and distribution of effects from these phenomena are the subject of ongoing research, but current science indicates a high likelihood that decreasing loading of total ammonia from the Sacramento Regional WWTP would have beneficial consequences for phytoplankton productivity and thus the productivity of the pelagic foodweb in and downstream of the Sacramento River in the Plan Area.

Parker et al. (2012) provide an overview of the decline in primary productivity in the San Francisco Estuary and the Delta, which has one of the lowest primary productivity rates reported for a river-dominated estuary. Spring and summer diatom blooms, previously common, now rarely occur. Recent studies indicate that this is at least partially due to ammonia levels that inhibit diatom production, but appear to promote cyanobacteria and dinoflagellate production, blooms of which are occurring more frequently.

High levels of ammonium in the Delta inhibit primary productivity (Dugdale et al. 2007; Dugdale et al. 2012 in Parker et al. 2012; Glibert 2010; Glibert et al. 2011; Parker et al. 2012; Wilkerson et al. 2006). A recent field study in the Sacramento River at and downstream of the Sacramento Regional WWTP outfall has provided strong evidence that ammonium discharges are disrupting nitrate uptake by phytoplankton, thereby inhibiting primary productivity (Parker et al. 2012). This study evaluated water quality at 21 stations along two, 150-kilometer-long transects in the Sacramento River, extending from upstream of the outfall, downstream to San Pablo Bay. Measurements were taken in March and again in April 2009. The results indicated that upstream of the outfall, phytoplankton primarily take up nitrogen in the form of nitrate and primary production of phytoplankton is high. Below the outfall, uptake immediately shifts to ammonium and primary production declines to its lowest values in the transect. Farther downstream, as ammonium concentrations decline, primary productivity again increases, largely recovering at the lower end of the transect in San Pablo Bay.

The authors interpret these results as indicating that phytoplankton productivity in the middle and lower river is inhibited by high ammonium concentrations, with the effect diminishing farther downstream where inhibition declines and both nitrate and ammonium uptake support primary production. Due to inhibition and low uptake rates, the phytoplankton have a minor effect on ammonium concentrations, using only about 6% of the available ammonium during their passage down the river. It is likely that bacterial denitrification is the primary process converting ammonium to nitrogen dioxide and nitrate in the river. Most importantly to the BDCP, this research suggests that a substantial reduction in ammonium discharge from the Sacramento Regional WWTP outfall is likely to produce a substantial increase in phytoplankton productivity throughout the Sacramento River in the Plan Area and on downstream into the San Francisco Bay. If the productivity rates observed upstream of the outfall were to continue downstream, productivity would increase by approximately 60%.

Ammonium inhibition of phytoplankton has also been demonstrated in San Francisco, San Pablo, and Suisun Bays during spring months (Wilkerson et al. 2006; Dugdale et al. 2007; Dugdale et al. 2012 in Parker et al. 2012) point out that two rare diatom blooms occurred in Suisun Bay in 2010 and one in 2000. Each of these blooms occurred following a decrease in ammonium concentrations, relative to typical conditions for that area (Wilkerson et al. 2006). Phytoplankton form the base of the foodweb from which much of the food energy for the Delta ecosystem is derived (Jassby and Cloern 2000). Therefore, improved phytoplankton production could also improve zooplankton productivity, improving the prey base for covered pelagic fish species, particularly delta and longfin smelt. Juvenile salmonids may also be affected by limited zooplankton abundance, although they primarily consume other organisms.

In addition to inhibiting the amount of primary productivity, ammonium has also been shown to shift the phytoplankton species assemblages from diatoms to dinoflagellates and cyanobacteria, which are a much less valuable food source (Essex Partnership 2009; Glibert 2010; Glibert et al. 2011; Parker et al. 2012). Glibert (2010) and Glibert et al. (2011) postulates that nutrient stoichiometry, especially the total-nitrogen-to-phosphorous ratio, has impacts on species assemblages beyond that of preferential uptake of ammonium by some species such as cyanobacteria and dinoflagellates. For example, Microcystis is a common cyanobacterium that poses concerns in the Delta, because its blooms can be toxic to aquatic life.

Increases in invasive species in the Delta have been linked to ammonium and changing nutrient stoichiometry. The invasive copepods *Pseudodiaptomus forbesi* and *Limnoithona tetraspina* became dominant as flagellates, and cyanobacteria gained dominance over diatoms. This shift in lower trophic level species assemblages was also correlated with observed declines in the pelagic fishes, delta and longfin smelt (Glibert 2010).

Ammonia may also have toxic effects on invertebrates that are prey items for covered fish species (Essex Partnership 2009; Teh et al. 2011). If food is limiting to delta and/or longfin smelt, a reduction in the abundance of prey could reduce the abundance of these fish species. A recent study of the nonnative copepod, *P. forbesi* (Teh et al. 2011) indicated that biota can be affected at concentrations as low as 0.38 mg/L of total ammonia nitrogen. In comparison, Foe et al. (2010) reported the highest average ammonia concentrations of 0.46 mg/L in the Sacramento River in 2009 and 2010 at Hood, downstream of the Sacramento Regional Wastewater Treatment Plant. Preliminary studies by CDFW have indicated that *P. forbesi* is an important food source for age-0 delta smelt and longfin smelt (Teh et al. 2011), so declines in its abundance could affect those species.

3.5.1.2 Description

As described above, upgrades to the Sacramento Regional Wastewater Treatment Plant would reduce total ammonia loading to the Sacramento River. This regional action could alter the likelihood of the conservation strategy achieving biological goals and objectives related to ecosystem productivity and food supply for covered fishes.

In December 2010, a revised NPDES discharge permit was issued to the Sacramento Regional WWTP. On May 7, 2012, the SRCSD issued a Notice of Preparation for a draft environmental impact report for the SRCSD Advanced Wastewater Treatment Plant Project (Sacramento Regional County Sanitation District 2012). The proposed facility would be designed to achieve compliance with the NPDES requirements, which include an ammonia discharge limit of 1.8 mg/L monthly average and a nitrate discharge limit of 10 mg/L monthly average (Sacramento Regional County Sanitation District 2012). Since the facility currently accounts for 63% of wastewater discharges in or near the Plan Area (158 million of 252 mgd), the proposed changes would substantially reduce total ammonia loading to the Sacramento River, proportionally reducing the adverse effects described above.

3.5.1.3 Expected Outcomes

The total ammonia loading reductions currently proposed by SRCSD would substantially reduce ammonium loads in the Plan Area downstream of the Sacramento Regional WWTP. Although frequency, distribution, and severity of potential adverse effects of ammonium on aquatic ecosystems in the Plan Area are currently not well understood, it is likely that the reduced loading would contribute to improvements in phytoplankton primary productivity and the phytoplankton species assemblage, supporting attainment of biological objectives related to ecosystem productivity and food supply for covered fishes. Reduced ammonia loadings also might result in reduced direct physiological effects on some of these fishes, although there is low confidence in this conclusion as very few data are available.

3.5.2 Hatchery Genetic Management Plans

3.5.2.1 Problem Statement

Hatchery-origin (fish spawned in and released from hatcheries) Chinook salmon and steelhead have a variety of adverse effects on natural-origin (fish spawned in streams) Chinook salmon and steelhead. Among these effects are the following (ICF International 2010:4–127).

- Effects related to predation, competition, and related changes in ecological relationships between hatchery-origin and natural-origin populations of native species.
- Effects related to nontarget harvest, which is the catch of natural-origin fish by fishers that are attracted to an area because the waters contain hatchery-origin fish.
- Effects related to invasive species and pathogens that may be accidentally introduced during hatchery release operations.
- Effects that arise from interbreeding of hatchery and wild fish, altering the genetic composition of wild populations.
- Effects that arise from accidental or otherwise unauthorized releases of hatchery fish.
- Effects that are caused by anglers during their pursuit of stocked fish.

One of the most significant of these potential hatchery-related effects is the interaction between natural-origin fish and hatchery-origin fish. These interactions take the form of both competition and predation as well as interbreeding.

The potential for predation and competition between hatchery- and natural-origin salmonids depends on the degree of spatial and temporal overlap; differences in size and feeding habitats; migration rate and duration of freshwater residence; and the distribution, habitat use, and densities of hatchery- and natural-origin juveniles (Mobrand et al. 2005). Concern has been expressed about the potential for hatchery-origin salmon and steelhead to prey on or compete with natural-origin juvenile Pacific salmonids and the effect this may have on threatened or endangered salmonid populations (Williams 2006). However, there is little evidence that wild salmonids are preyed on by other salmonids in estuarine environments such as the Delta. Numerous studies suggest that salmonids (hatchery-origin or natural-origin) are not significant predators on juvenile salmonids in these environments, but no studies have been designed to specifically investigate predation by hatchery-reared salmonids (Hatchery Scientific Review Group 2004).

The principal mechanisms by which anadromous hatchery and stocking programs may affect the genetic integrity of native fish include the capture of native fish that might otherwise spawn in natural waters, the rearing of fish in artificial channels and ponds that causes a preferential selection for traits beneficial in the hatchery environment but unfavorable for survival in stream habitats, and the interbreeding of fish exhibiting hatchery-selected genetic traits with the natural-origin fish population (ICF International 2010:4–172). These mechanisms may result in two types of genetic hazards to natural-origin salmon and steelhead populations: loss of genetic diversity within and among populations, and reduced fitness of a population affecting productivity and abundance. Araki et al. (2008) summarized a number of studies that reported a loss of reproductive success ("fitness") of hatchery fish in nature. Araki et al. (2009) further investigated the effects of interbreeding of hatchery fish with natural-origin populations and concluded a loss of fitness of the receiving natural-origin population, suggesting a loss of genetic fitness of the population. Some populations may be more affected than others due to a variety of factors such as the length of exposure to the hatchery environment, the use of nonlocal stocks in the hatchery broodstock, the degree of habitat fragmentation, the degree of interbreeding, and the reproductive success of hatchery fish when introduced to habitat.

3.5.2.2 Description

Hatchery and genetic management plans (HGMPs) are required by NMFS in regulations that govern permissible incidental take of ESA-listed species—called "4(d) rules" because they are required under Section 4(d) of the ESA—of west coast salmon and steelhead via hatchery operations. NMFS uses the information provided by HGMPs to evaluate impacts on ESA-listed salmon and steelhead. Thus, an HGMP is required to describe a hatchery's operations in detail, particularly with regard to actions that serve to minimize potential adverse effects on listed species.

Draft HGMPs have been developed for nearly all Central Valley hatcheries, but none have been approved yet by NMFS. None of the affected hatcheries are located in the Plan Area.

3.5.2.3 Expected Outcomes

HGMP implementation is expected to employ a variety of techniques to minimize interactions between natural-origin and hatchery-origin fish. Examples of such techniques include releasing juveniles at times and in locations where there is low potential for predation or competition interactions, and managing broodstock collection and hatchery to minimize genetic effects.

A recent review of the anadromous fish hatchery and stocking programs in the Central Valley recommended adoption of HGMPs at certain California salmon and steelhead hatcheries as an effective way to minimize competition, predation, and genetic interactions between hatchery-origin and natural-origin fish. Nonetheless, the review found that even with implementation of HGMPs, the existing programs would have significant and unavoidable impacts on spring- and fall-run Chinook salmon through the mechanisms of competition and predation, and also through the mechanism of genetic effects (ICF International 2010: Chapter 4).

3.5.3 References Cited

Araki, H., A. B. Berejikian, M. J. Ford, and M. S. Blouin. 2008. Fitness of Hatchery-Reared Salmonids in the Wild. *Evolutionary Applications* 1:342–355.

Araki, H. A., B. Cooper, and M. S. Blouin. 2009. Carry-Over Effect of Captive Breeding Reduces Reproductive Fitness of Wild-Born Descendants in the Wild. *Biology Letters* 5(5):621–624.

Ballard, A., R. Breur, F. Brewster, C. Dahm, K. Laren, A. Mueller-Solger, and A. Vargas. 2009. *Background/Summary of Ammonia Investigations in the Sacramento–San Joaquin Delta and Suisan Bay*. March.

Baxter, R., R. Breuer L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solger, T. Sommer, and K. Souza. 2010. *Interagency Ecological Program 2010 Pelagic Organism Decline Work Plan and Synthesis of Results*. December.

City of Stockton. 2011. *Treatment Plant Process*. Available: <http://www.stocktongov.com/government/departments/municipalUtilities/utilPlantTreat.html>. Accessed: August 25, 2011.

Dugdale, R. C., F. P. Wilkerson, V. E. Hogue, and A. Marchi. 2007. The Role of Ammonium and Nitrate in Spring Bloom Development in San Francisco Bay. *Estuarine Coastal and Shelf Science* 73:17–29.

Dugdale, R. C., F. P. Wilkerson, A. E. Parker, A. Marchi, and K. Taberski. 2012. Anthropogenic Ammonium Impacts Spring Phytoplankton Blooms in the San Francisco Estuary: The Cause of Blooms in 2000 and 2010. *Estuarine and Coastal Shelf Science*. Submitted for publication. As cited in Parker, A. E., R. C. Dugdale, and F. P. Wilkerson. 2012. Elevated Ammonium Concentrations from Wastewater Discharge Depress Primary Productivity in the Sacramento River and the Northern San Francisco Estuary. *Marine Pollution Bulletin* 64:574–586.

Essex Partnership. 2009. *DRERIP Evaluations of BDCP Draft Conservation Measures. Summary Report*. Available: <http://science.calwater.ca.gov/pdf/workshops/workshop_eco_052209_BDCP-DRERIP_Summary_with_Appendices1.pdf>. Accessed: December 9, 2011.

Foe, C., A. Ballard, and F. Stephanie. 2010. *Nutrient Concentrations and Biological Effects in the Sacramento–San Joaquin Delta*. July. Prepared by California Regional Water Quality Control Board, Central Valley Region, Rancho Cordova, CA.

Glibert, P. M., D. Fullerton, J. M. Burkholder, J. C. Cornwell, and T. M. Kana. 2011. Ecological Stoichiometry, Biogeochemical Cycling, Invasive Species, and Aquatic Food Webs: San Francisco Estuary and Comparative Systems. *Reviews in Fisheries Science* 19(4):358–417.

Glibert, P. M. 2010. Long-Term Changes in Nutrient Loading and Stoichiometry and Their Relationships with Changes in the Food Web and Dominant Pelagic Fish Species in the San Francisco Estuary. *Reviews in Fisheries Science* 18(2):211–232.

Hatchery Scientific Review Group. 2004. *Hatchery Reform: Principles and Recommendations of the HSRG*. Prepared by Lars Mobrand (chair), John Barr, Lee Blankenship, Don Campton, Trevor Evelyn, Tom Flagg, Conrad Mahnken, Robert Piper, Paul Seidel, Lisa Seeb and Bill Smoker. Seattle, WA: Long Live the Kings.

ICF International. 2010. *Final Hatchery And Stocking Program Environmental Impact Report/Environmental Impact Statement*. January. Prepared for California Department of Fish and Game and U.S. Fish and Wildlife Service.

Jabusch, T. 2011. Ammonia in the Delta: State of the Science, Implications for Management. Pages 30–39 in *The Pulse of the Delta: Monitoring and Managing Water Quality in the Sacramento–San Joaquin Delta. Re-Thinking Water Quality Monitoring*. Contribution 630. Oakland, CA: Aquatic Science Center. Available: <http://www.aquaticscience.org/ 2011_ASC_PulseOfTheDelta_final.pdf>. Accessed: November 8, 2012.

Jassby, A. 2008. Phytoplankton in the Upper San Francisco Estuary: Recent Biomass Trends, Their Causes and Their Trophic Significance. *San Francisco Estuary and Watershed Science* 6:1–24.

Jassby, A. D., and J. E. Cloern. 2000. Organic Matter Sources and Rehabilitation of the Sacramento-San Joaquin Delta (California, USA). *Aquatic Conservation: Marine and Freshwater Ecosystems* 10:323–352.

Lehman, P. W., G. Boyer, M. Satchwell, and S. Waller. 2008. The Influence of Environmental Conditions on the Seasonal Variation of *Microcystis* Cell Density and Microcystins Concentration in San Francisco Estuary. *Hydrobiologia* 600:187–204.

Mobrand, L. E., J. Barr, L. Blankenship, D. E. Campton, T. T. P. Evelyn, T. A. Flagg, C. V. W. Mahnken. L. W. Seeb, P. Seidel, and W. W. Smoker. 2005. Hatchery Reform in Washington State: Principles and Emerging Issues. *Fisheries* 30:11–22.

Parker, A. E., R. C. Dugdale, and F. P. Wilkerson. 2012. Elevated Ammonium Concentrations from Wastewater Discharge Depress Primary Productivity in the Sacramento River and the Northern San Francisco Estuary. *Marine Pollution Bulletin* 64:574–586.

Sacramento Regional County Sanitation District. 2003. *Draft Environmental Impact Report for the Sacramento Regional County Sanitation District, Sacramento Regional Wastewater Treatment Plant 2020 Master Plan*. Volume 1—EIR Text.

Sacramento Regional County Sanitation District. 2012. *Notice of Preparation of a Draft Environmental Impact Report for SRCSD Advanced Wastewater Treatment Plant (AWTP) Project*. Control Number 2012-70044. Available: < http://www.srcsd.com/pdf/notice-draftEIR.pdf>. Accessed: July 24, 2012.

Teh, Swee, I. Flores, M. Kawaguchi, S. Lesmeister, C. Teh. 2011. Full Life-Cycle Bioassay Approach to assess Chronic Exposure of Pseudodiaptomus forbesi to Ammonia/Ammonium. State Water Board / UC Davis Agreement No. 06-447=300. August 31.

Werner, I., L. A. Deanovic, M. Stillway, and D. Markiewicz. 2008. *The Effects of Wastewater Treatment Effluent-Associated Contaminants on Delta Smelt, Final Report*. September. Aquatic Toxicology Laboratory, School of Veterinary Medicine, University of California, Davis, CA.

Wilkerson, F. P., R. C. Dugdale, V. E. Hogue, and A. Marchi. 2006. Phytoplankton Blooms and Nitrogen Productivity in San Francisco Estuary. *Estuaries and Coasts* 29:401–416.

Williams, J. G. 2006. Central Valley Salmon: a Perspective on Chinook and Steelhead in the Central Valley of California. *San Francisco Estuary and Watershed Science* 4(3):Article 2.

3.6 Adaptive Management and Monitoring Program

The conservation strategy consists of 22 conservation measures that are designed to achieve the biological goals and objectives described in Section 3.3, *Biological Goals and Objectives*. The conservation measures include actions to improve flow conditions, increase aquatic food production, restore habitat for the covered species, and reduce the adverse effects of many biological and physical stressors on those species. This strategy also recognizes the considerable uncertainty that exists regarding the understanding of the Delta ecosystem and the likely outcomes of implementing the conservation measures, both in terms of the nature and the magnitude of the response of covered species and of ecosystem processes that support the species.

As a component of the conservation strategy, the adaptive management and monitoring program has been designed to use new information and insight gained during the course of Plan implementation to develop and potentially implement alternative strategies to achieve the biological goals and objectives. It is possible that some of the conservation measures will not achieve their expected outcomes, while others will produce better results than expected. The adaptive management process describes how changes to the conservation measures may made in order to improve the effectiveness of the Plan over time.

Monitoring and research will be used to confirm Plan implementation and to measure the efficacy of the conservation measures, factors affecting the response of the ecosystem and covered species to these measures, and the influence of factors present outside the Plan Area (including other conservation planning efforts). Monitoring and research conducted under the BDCP and other programs will provide insights into changes in Delta conditions that result from climate change (e.g., sea level rise, changing hydrology in the Delta watershed, and increased water temperatures), seismic events, land uses, and other factors. Extensive monitoring and research are currently underway in the Delta. To address the specific requirements of the Plan, some of these monitoring activities will continue and, in some cases, be expanded. In other cases, existing monitoring activities will be modified to reflect specific implementation needs of the Plan. The BDCP will also require that new types of monitoring activities be conducted in the Delta to support Plan implementation. This section provides the framework and guidelines for these monitoring and research plans.

This adaptive management and monitoring program was designed with the expert advice of independent science advisors. The results of the deliberations of these scientists are reflected in the *BDCP Independent Science Advisors' Report on Adaptive Management* (Dahm et al. 2009). The following principles have been adapted for effective adaptive management, which will guide the development of the adaptive management program for the BDCP.

- The scope and degree of reversibility of each conservation measure and other factors determine the form of adaptive management that should be applied (e.g., "active" or experimental adaptive management versus "passive" adaptive management).
- The knowledge base about the ecosystem is key to decisions about what to do and what to monitor, and includes all relevant information, not just information derived from monitoring and analysis within the context of the BDCP.

- Program goals should relate directly to the problems being addressed and provide the intent behind the conservation measures; objectives should correspond to measurable, predicted outcomes.
- Models, including conceptual models, should be used to formalize the knowledge base, develop expectations of future conditions and conservation outcomes that can be tested by monitoring and analysis, assess the likelihood of various outcomes, and identify tradeoffs among conservation measures. Alternative conceptual models can also be used to precisely identify areas of disagreement and to formulate appropriate experimental tests.
- Monitoring should be targeted at specific mechanisms thought to underlie the conservation measures and must be integrated with an explicitly funded program for assessing the resulting data.
- Prioritization and sequencing of conservation measures should be assessed at multiple points in the adaptive management process.
- Specifically targeted institutional arrangements are required to establish effective feedback mechanisms to inform decisions about whether to retain, modify, or replace conservation measures.
- A dedicated Adaptive Management Team is essential to administer the functional steps of adaptive management and assimilate knowledge from monitoring and technical studies and formulate recommendations to senior decision makers regarding programmatic changes.

These principles and other recommendations of independent science advisors (Reed et al. 2007; Dahm et al. 2010; Reed et al. 2010; National Research Council 2010, 2011; Parker et al. 2011, 2012) are reflected in the approaches to adaptive management and monitoring set out in this chapter.

Adaptive management and monitoring activities will be reflected in the Annual Work Plans and Budgets (as described in Chapter 6, Section 6.3.1) and will be implemented through a single, comprehensive program under the administration of the Adaptive Management Team that is integrated, to the extent appropriate, with the activities carried out under the Delta Science Plan and other relevant efforts. Information obtained from monitoring and research activities will be used to improve the effectiveness of the conservation measures toward advancing the biological goals and objectives. The adaptive management and monitoring program is directly related to several key components of the BDCP (Table 3.6-1), and is consistent with the approach to adaptive management advocated by the Delta Stewardship Council and presented in the Delta Plan (Delta Stewardship Council 2013).

Table 3.6-1. Role of Adaptive Management in Relation to Other Parts of the Plan

Plan Component	Section	Relationship to Adaptive Management and Monitoring Program
Biological goals and objectives	Section 3.3, *Biological Goals and Objectives*	• Define the outcomes to be achieved by plan implementation, and act as targets for adaptive management of the conservation measures. • Monitoring will be used to track progress toward meeting the biological goals and objectives. • Biological objectives will be reexamined through the adaptive management process and may be modified, added, or eliminated if new information changes our understanding of the efficacy or appropriateness of existing objectives or reveals a need for other. Biological goals are not subject to change through the adaptive management process.
Conservation measures	Section 3.4, *Conservation Measures*	• Adaptive management provides a means by which conservation measures may be reexamined, modified, added, or eliminated to enhance the effectiveness of the conservation strategy. • Compliance monitoring will be used to verify the conservation measures are being properly implemented. • Effectiveness monitoring will be used to track the effectiveness of the conservation measures with respect to moving toward or achieving the intended outcomes. • Research efforts will be used to help resolve uncertainties regarding the effect of covered activities on covered species and their habitats and the effectiveness of conservation measures at achieving objectives and moving toward goals.
Changed circumstances	Section 6.4.2, *Changed Circumstances*	• Certain remedial actions taken in response to certain changed circumstances will be developed and implemented through the adaptive management process.
Plan implementation	Chapter 6, *Plan Implementation*	• The priority, schedule, and sequence of the implementation of the conservation measures set out in the BDCP will be reexamined, and potentially modified, through the adaptive management process. • Decisions made through the adaptive management process, and information gained through monitoring and research efforts, will be reflected in the annual reports that will be prepared under the BDCP.
Governance	Chapter 7, *Implementation Structure*	• The BDCP governance structure sets out the manner and approach by which adaptive management and monitoring decisions will be made.

3.6.1 Regulatory Context

Adaptive management serves as a tool to address the uncertainty associated with the needs of species covered by an HCP or NCCP. Within established limitations (Section 3.4.23, *Supplemental Adaptive Management Fund*), permit holders may be required to bear some responsibility for the risks associated with uncertainty and assume obligations beyond those reflected in the planned conservation measures set out in the HCP/NCCP.

By regulation, an HCP must provide for the establishment of a monitoring program that generates information necessary to assess compliance and verify progress toward achieving the biological goals and objectives of the plan (see generally, 50 CFR 17.22 (b)(1) and 50 CFR 222.307(b)(5)). Adaptive management programs are generally recommended for plans with data gaps and scientific uncertainty that would substantively affect how species are managed and monitored in the future. The USFWS and NMFS five-point policy (65 FR 35241–35257) describes adaptive management as an integrated method for addressing uncertainty in natural resource management and states that management must be linked to measurable biological goals and monitoring. Embedded within the guidance from the five-point policy is the concept that the scale of adaptive management and monitoring should be commensurate with the scope of the effects of the proposed action.

An NCCP must include both a monitoring program and an adaptive management program (Fish & Game Code Section 2820-7–8). An NCCP also must integrate adaptive management strategies that are periodically reviewed and modified on the basis of the results of monitoring efforts and other sources of new information (Fish & Game Code Section 2820(a)(2)).

In addition, the Delta Reform Act requires the use of science-based, transparent, and formal adaptive management strategies for ongoing ecosystem restoration and water management decisions (Water Code Section 85308(f)), and that DWR, in coordination with CDFW, or any successor agencies charged with BDCP implementation, shall report to the Delta Stewardship Council on the implementation of the BDCP at least once a year, including the status of monitoring programs and adaptive management (Water Code Section 85320(f)). The Delta Reform Act further requires the Delta Independent Science Board to provide oversight of scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews of each of those programs to ensure that all Delta scientific research, monitoring, and assessment programs are reviewed at least once every 4 years (Water Code Section 85280 (a)(3)).

The adaptive management and monitoring program described in this section is intended to meet HCP and NCCP requirements to monitor covered species, natural communities, and ecosystem responses to management activities, and to provide a process by which to adapt those conservation actions, as appropriate, to advance the biological goals and objectives.

3.6.2 Structure of the Adaptive Management Program

The institutional structure and organizational arrangements that will be established to govern and implement the BDCP are described in Chapter 7, *Implementation Structure*. Information concerning the roles, functions, authorities, and responsibilities of the BDCP entities, responsible for implementing the adaptive management and monitoring program, is provided in Chapter 7, and developed further for the Adaptive Management Team and BDCP Science Manager in this section.

3.6.2.1 Science Manager

The Science Manager's responsibilities are described in Chapter 7, Section 7.1.1.2, *Science Manager: Selection and Function*. The Science Manager will report to the Program Manager and will, among other things, serve as Chair of the Adaptive Management Team and assist the team in the development and administration of the adaptive management and monitoring program, in coordination with the Interagency Ecological Program (IEP) and other science programs. In addition to chairing the Adaptive Management Team, the Science Manager will serve as the BDCP representative on the Science Steering Committee and the Policy-Science Forum established through implementation of the Delta Science Plan. The Science Manager will work, with the guidance of the Adaptive Management Team, with the Delta Science Program, and with others to integrate, to the extent appropriate, the BDCP adaptive management and monitoring program with the Delta Science Plan.

3.6.2.2 Adaptive Management Team

The Adaptive Management Team will be chaired by the Science Manager, and will consist of representatives of DWR, Reclamation, two participating state and federal water contractors (one each representing the SWP and CVP), CDFW, USFWS, and NMFS as voting members. Advisory, nonvoting members will be the IEP Lead Scientist, the Delta Science Program Lead Scientist or designee, and the Director of the NOAA Southwest Fisheries Science Center. The directors of DWR and CDFW and the regional directors of Reclamation, USFWS, and NMFS will each designate a management-level representative to the Adaptive Management Team who can represent both policy and scientific perspectives on behalf of their agency, including on matters related to adaptive management proposals and research priorities.

The Adaptive Management Team will have primary responsibility for administration of the adaptive management and monitoring program, and will decide when and on what terms to seek independent science review to evaluate technical issues for the purpose of supporting adaptive management decision making. These decisions to seek independent science review will be made considering budget and schedule limitations and other factors. The Adaptive Management Team will have primary responsibility for the development of performance measures, effectiveness monitoring and research plans; analysis, synthesis and evaluation of monitoring and research results; soliciting independent scientific review; and developing proposals to adapt (e.g., modify a conservation measure) as resource conditions change and understanding evolves. The Adaptive Management Team will provide recommendations to the Program Manager, to be incorporated into the Annual Work Plans and Budgets, including amendment of the current-year budget, to help ensure that the conservation measures achieve the biological objectives and that the biological objectives remain appropriate. These recommendations will be informed by the monitoring and research program (Section 3.6.4) and will help ensure that the BDCP continues to be implemented consistent with ESA and NCCPA permit issuance criteria. These responsibilities will be carried out in a manner that satisfies State and Federal regulatory and other legal requirements.

The administrative role of the Adaptive Management Team is intended to create a collaborative adaptive management process and a single unified science program for the BDCP that will ensure appropriate scientific information is developed to inform BDCP implementation and that appropriate adjustments are made in a timely fashion to ensure Plan success. To this end, the Adaptive Management Team will ensure that the adaptive management and monitoring program focuses on *management-relevant science*, that studies and monitoring are subjected to independent scientific review as appropriate (see further discussion below), and that results are made available in a timely fashion. The Adaptive Management Team will ensure an appropriate level of integration between the adaptive management and monitoring program and the Delta Science Plan. Information obtained from monitoring and research activities will be used by the Adaptive Management Team to develop proposed changes to conservation measures, biological objectives, or other components of the adaptive management program to improve, on an ongoing basis, the outcomes associated with water resource management and ecological restoration commitments reflected in this plan.

The Adaptive Management Team will operate by consensus.[47] In the event that consensus is not achieved, the matter will be elevated to the Authorized Entity Group and the Permit Oversight Group for resolution. Any proposed changes to conservation measures and biological objectives will be elevated to the Authorized Entity Group and the Permit Oversight Group for their concurrence or for their own determination regarding the matter. If concurrence is not achieved, the dispute will be elevated subject to the dispute review process set forth in Chapter 7, Section 7.1.7, *Elevation and Review of Implementation Decisions.*

The Adaptive Management Team may invite individuals or convene subteams consisting of individuals who are not members of the Adaptive Management Team to provide input into specific issues under consideration. These individuals or groups of individuals may be from the technical staffs of the entities represented on the Adaptive Management Team, the Technical Facilitation Subgroup of the Stakeholder Council, or other entities or institutions, as deemed appropriate by the Adaptive Management Team. The Adaptive Management Team will also ensure that the Technical Facilitation Subgroup of the Stakeholder Council is afforded sufficient opportunity to provide input into matters under consideration by the Adaptive Management Team.

The Program Manager may request that the Adaptive Management Team provide internal scientific review (internal to the Implementation Office) on specific technical issues of importance to the success of the adaptive management program and the conservation strategy implementation.

The Adaptive Management Team will also assess on a regular basis the overall efficacy of the adaptive management program, including the results of effectiveness monitoring, selection of research and adaptive management experiments, and relevance of new scientific information developed by others to determine whether changes in the implementation of the conservation measures and the monitoring program would improve the effectiveness of the BDCP in achieving its biological goals and objectives. In doing this, the Adaptive Management Team will consider, among other sources of information, new information obtained through implementation of the Delta Science Plan (e.g., integrated synthesis products such as the *State of Bay-Delta Science*), and input from the Delta Independent Science Board.

The Adaptive Management Team will hold public meetings at least quarterly and will otherwise determine its meeting schedule and rules of operation. The Program Manager will institute procedures with respect to public notice of and access to these meetings. Other -Adaptive Management Team meetings in which changes to components of the Conservation Strategy (e.g., biological objectives or conservation measures) are being proposed will also be noticed and open to the public. Information considered in developing any proposed actions will be presented in those public meetings.

[47] For the purpose of this section, "consensus" will be considered to be reached if either all members of the Adaptive Management Team agree to the proposal at hand or no member of the team dissents from the proposal.

3.6.2.3 Independent Scientific Review

Matters relating to the conduct of scientific reviews and the solicitation of independent scientific advice to assist in the implementation of the BDCP, including independent science review of adaptive management decisions affecting water operations, will be administered by the Adaptive Management Team, in a manner that ensures their independence and scientific integrity. The Adaptive Management Team, through the Science Manager, will coordinate such efforts with the Delta Science Program, IEP, Stakeholder Council, the Authorized Entity Group, and the Permit Oversight Group. Consistent with its oversight responsibilities, the Delta Independent Science Board will review the adaptive management and monitoring program at least once every 4 years (Water Code Section 85280(a)(3)).

The Authorized Entity Group or the Permit Oversight Group may seek its own independent science review of any recommendations coming out of the Adaptive Management Team. However, except as provided in Chapter 7, Section 7.1.7, *Elevation and Review of Implementation Decisions,* decision makers will not be obligated to wait for the outcome of any such outside science process to make their decisions on BDCP-related issues. Furthermore, any independent review undertaken outside the collaborative Adaptive Management Team, or by the AEG or POG acting separately from one another, will not use any existing panel or review provider already being used at that time by the Adaptive Management Team.

3.6.2.4 Integration with the Delta Science Plan

The Delta Plan (Delta Stewardship Council 2013) calls for the Delta Science Program to work with the BDCP, IEP, CDFW, and other agencies to develop a Delta Science Plan. The Delta Science Plan is envisioned to address the Delta's large-scale, persistent, and difficult policy and management issues (called "grand challenges") through a shared approach for organizing and integrating ongoing scientific research, monitoring, data management, analysis, synthesis, and communication. The Delta Science Program has proposed a three-part Delta Science Strategy that consists of a Delta Science Plan, a Science Action Agenda, and the State of Bay-Delta Science.

The Delta Science Plan sets a shared vision for Delta science and a living framework for guiding, organizing, and integrating science in the Delta. It establishes the major elements, organizational structures, and key actions for improving the efficiency, utility, and application of Delta Science across agencies and institutions. Two key components of the plan include creation of (1) a new forum ("Policy-Science Forum") for direct interaction between leaders of government institutions and the science community around immediate and long-term issues and (2) a new science leadership group ("Science Steering Committee") responsible for guiding the development of synthesis products, including updates to the State of Bay-Delta Science, and translating the grand challenges articulated by the Policy-Science Forum into research priorities and actionable questions. The plan also presents strategies for improving the application of adaptive management and enhancing the infrastructure necessary to develop the science needed to inform complex decisions surrounding management of the Delta (e.g., modeling, comprehensive monitoring and research, data management and accessibility, synthesis, independent scientific peer review and advice, and communication).

The Science Action Agenda prioritizes near-term actions and research to achieve the objectives of the Delta Science Plan on a 4-year cycle. It will serve as the common agenda from which agencies and programs develop their science work plans. Developed collaboratively with federal and state agencies, local government, science programs, academic institutions, interested public and the Science Steering Committee, the Science Action Agenda identifies priorities for research, monitoring, data management, modeling, synthesis, communication, and building science capacity in order to address the grand challenges.

The State of Bay-Delta Science is a summary synthesis of the current scientific knowledge for the Delta. It will be published every 4 years (offset from development of the Science Action Agenda) by relevant science experts with guidance from the Science Steering Committee.

The Delta Science Plan is currently under development. A final version is to be completed by December 31, 2013. The intent is for the Delta Science Plan to be a living document that is updated every 5 years or more often if needed. As highlighted throughout this section (3.6), multiple points of coordination and integration exist between the adaptive management and monitoring program and the Delta Science Plan. While the Delta Science Plan is still under development, the intent is for the adaptive management and monitoring program to be well integrated with the Delta Science Plan, including through the following expectations.

- Overlapping memberships between the Delta Science Plan Policy-Science Forum and Science Steering Committee, as well as the Adaptive Management Team.
- Extensive reliance on the Delta Science Program for independent science advice and review.
- Close collaboration on establishment of research priorities (Science Action Agenda), implementation of monitoring and research, model development, data management and accessibility, and science synthesis and communication activities.
- Collaboration on a shared tracking system for adaptive management programs throughout the Delta.

Details of the arrangements will likely be memorialized in inter-agency agreements between the Delta Science Program and the Implementation Office, and will be re-examined on a regular basis and adjusted as necessary, to ensure such activities support effective implementation of the BDCP.

3.6.3 Adaptive Management Process

3.6.3.1 Principles of Adaptive Management

Adaptive management is a systematic process to continually improve management policies and practices by learning from our actions (Holling 1978; Walters 1986). It requires well-articulated management objectives to guide decisions about what to try, and explicit assumptions about expected outcomes to compare against actual outcomes (Williams et al. 2009). The structured decision-making process used in adaptive management, involving "front-loading" the process to clearly articulate objectives, identify management alternatives, predict management consequences, and recognize key uncertainties in advance; and monitor and evaluate of outcomes, is what differentiates it from a trial and error approach (National Research Council 2004a, Williams 2011a). Learning, facilitated through deliberate design and testing, is an integral component of adaptive management (Williams et al. 2009, Allen et al. 2011, Williams 2011a). Adaptive management is a particularly useful framework in the face of substantial scientific uncertainty. The principles of adaptive management lend themselves to water management and ecological restoration in the Bay-Delta (CALFED Bay-Delta Program 2000, Reed et al. 2007, Healey 2008, Dahm et al. 2009, National Research Council 2011, Delta Stewardship Council 2013). In particular, a National Research Council

(2011) panel found that despite the challenges, there often is no better option for implementing management regimes, and thus the use of adaptive management is appropriate for the BDCP.

The traditional concept and application of adaptive management as a natural resource management tool has been improving since the 1970s (Holling 1978; Walters 1986; Pahl-Wostl 1995; Lee 1999; Oglethorpe 2002). It has been applied to a wide range of resource management efforts (Walters 1986; Christensen et al. 1996; Stanford and Poole 1996; Oglethorpe 2002; Habron 2003; Kaplan and Norton 2008; Lyons et al. 2008; Williams et al. 2009). Many of these, including the following, involve water supply management and ecosystem restoration activities:

- Glen Canyon Dam and the Colorado River ecosystem (National Research Council 1999)
- Missouri River ecosystem (National Research Council 2002)
- USACE water resource project planning (National Research Council 2004a)
- Columbia River system (National Research Council 2004b; Vail and Skaggs 2002)
- Everglades ecosystem (Gunderson and Light 2006).

3.6.3.2 Building on Lessons Learned from Other Adaptive Management Programs

Lessons learned from experience applying adaptive management, as well as advances in other scientific disciplines, have improved the utility of the adaptive management concept. For example, advances in three specific areas are relevant to the adaptive management and monitoring program.

- **Ecological variability.** Since inception of the original concept, there has been significant advancement in the recognition of the dynamic nature of the natural environment (Oglethorpe 2002). That is, natural systems prove to be variable, nonlinear, complex, rarely predictable, and have the potential for irreversible change (Botkin 1990; Frontier and Pichod-Viale 1993).
- **Ecological economics.** Adaptive management practitioners have recognized that understanding the interactions between natural and social systems is important when making natural resource management decisions (Costanza 1991; Jansson et al. 1994; Pahl-Wostl 2006).
- **Decision making.** The scientific knowledge and understanding of how to identify and quantify preferences when making decisions associated with multiple criteria and objectives has emerged as an important discipline for assisting natural resource managers to make difficult decisions (Keeney and Raiffa 2004; Kirkwood 1997; Clement and Reilly 2001; Lyons et al. 2008; 76 FR 26089).

To help ensure development of a science-based adaptive management and monitoring program for the BDCP that can be successfully implemented, independent science advisors were engaged early in the process to provide expert advice and guidance (Reed et al. 2007; Dahm et al. 2009). Guidance from federal and state agencies as well as the National Research Council was also important to the development of the adaptive management and monitoring program. Additionally, the Secretaries of the Interior and Commerce requested that the National Research Council review the draft BDCP in terms of its use of science and adaptive management. In response, a panel was convened to review an earlier draft of the BDCP (National Research Council 2011). The panel's report (National Research Council 2011) included a number of recommendations that informed the development of the adaptive management and monitoring program. Chapter 10, *Integration of Independent Science* *in BDCP Development*, provides more details on these independent science reviews, the recommendations provided, and how those recommendations were incorporated into the BDCP.

While adaptive management has been widely recognized as an appropriate management approach for the BDCP (Reed et al. 2007, Dahm et al. 2009, National Research Council 2011), its application in other settings has been less successful than one would expect (Walters 2007). Previous efforts to develop and implement adaptive management strategies have provided insights into a number of impediments that have hindered successful implementation (Walters 1997, Gregory et al. 2006, Walters 2007, Allen and Gunderson 2011). Several features of the adaptive management and monitoring program that have been designed to help overcome these impediments are described below.

- Adaptive management has become widely recognized as an important tool for addressing uncertainties and improving decision making pertinent to water operations and habitat restoration in the Delta. As described in Section 3.6.1, *Regulatory Context*, the application of adaptive management and monitoring are mandated pursuant to regulatory requirements associated with issuance of HCPs and NCCPs. In addition, the Delta Reform Act requires the use of science-based, transparent, and formal adaptive management strategies for ongoing ecosystem restoration and water management decisions (Water Code Section 85308(f)). These mandates provide decision-makers a clearer understanding as to why adaptive management is needed (Walters 2007), addressing this potential impediment to the implementation of the adaptive management and monitoring program.
- The institutional structure and organizational arrangements established to govern and implement the BDCP, including the roles, functions, authorities, and responsibilities of the various entities engaged in Plan implementation are described in Chapter 7, *Implementation Structure*. The BDCP establishes that adaptive management will be based on accomplishment of clearly stated goals and objectives, establishes a clear mechanism for adaptive management decision-making, and clearly assigns responsibility for implementation of decisions. This structure was established to ensure that the responsibilities of overlapping management agencies are clearly defined with respect to implementation of the adaptive management and monitoring program (Gregory et al. 2006).
- In order to ensure adequate leadership for the complex process of implementing an adaptive approach (Walters 2007), a Science Manager and dedicated Adaptive Management Team have been established and tasked with administering the adaptive management and monitoring program. In addition, an Implementation Office will administer the implementation of the BDCP, including providing technical, logistical, and financial support to the Adaptive Management Team.
- The Adaptive Management Team has been structured as a team of managers, recognizing that adaptive management is, first and foremost, a management activity. This choice was intended to ensure that BDCP research and monitoring serve the implementation of the Plan (i.e., provide information that can be directly used by decision makers [Gregory et al. 2006]). The BDCP Science Manager and agency managers and scientists will participate in the Science Steering Committee and Policy-Science Forum to be established through implementation of the Delta Science Plan (Section 3.6.2.4, *Integration with the Delta Science Plan*), to ensure that management priorities of the BDCP are clearly translated into relevant research activities. Such efforts will ensure that involved scientists understand the broader array of management

priorities (Gregory et al. 2006) and that management goals are not hijacked for research interests (Walters 1997).

- The adaptive management decision process includes a diversity of participants, ensuring that a range of viewpoints are represented. The escalation process ensures that where multiple points of view exist, recommendations representing both, or all, sides of discussion are presented to decision-makers. As a result, it is anticipated that decision-makers will always make an affirmative policy choice on matters presented to them, countering the potential impediment in which bureaucratic and political inaction are used as a policy choice (Walters 1997).
- The Adaptive Management Team is designed as a broad-based group to ensure that stakeholder views are incorporated into discussions of adaptive management matters. A Stakeholder Council will also be established in order to provide a forum for stakeholders to assess the implementation of the Plan, and to propose to the Implementation Office ways in which Plan implementation may be improved (Chapter 7, Section 7.1.10, *Stakeholder Council*). In addition, a Technical Facilitation Subgroup of the Stakeholder Council will be established to provide input to the Implementation Office and the Adaptive Management Team on technical and scientific matters. The Stakeholder Council process will complement, but not substitute for, ongoing collaboration and communication between stakeholders and the Implementation Office, the Authorized Entity Group, the Permit Oversight Group, and their member entities. These efforts are meant to support the processes required for building shared understanding and shared decision-making among diverse stakeholders (Gregory et al. 2006).
- The BDCP explicitly contemplates management experiments and other approaches to ensure that learning a key component of Plan implementation, notably as an explicit objective of the adaptive management and monitoring program. The Adaptive Management and Monitoring Program will emphasize scientific planning and quality control, including external expert review of research strategies and study designs in advance of field work, as a means to ensure that practical scientific activities produce scientifically defensible new information that is relevant to management objectives. In other venues, valuing action more than learning has been identified as an impediment to successful implementation of adaptive management (Lee 1999).
- Difficulties associated with translating learning into practice have been identified as a key impediment to successful implementation of adaptive management (Lee 1999, Dahm et al. 2009). The Adaptive Management Team anticipates utilizing science synthesis approaches under development by the Delta Science Program, working with teams established under the Delta Science Plan and others, such as the IEP's Management, Analysis, and Synthesis Team, to assemble, analyze, and synthesize the results of monitoring and research activities conducted through the BDCP, as well as other relevant efforts. The Adaptive Management Team will assimilate this new information and use it as a basis for evaluation of the effectiveness of implementation actions and to formulate recommendations regarding Plan implementation.
- The BDCP includes adequate budget for and assurances that sufficient funds will be available to carry out the monitoring and research activities necessary to implement the adaptive management and monitoring program (see Chapter 8, *Implementation Costs and Funding Sources*, for an accounting of costs and funding assurances). Integration of the BDCP monitoring and research program, where practicable, with the common activities of the IEP, Delta Science Program and other relevant programs has been factored into the cost estimates. The funding structure and integration efforts are important elements of this Plan. Inadequate funding for the ecological monitoring needed to compare the outcomes of alternative policies has proven to be a

common impediment to successful implementation of other adaptive management programs (Walters 2007).

3.6.3.3 Addressing Uncertainty

Adaptive management addresses uncertainty through a structured process that provides for the improvement of relevant knowledge, while seeking to minimize management risks associated with proposed activities (Keith et al. 2011). Successful adaptive management programs reduce the uncertainty of management decisions but recognize that uncertainty and its associated risks will always be a component of ecological systems. It is essential to accept that the consequences of natural events and or management decisions that operate at an ecosystem scale are sometimes unknown. Therefore, it should be expected that adjustments to implementation actions might entail major corrective actions. This may require the need for a commitment, most often driven by models, for identifying and experimentally evaluating alternative hypotheses about responses to resource management actions (Briceño-Linares et al. 2011; Kingsford et al. 2011; Van Wilgen and Biggs 2011). Such an approach is characterized as “active” adaptive management, through which management interventions are explicitly directed at reducing uncertainty (Williams 2011b). It is envisioned that both active and passive approaches to adaptive management will be implemented over the course of Plan implementation (Section 3.6.3.4, *Nine-Step Plan*).

Most adaptive management programs associated with ecological restoration accommodate at least some experimental management approaches (e.g., research, targeted studies) aimed at improving the performance of implementation actions (Keith et al. 2011). Responses to specific restoration actions are often confounded by responses to other, uncontrolled factors that drive ecological change. Well-defined experiments, supplemented by expert knowledge, are often applied to evaluate the assumptions underlying resource management strategies (Rumpff et al. 2011). Simple experimental designs can go a long way toward separating implementation action effects from other causes of ecological change (Mackenzie and Keith 2009). In some cases, low numbers, small areas, and urgent time frames place severe constraints on experimental design. In these situations, a succession of trial-and-error evaluations may offer the only practical insights that adjust management strategies (Briceño-Linares et al. 2011). The design of targeted studies that address key uncertainties will be driven by stated hypotheses about key factors of the landscape, natural community, and/or species to which the implementation action is applied, and their interrelationships. Such hypotheses are normally described as conceptual models, and often incorporate both quantitative and qualitative components. Adaptive management and monitoring will be directed toward evaluating support for management hypotheses, by evaluating evidence bearing on the adequacy of model representation of component processes and the overall predictive power of the conceptual model or models.

3.6.3.4 Nine-Step Plan

The adaptive management process is largely based on the recommendations of the *BDCP Independent Science Advisors’ Report on Adaptive Management* (Dahm et al. 2009) and the *Delta Plan* (Delta Stewardship Council 2013). This approach is well-aligned with the U.S. Department of the Interior technical guide for adaptive management strategies (Williams et al. 2009) and the USFWS and NMFS HCP Handbook Addendum (or “Five-Point Policy”) (65 FR 35241–35257). The process is designed to use new information to inform a systematic and integrated critical review, at regular intervals, of environmental stressors, biological goals and objectives, analytical methods, predicted outcomes, and conservation measures. Once selected, the implementation actions will be performed according to a rigorous process of design, monitoring and research, evaluation, reporting, and decision making (Figure 3.6-1).

A distinction is often made between "active" and "passive" approaches to adaptive management. Active adaptive management is experimental, involving manipulations intended to achieve management objectives but also to reduce uncertainty and improve knowledge. Through passive adaptive management, a best management option is selected on the basis of the current understanding about system dynamics and this option is fine-tuned in relation to experience. Both the Independent Science Advisors (Dahm et al. 2009) and National Research Council (2011) emphasized the need to recognize where an adaptive management strategy resides on the active-to-passive spectrum during the design phase and the Adaptive Management Team will do so based on a variety of factors, including scope, degree of reversibility, opportunities for experimental manipulation, and level of confidence in expected outcomes.

Implementation of adaptive management can be described in terms of two broad phases: the "setup" phase in which its key components are established, and the "iterative" phase that uses those components in a sequential decision process aimed at improving understanding and management (Williams et al. 2009). The setup phase represents the formulation of the conservation strategy, including characterizing the problem, establishing goals and objectives, using predictive conceptual and numerical models to evaluate a range of alternative actions, selecting and designing the initial suite of implementation actions for each conservation measure, and designing a monitoring and research program to assess their effectiveness and address scientific and management uncertainties (see Steps 1 through 4 and the design element of Step 6 as described below).

For the BDCP, the setup phase is complete at the programmatic level through the development of this Plan with extensive stakeholder input. Components of the setup phase are described in Section 3.3, *Biological Goals and Objectives*; Section 3.4, *Conservation Measures*; and Chapter 5, *Effects Analysis*. In order to implement many conservation actions, additional project-level setup will be needed. The iterative phase follows implementation of the initial suite of actions. At that point, the adaptive management process enters the iterative phase wherein data and information generated through the monitoring are research program are used to assess the effectiveness of implementation actions and update understanding. The results from this ongoing assessment guides decision making and the periodic revisiting of the conservation strategy to make modifications, as appropriate, to conservation measures, biological objectives, and other elements to enhance Plan effectiveness. For the BDCP, the iterative phase begins with Plan implementation.

Anine-step model of the adaptive management process, described in detail below, includes the following steps (Figure 3.6-1).

1. Characterize the problem.
2. Identify biological goals and objectives.
3. Model linkages between objectives and proposed implementation actions.
4. Plan and design implementation actions.
5. Perform implementation actions.
6. Design and implement performance measures, and monitoring and research plans.
7. Analyze, synthesize, and evaluate.

8. Communicate current understanding.
9. Adapt.

3.6.3.4.1 Step 1: Characterize the Problem

A problem statement, specifying the issue or concern that conservation measures are intended to solve or mitigate, is used to define the problem. This entails determining the spatial and temporal bounds of the problem and the ecological processes, communities, species, and/or interactions that are affected. The problem statement links directly to the biological goals and objectives (Step 2). Problems may have both scientific and operational or economic components. For example, one broad class of problems will revolve around the challenge of achieving specific biological objectives in a manner that avoids or minimizes adverse impacts on water supply under *CM1 Water Facilities and Operation*.

Ecological problems and associated environmental stressors are described in Chapter 2, *Existing Ecological Conditions*, and Chapter 3, *Conservation Strategy*, as well as in Chapter 5, *Effects Analysis*, and its associated appendices. A component of the "Evaluate and Respond" phase of adaptive management is assessing whether the target problem has been solved, transformed, or is still a problem (Dahm et al. 2009). Through such an evaluation, the Adaptive Management Team may determine that the problem statement warrants revision. The approach and decision-making process for such a change is described in Section 3.6.3.5, *Adaptive Management Decision Process*.

3.6.3.4.2 Step 2: Identify Biological Goals and Objectives

Biological goals and objectives describe the outcomes the BDCP is designed to achieve.

Biological goals provide broad statements of a desired action's outcome. They are general intentions or visions for some aspect of the system. Goals propose broad solutions and encapsulate desired future conditions.

Biological objectives are specific, often quantitative, statements that reflect the intended outcomes of the conservation strategy. Some objectives are stated as quantitative targets for species or locations in a hierarchical arrangement; others characterize desired attributes of ecosystem structure or function. It is not always possible or appropriate to develop quantitative objectives for all species, communities, or processes. In such cases, objectives are described qualitatively. Nevertheless, as information accumulates, it may be possible to refine objectives so that they become more quantitative.

The biological goals and objectives are defined at three ecological scales: landscape, natural community, and species. The biological goals and objectives are described in detail in Section 3.3, *Biological Goals and Objectives*. The biological goals are not subject to change through the adaptive management program.

3.6.3.4.3 Step 3: Model Linkages between Objectives and Proposed Implementation Actions

Models are used to formalize and apply current scientific understanding. Most of the models that have been used to evaluate the likely effects of the conservation strategy and other stressors on covered species and natural communities are conceptual ecological models. These models may be qualitative or quantitative, and vary in the degree of mechanistic detail they present, but all explicitly describe the relationships between biological outcomes and various environmental variables by modeling processes that link these variables (DiGennaro et al. 2012). Ecological models provide a basis for predicting the consequences of changing environmental variables on the biological outcomes that depend, or may depend, on them. Models for individual species primarily appear in Appendix 2.A, *Covered Species Accounts*; and in the some of the appendices supporting Chapter 5, *Effects Analysis*.

Adaptive management under the BDCP uses conceptual models, because they clearly show presumed causal relationships. In cases where disagreements result from competing conceptual models, the clear representation of hypothesized causal relationships allows for precise characterization of the implications of the competing beliefs, which facilitates development of studies that can resolve which conceptual model is likely to provide more accurate outputs. Conceptual models also provide transparency, which is of benefit to decision makers, scientists, and the public.

Because they explicitly model relationships, conceptual models help managers identify and prioritize key uncertainties requiring study and research. Thus, these models provide a road map for exploring hypotheses through statements that describe the expected outcome of a conservation measure or other change to a biological system. Conceptual models used in the BDCP provide a useful framework for understanding how individual species are expected to react to the same implementation actions.

Refinement of ecological models may be appropriate in the context of new information and current understanding. In cases where a problem statement identifies an issue not clearly addressed in an existing model, the Adaptive Management Team will determine which models are relevant, if model refinement or development is warranted, and how the models may be used to reformulate the problem statement in the form of an answerable scientific question.

3.6.3.4.4 Step 4: Plan and Design Implementation Actions

Section 3.4, *Conservation Measures*, provides the design requirements and guidelines for implementation actions. The conservation measures have been designed to achieve the biological goals and objectives described in Section 3.3, *Biological Goals and Objectives*. Any given implementation action is intended to address one or more biological goals and objectives. A complex action, such as construction and operation of the Fremont Weir operable gate, which is one of many actions to be taken under *CM2 Yolo Bypass Fisheries Enhancement*, may contribute to achieving many different biological goals and objectives.

Monitoring and research elements described in Step 6 are required to evaluate how well implementation actions achieve performance measures, contribute to achieving biological goals and objectives, and test specific hypotheses. Therefore, Step 6 will occur in parallel with the planning and design of implementation actions.

Some implementation actions will require additional planning to identify locations and types of actions that will optimize conservation measure effectiveness. For example, *CM13 Invasive Aquatic Vegetation Control* calls for a Plan-area-wide evaluation of the status of invasive aquatic vegetation to identify and prioritize sites for control actions. Some actions will also require additional design beyond the guidelines and specifications identified in the conservation measures. For example, once a site is selected, channel margin enhancement as part of *CM6 Channel Margin Enhancement* must be designed through a sequence of progressively more specific conceptual and engineering schematics that lead to construction bid documents.

As appropriate, implementation actions will be designed for implementation in an adaptive management context. That is, actions will be tied to specific biological goals and objectives, will, when appropriate, specify conceptual models and testable hypotheses, and will be linked to an effectiveness monitoring program. The Implementation Office will plan and design all implementation actions, with advice and input from the Adaptive Management Team and other experts, as needed.

Prioritization and sequencing are used to address path-sensitive issues logically and to allocate available funding appropriately. Prioritization considers the scale and breadth of the expected outcomes relative to the objective. For example, actions that address multiple objectives often have a higher priority than actions that only address one objective. Sequencing criteria are a component of the prioritization process. Sequencing criteria may include ease of implementation, interdependence/independence of actions, feasibility of near-term implementation, funding available within existing budgets, uncertainty of action implementation and outcomes, and the potential for synergies among actions. The prioritization and sequencing process inform the planning process at multiple timescales (e.g., Annual Work Plan and 5-Year Implementation Plan). The prioritization process used to inform adaptive management changes is discussed in Step 9 and in Section 3.4.23, *Resources to Support Adaptive Management*.

3.6.3.4.5 Step 5: Perform Implementation Actions

As described in Chapter 7, Section 7.2, *Implementation Office*, implementation actions that have been approved as part of the Annual Work Plan and Budget will be performed by the Implementation Office, which will coordinate with other entities as required or appropriate. The Implementation Office will ensure that actions are implemented consistent with the provisions of the Plan, associated regulatory authorizations and with planning and design requirements established in Step 4. The Implementation Office will also ensure that implementation actions are monitored and reported consistent with Plan requirements and with the monitoring requirements established in Step 6.

3.6.3.4.6 Step 6: Design and Implement Performance Measures and Monitoring and Research Plans

Monitoring and research elements are required in the design and implementation of each implementation action (steps 4 and 5), therefore this step will occur in parallel with those steps. The expected outcomes associated with implementing the conservation strategy are described in Chapter 5, *Effects Analysis,* and its associated appendices. A key component of adaptive management is the definition of measurable outcomes and associated performance measures that are directly related to the biological objectives (Dahm et al. 2009). Measurable outcomes and performance measures are critical for several reasons (Dahm et al. 2009), including the following:

- To document desires and expectations about how the system could function in the future following implementation of conservation measures.
- To identify monitoring actions essential to evaluation of each implementation action.
- To track progress toward meeting the objectives (measure performance).

Performance measures use a specific indicator or set of indicators to assess program performance and may be quantitative or qualitative. The Adaptive Management Team will have primary responsibility for developing performance measures.

Monitoring and research provide a means by which information necessary to successfully implement the BDCP over time will be collected, compiled, evaluated, and reported for use by the Implementation Office and Adaptive Management Team. The following types of monitoring will be conducted in association with Plan implementation.

- Compliance monitoring will provide basic information necessary for the Implementation Office to track implementation actions and compliance with the Plan and the associated regulatory authorizations (Section 3.6.4.3, *Compliance Monitoring*). The Program Manager, through the Implementation Office, will be responsible for carrying out compliance monitoring and associated reporting requirements.
- Effectiveness monitoring will provide information about the state of the ecosystem. This type of monitoring includes baseline monitoring and status monitoring, and is intended to provide information about the nature and extent of changes in ecosystem conditions as conservation measures are being implemented, as well as to help identify long-term trends in ecosystem conditions. The information can be used to assess the response of the ecosystem, natural communities, and covered species, and progress toward achieving the Plan's goals and objectives over time (Section 3.6.4.4, *Effectiveness Monitoring*). Based on guidance from the Adaptive Management Team, the Program Manager will incorporate effectiveness monitoring activities into the Annual Work Plan and Budget.
- Research will address key uncertainties regarding covered species, natural communities, and landscape-scale processes so that conceptual ecological models can be refined and, if appropriate, conservation measures, biological objectives, or other components of the adaptive management framework modified in accordance with the changed understanding (Section 3.6.4.5, *Research*).

The Adaptive Management Team will be responsible for guidance and oversight of the effectiveness monitoring and research program. With the guidance of the Adaptive Management Team, the Implementation Office will prepare as part of the Annual Work Plan an annual effectiveness monitoring and research plan, to be integrated as appropriate with the Delta Science Plan, for approval by the Authorized Entity Group and the Permit Oversight Group by the end of each calendar year. The Adaptive Management Team will ensure the quality of research and monitoring through the use of independent expert review, where appropriate.

The BDCP will, over time, accumulate a very large body of monitoring and research data. Those data must be organized and stored in such a way that they can readily be recovered and used in analyses. Establishment of structures to collect, store, and manage these data is described in Section 3.6.5, *Data Management*.

3.6.3.4.7 Step 7: Analyze, Synthesize, and Evaluate

Analysis, synthesis, and evaluation of research and monitoring data will be used to assess progress in reducing key uncertainties and attaining biological goals and objectives. Performance measures represent a key component of this process. The Adaptive Management Team anticipates utilizing science synthesis approaches in the Delta Science Plan and work with the Delta Science Program and others to assemble, analyze, and synthesize the results of monitoring and research actions on an ongoing basis and integrate the results of new, relevant scientific research and studies. The analysis will be cumulative, addressing each year's data and conclusions. The analysis will address issues of direct relevance to Plan implementation, including effectiveness monitoring and the key uncertainties and potential research actions identified in Tables 3.D-2, *Effectiveness Monitoring Actions,* and 3.D-3, *Key Uncertainties and Research Actions*, in Appendix 3.D, *Monitoring and Research Actions*.

This enhanced knowledge base will support a number of functions, including evaluating program effectiveness, making recommendations on future research needed to address uncertainties related to implementation of the Plan, and informing decisions regarding Plan implementation. When progress is below expectations, this information will be used to understand why this is occurring and to develop potential solutions. For example, the analysis will include a discussion of whether the probability of the desired outcome has changed and, if so, how this affects the decisions about the action. These analyses will be communicated in logical and properly organized reports (Section 3.6.5, *Data Management*).

3.6.3.4.8 Step 8: Communicate Current Understanding

An important task of both the Implementation Office and the Adaptive Management Team will be to communicate the results of implementation actions, research, and monitoring to policy makers, managers, stakeholders, the scientific community, and the public, so that they can understand and evaluate the Plan and its progress and respond as necessary. With the guidance of the Adaptive Management Team, the Science Manager will prepare communications from time to time, as needed, and develop materials regarding adaptive management and monitoring matters for presentation to the Authorized Entity Group and Permit Oversight Group. The Adaptive Management Team will ensure that study products are unbiased and explicitly and evenhandedly deal with uncertainty and disagreement in the analysis and interpretation, and that opposing points of view are clearly and evenhandedly presented in materials presented to the Authorized Entity Group, the Permit Oversight Group, external review bodies, and all others. To facilitate this understanding, the Program Manager will, with the guidance of the Adaptive Management Team, over the term of the BDCP, submit reports to the fish and wildlife agencies (USFWS, NMFS, and CDFW) and the public that serve the following purposes.

- Provide the necessary data and information to demonstrate that the Plan is being properly implemented.
- Identify the effect of Plan implementation on covered species and the effectiveness of the conservation strategy in advancing the biological goals and objectives.
- Document actions taken under the adaptive management program (e.g., process, decisions, changes, results, or corrective actions).
- Disclose issues and challenges concerning Plan implementation and identify potential modifications or amendments to the BDCP that would increase the likelihood of success.
- Describe schedule and cost related to the Plan implementation over 1-year and 5-year timeframes.

To demonstrate compliance with BDCP permit requirements, an Annual Progress Report will be prepared by the Implementation Office and submitted to the Permit Oversight Group. The highlights of the Annual Progress Report will be presented at a BDCP public workshop, and the report will be made available to the public. These reporting requirements are described in greater detail in

Chapter 6, Section 6.3, *Planning, Compliance, and Progress Reporting*. The Adaptive Management Team will also ensure that research carried out under the auspices of the BDCP meets best science practice standards and results in a high-quality written product that could be included in peer-reviewed scientific outlets, if appropriate.

3.6.3.4.9 Step 9: Adapt

The Adaptive Management Team will reexamine elements of the conservation strategy in the context of the nine-step adaptive management process and recommend revised management approaches, as appropriate. For example, this may entail revisions to problem statements, biological objectives, conceptual models, implementation actions, or monitoring actions. The Adaptive Management Team will recommend changes to conservation measures or biological objectives consistent with the sequencing of tools and resources described in Section 3.4.23, *Resources to Support Adaptive Management,* to the Authorized Entity Group and Permit Oversight Group for decision. The efforts of the Adaptive Management Team to assimilate new information and formulate decisions and recommendations will be carried out on a continual basis but over a range of time scales (e.g., daily, yearly, or decadal), depending on the nature of the adaptive management action. For example, individual components of the knowledge base might be refined gradually and annually, whereas a specific conservation measure might be refined only after several years of project implementation (Dahm et al. 2009). Generally, this work will happen on a schedule identified in planning documents for each individual implementation action. As part of its deliberations, the Adaptive Management Team may seek input from independent scientists or from other appropriate sources, including the Technical Facilitation Subgroup of the Stakeholder Council.

The decision process through which adaptive management responses are developed and adopted is described in the following sections.

3.6.3.5 Adaptive Management Decision Process

The adaptive management decision process has been designed to provide a transparent, structured, and deliberative process, including making adjustments to the problem statements, biological objectives, conservation measures, conceptual ecological models, or the monitoring and research program. Such adjustments will be made through the adaptive management decision process, not through the day-to-day implementation of the Plan.

The Implementation Office will be responsible for implementation of conservation measures, monitoring, and other aspects of the Plan as described in this chapter. During implementation, the Implementation Office will consider all issues on which the Adaptive Management Team has provided guidance. Where guidance is referenced, it means recommendations and advice that the Implementation Office must consider. If a recommendation is not followed, the Implementation Office must document the reasons for not doing so. As described below, the Adaptive Management Team also has specific responsibility to make decisions and formal recommendations in certain situations.

The following sections set out the roles and responsibilities of the Adaptive Management Team, with respect to the Authorized Entity Group, the Permit Oversight Group, Implementation Office, and the other relevant parties in the process for the consideration and potential adoption of adaptive management decisions. These sections also describe the conditions under which adaptive management responses would be proposed, developed, and ultimately adopted.

3.6.3.5.1 Role of the Adaptive Management Team

The adaptive management process and the roles and responsibilities for implementation are summarized below.

- Steps 1 and 2 (characterize the problem and identify the goals and objectives) have been completed for the setup phase and are described in this chapter for each conservation measure. However, the Adaptive Management Team will reassess and revisit those problem statements and goals and objectives during the iterative phase in light of monitoring data and other information during implementation.
- Step 3 (model linkages between objectives and proposed implementation actions) has also been accomplished at a programmatic level in the Plan[48] but more work will be needed to support Step 4 during the process of evaluating, selecting, and designing specific implementation actions and to refine ecological models based on new information. The Adaptive Management Team will oversee the development of new ecological models or refinement of existing models used in the Plan. In particular, the Adaptive Management Team will oversee the development or refinement of ecological models to inform the design and evaluation of implementation actions and design of monitoring and research plans and performance measures (Step 6).
- Step 4 (plan and design recommended implementation actions) is a fundamental adaptive management step in which the linkages described in Step 3 are used to develop management actions that are likely to achieve the objectives articulated in the plan. Initial BDCP implementation actions are described conceptually in this chapter (Section 3.4, *Conservation Measures*) for each conservation measure. Additional planning and design work (and in some cases, permitting and additional environmental compliance) will be needed to implement these actions and develop alternative approaches (as appropriate) for study. The Implementation Office, with guidance from the Adaptive Management Team, will conduct the additional planning and design efforts for the initial implementation actions, while the Adaptive Management Team will guide prioritization and sequencing of implementation actions and development of alternative recommended approaches (where appropriate). In addition, the Adaptive Management Team will provide advice to the Implementation Office on how well the site-specific plans and designs align with the appropriate problem statements, biological objectives (Steps 1 and 2), ecological models (Step 3), and the monitoring and research program (Step 6).
- Step 5 (perform implementation actions) will be carried out by the Implementation Office. The Adaptive Management Team may provide guidance to the Implementation Office on implementation techniques that may be important to the effectiveness of a conservation measure.
- Step 6 (design performance measures and monitoring and research plans) will be the responsibility of the Adaptive Management Team with support from the Implementation Office. The Adaptive Management Team will have primary responsibility for the overall development of the effectiveness monitoring and research program, to be implemented by the Implementation Office. Compliance monitoring will be the responsibility of the Implementation Office (see Section 3.6.4, *Monitoring and Research,* for the definition of these two forms of monitoring), with guidance provided by the Adaptive Management Team.

[48] See Appendix 2.A, *Covered Species Accounts* and some of the appendices supporting Chapter 5, *Effects Analysis.*

- Step 7 (analyze, synthesize, and evaluate) will be the responsibility of the Adaptive Management Team with support from the Delta Science Program and others. The Adaptive Management Team will assemble, analyze, and synthesize the results of monitoring and research actions and integrate the results of new, relevant scientific research and studies to address issues of direct relevance to Plan implementation.
- Step 8 (communicate current understanding). The Adaptive Management Team will communicate the results of the adaptive management program, with the support of the Implementation Office, to policy makers, managers, stakeholders, the scientific community, and the public so that they can understand and evaluate the Plan and its progress.
- Step 9 (adapt) is the primary decision-making step of the adaptive management process. The Adaptive Management Team will periodically reexamine all elements of the conservation strategy in the context of the adaptive management process and recommend revisions, as appropriate.

3.6.3.5.2 Operation of the Adaptive Management Team

The Adaptive Management Team will make decisions and recommendations by consensus. The Adaptive Management Team will administer the 9-step process as described in 3.6.3.5.1, *Role of the Adaptive Management Team*. The Adaptive Management Team will consider but not decide matters involving budget and funding, and will have a recommending role with respect to changes to biological objectives and conservation measures. In all discussions and recommendations involving adaptive management experiments or potential changes to biological objectives or conservation measures, the Adaptive Management Team will consider the relationship between the BDCP actions and the ecological circumstances at issue, including whether an experimental management strategy or potential change to a conservation measure or biological objective would be reasonably expected to offset impacts of covered activities or better achieve biological objectives. The decision process for biological objectives and conservation measures is described in more detail in Section 3.6.3.5.3, *Changing a Conservation Measure or Biological Objective*.

In its consideration of issues and development of recommendations the Adaptive Management Team will identify relevant policy, legal, and regulatory principles and will make their recommendations consistent with the schedule and budget. The Science Manager will work with the Program Manager to define policy, legal, budget or schedule issues using appropriate resources and experts and will provide that information to the Adaptive Management Team prior to the Adaptive Management Team recommendation. It will be the responsibility of Adaptive Management Team members who have concerns in these areas to brief the Team on such concerns. The Adaptive Management Team will consider technical input that may be received from the Technical Facilitation Subgroup of the Stakeholder Council, as described in Chapter 7, Section 7.1.6, *Adaptive Management Team*.

If consensus can be achieved on a decision or recommendation under consideration, the decision or recommendation will be forwarded by the Program Manager, without modification, to the Authorized Entity Group and Permit Oversight Group for their concurrence. When forwarding the decision or recommendation, the Program Manager may include any additional information the Program Manager believes will assist the Authorized Entity Group and Permit Oversight Group with deciding if they will concur. Some routine decisions (see below) may not be elevated if there is consensus as to their resolution within the Adaptive Management Team. If the Adaptive Management Team cannot achieve consensus on a matter under consideration, it will prepare a recommendation package on the issue that includes a statement of the matter being addressed and opposing points of view on its resolution. The recommendation package will be forwarded to the Program Manager, who will convey it without modification to the Authorized Entity Group and the Permit Oversight Group for their consideration. When forwarding the recommendation package, the Program Manager may include any additional information the Program Manager believes will assist the Authorized Entity Group and Permit Oversight Group in reaching a decision. In such instances, the Permit Oversight Group will attempt to decide by unanimous agreement, jointly with the Authorized Entity Group, how to resolve the issue. The Authorized Entity Group and Permit Oversight Group may jointly meet with the Adaptive Management Team to discuss such matters. If the Permit Oversight Group and Authorized Entity Group are unable to agree, then the dispute review process will be applied, as described in Chapter 7, Section 7.1.7, *Elevation and Review of Implementation Decisions*. After having received the advice of the panel described in this section, the fish and wildlife agency or agencies with jurisdiction over species affected by the decision will have final authority to decide the matter (Table 7.1, *BDCP Governance Decision-Making*, in Chapter 7).

The Adaptive Management Team will make decisions on routine scientific matters and administration of the adaptive management program (e.g., adjusting problem statements and conceptual models, synthesis of scientific information, communication products, meeting frequency, meeting formats); these routine decisions can be made independently of the Authorized Entity Group and the Permit Oversight Group. However, the Adaptive Management Team, through the Science Manager, will report all internal decisions to the Program Manager. The Authorized Entity Group and Permit Oversight Group will be notified of all activities of the Adaptive Management Team in the form of meeting notes. For other matters concerning guidance and advice to the Implementation Office on aspects of Plan implementation described in the 9 steps above, the Adaptive Management Team can provide this guidance and advice directly to the Implementation Office (i.e., without review by the Authorized Entity Group and the Permit Oversight Group).

It is expected that most proposals to make adaptive management changes will arise from within the Adaptive Management Team or the entities represented on the Adaptive Management Team. However, the Authorized Entity Group, Permit Oversight Group, or Stakeholder Council may submit proposals to the Adaptive Management Team for adaptive management action or decisions. The Adaptive Management Team may receive other proposals at its discretion, but it will have no obligation to reply to such proposals beyond acknowledging their receipt.

As part of its deliberations, the Adaptive Management Team may seek independent scientific advice on issues related to the proposals. The Adaptive Management Team will work with the Delta Science Program or other peer review provider to frame the issues to be addressed, provide the charge-to-reviewers, and prepare packages of review materials for any independent peer review.

The Implementation Office will ensure that a record of Adaptive Management Team meetings and activities, including meeting attendance, agendas, decisions, work assignments, audiovisual presentations or other materials that are discussed at meetings, and other documents reflecting the working of the Adaptive Management Team, are posted to a website for public access.

3.6.3.5.3 Changing a Conservation Measure or Biological Objective

Changing a conservation measure or biological objective is a major decision that will be made in accordance with the procedure set forth here. This section implements the decision process set forth in Chapter 7, Section 7.1, *Roles and Responsibilities of Entities Involved in BDCP Implementation*. These decisions will be made jointly by the Authorized Entity Group and Permit Oversight Group if agreement can be reached, or, with advice from the dispute resolution panel, by the fish and wildlife agencies as final authorities in these matters, if attempts by the Authorized Entity Group and Permit Oversight Group to reach agreement are unavailing. With respect to potential changes to conservation measures or biological objectives, the role of the Adaptive Management Team is to develop recommendations for changes that will be forwarded to the Authorized Entity Group and Permit Oversight Group for consideration. These changes would be made consistent with the commitments in the Plan, the governance process described in Chapter 7, *Implementation Structure*, and the regulatory assurances described in Chapter 6, *Plan Implementation*.

If, after a change to a conservation measure or biological objective is proposed by a member of the Team, the Adaptive Management Team reaches consensus that the change is advisable, then the Adaptive Management Team will provide a consensus recommendation package to the Program Manager for forwarding to the Authorized Entity Group and Permit Oversight Group consistent with Section 3.6.3.5.2, *Operation of the Adaptive Management Team*. If the Adaptive Management Team cannot reach consensus, it will forward a recommendation package to the Program Manager consisting of proposals, each prepared by a member or group of members within the team, that represent the differing views of how the matter should be resolved. Recommendations submitted to the Authorized Entity Group and Permit Oversight Group regarding potential changes to conservation measures or biological objectives will include the following.

- A description of the proposed change, including, as applicable, the extent, magnitude, and timing of the proposed modifications.
- The scientific rationale for the proposed change, and why it is reasonably expected to better achieve the biological objectives (if the change is to a conservation measure) or goals (if the change is to an objective) of the Plan.
- Any alternatives that were considered and why they were rejected.
- Any uncertainty associated with the change and the potential approaches to reducing that uncertainty. If the proposal is to temporarily change a conservation measure as part of the adaptive management learning process, a description of the underlying conceptual model and experimental design will be included.
- A report of relevant independent science review that has been applied to the scientific information in the recommendation package.
- A report of the potential costs in water, money, or other resources of the change being proposed.
- A cover letter and any information the Program Manager believes may be helpful in assisting the Authorized Entity Group and the Permit Oversight Group in making their decision.

The Authorized Entity Group and the Permit Oversight Group will jointly meet to consider and act on the proposals of the Adaptive Management Team. As part of these deliberations, the parties will consider the policy, legal, and regulatory principles set forth below, as well as budgetary and scheduling considerations, to guide such decisions. It will be the responsibility of members with concerns to brief the Groups on those concerns. If the Authorized Entity Group and the Permit Oversight Group agree that the proposed changes are warranted, the relevant conservation measures or biological objectives will be modified and such changes implemented as directed. The Authorized Entity Group and Permit Oversight Group will attempt to make a decision based on the information they have received from the Adaptive Management Team and the Program Manager, or may consult with either for further information, or may commission independent expert review.

Any member of the Authorized Entity Group or Permit Oversight Group may introduce information not contained in the recommendation package to inform a decision, and may enlist independent expert review of that new information if it has not already been obtained. In the event a member of the Authorized Entity Group or Permit Oversight Group wishes to bring in such new information to inform a decision, that information will, if any member of either Group requests it, first be provided to the Adaptive Management Team for comment. If any member of either Group requests it, the Adaptive Management Team will consider the new information and respond either with a consensus report or, if there is no consensus, with individual comments, in writing, to the Authorized Entity Group and Permit Oversight Group with an assessment of the value and applicability of the information to the decision at hand. The Program Manager will be responsible for documenting any changes made to the conservation measures or the biological objectives. Such information will be included in the Annual Progress Report, as described in Chapter 6, Section 6.3.3.

As part of their deliberations on changes to conservation measures, the Authorized Entity Group and the Permit Oversight Group will take into account the following considerations.

- The scope and nature of a proposed change will be considered within the totality of the circumstances, including the degree to which the change is reasonably expected to offset the impacts of covered activities and Plan implementation or to better achieve plan biological objectives.
- The Adaptive Management process will be used to help ensure that conservation measures are in conformity with ESA and NCCPA permit issuance criteria throughout the course of Plan implementation. Changes to conservation measures will be consistent with Section 3.4.23, *Resources to Support Adaptive Management*. Changes to a conservation measure will be limited to those actions reasonably likely to ensure that (1) the impacts (or levels of impacts) of a covered activity on covered species that were not previously considered or known are adequately addressed or (2) a conservation measure or suite of conservation measures that is less than effective, particularly with respect to effectiveness at advancing the biological goals and objectives, is modified, replaced, or supplemented to produce the expected biological benefit.[49]
- The strength of the scientific evidence linking the proposed change to a conservation measure to the ability of the BDCP to achieve the relevant biological objective or objectives.
- An assessment will be made of a potential adaptive change so that the desired outcome(s) will be achieved with the least resource costs. As long as equal or greater biological benefits can be achieved, adaptive responses will favor changes that minimize impacts on water supply or reliability.
- Prior to any decision to formally change a conservation measure in a manner that would potentially result in the modification of water supplies consistent with Section 3.4.23, *Resources to Support Adaptive Management*, nonoperational alternatives will be considered and, if such alternatives are rejected, the Adaptive Management Team will provide a written explanation to the Authorized Entity Group and the Permit Oversight Group as to why they were not sufficient to address the effects of the covered activity or achieve the biological objective(s) of the plan.

[49] The occurrence of a “changed circumstance” may also lead to an adaptive response subject to this paragraph, as provided in Chapter 6.4.2, *Changed Circumstances*.

In the event that the Authorized Entity Group and the Permit Oversight Group are unable to reach agreement on a proposed change to a conservation measure or biological objective, the dispute review process described in Chapter 7, Section 7.1.7, *Elevation and Review of Implementation Decisions,* will be used. After considering the available information and advice of the dispute resolution panel, the regulatory agency(ies) (director of CDFW and/or regional director of NMFS or USFWS) with jurisdiction over the species and/or habitat intended to benefit from the action will determine whether the proposed action, or an alternative to that action, will be adopted. With respect to adaptive management issues other than proposed changes to conservation measures or objectives, if the Authorized Entity Group and Permit Oversight Group are unable to reach agreement, the Permit Oversight Group will decide the matter.

3.6.3.5.4 Relationship of Adaptive Management to Real-Time Operations

Under *CM1 Water Facilities and Operation*, a "real-time operations" mechanism will allow for adjustment of water operations, within established conditions, to respond in real time to changing conditions for the purpose of maximizing opportunities to benefit covered fish species (Section 3.4.1.4.5, *Real-Time Operations*). The adaptive management and decision-making processes described in this section do not apply to these real-time operations. However, changing operational criteria in CM1 through the adaptive management process may affect how real-time operations are implemented.

3.6.3.5.5 Periodic Review of the BDCP Conservation Strategy and Implementation

In addition to the annual adaptive management review process contemplated above, the Implementation Office will commission a comprehensive review of the BDCP every 5 years. Part of that review, to be conducted under the direction of the Adaptive Management Team, will assess the effectiveness to date of conservation measures in achieving the biological objectives; it will also include a status and trends review of covered species and natural community conditions. The Implementation Office will oversee preparation of other parts of the comprehensive review, including compliance actions taken, as described in Chapter 6, Section 6.3.5, *Five-Year Comprehensive Review*.

3.6.4 Monitoring and Research

Monitoring and research are critical elements of adaptive management, providing the data and analysis structure needed for informed decision making. Monitoring and research actions will be conducted primarily to meet the following objectives.

- Document compliance with terms and conditions of BDCP permits.
- Collect data necessary to effectively and successfully implement conservation measures.
- Document and evaluate the effectiveness of conservation measures in achieving biological goals and objectives.
- Resolve key uncertainties in the science underlying conceptual models that act as the basis for biological goals and objectives and for the conservation measures.

The Adaptive Management Team, with support of the Implementation Office, will have primary responsibility for the overall development, management, and oversight of the biological monitoring and research program. The monitoring and research program will be coordinated with the comprehensive monitoring framework and other elements of the Delta Science Plan to the extent appropriate, while still ensuring that BDCP regulatory requirements are met. While this section provides a good framework to guide initial implementation of the monitoring and research program, the Adaptive Management Team will reexamine elements of the program over the course of Plan implementation and revise approaches, as appropriate, to ensure the program is conducted to effectively and efficiently support adaptive decision making. The Science Manager, guided by the Adaptive Management Team, will coordinate such efforts with the Authorized Entity Group, Permit Oversight Group, Stakeholder Council, IEP coordinators, the Management Analysis and Synthesis Team, and Delta Science Program and, as necessary, the Delta Independent Science Board, with additional coordination as needed to ensure consistency of reporting and to minimize duplication of effort with the ongoing monitoring programs identified in Table 3.6-.

As part of Plan implementation, and by the end of each calendar year, the Implementation Office will prepare an annual effectiveness monitoring and research plan, based on the recommendations and guidance provided by the Adaptive Management Team, for approval by the Authorized Entity Group and the Permit Oversight Group. The annual monitoring and research plan will be incorporated into the Annual Work Plan and Budget, as described in Chapter 6, Section 6.3.1. The annual monitoring and research plan will include the following elements.

- What will be monitored or researched.
- Why the monitoring or research is needed (e.g., comply with permit(s), address key uncertainty, evaluate progress on a biological objective).
- When the effort will occur and at what frequency.
- The conceptual and/or quantitative model(s) underlying the selection of the monitoring or research action.
- The geographic area where it will be implemented, including sampling locations.
- The specific variables that will be measured and the protocol that will be used, if known at the time (specific metrics or protocols may be developed later).
- Potential management responses to a range of monitoring results.
- The time frame, spatial area and ecological scale over which change is expected to be demonstrated.

Monitoring actions generally fall within the following three categories, which are described in subsequent sections: compliance, effectiveness, and directed research.

3.6.4.1 Approach for Monitoring and Research

Monitoring (particularly effectiveness monitoring) and research deal with issues that derive primarily from conceptual ecological models of how an ecosystem will respond to changed inputs. In the BDCP, most monitoring and research actions are expected to focus on inputs that have changed through implementation of the conservation strategy. Therefore, monitoring and research actions must always be framed within the context of rigorous scientific investigation of the processes underlying the conceptual models being used by the Adaptive Management Team. Some monitoring actions, such as those that measure progress toward meeting a performance target, consist simply of tracking relevant metrics. More complex investigations may test hypotheses or answer questions using combinations of observational study, experimentation, mathematical modeling, or statistical inference. Monitoring and research will, whenever practicable, comply with all the following scientific guidelines.

- Formally state or cite the conceptual ecological models relevant to each monitoring or research action.
- Explicitly test null and alternative hypotheses stated in terms of the applicable conceptual ecological model.
- Use an experimental design with sufficient statistical power to detect effects.
- Incorporate scientific principles of replication, control, or pre- and posttreatment monitoring, depending on the logistical constraints of the implementation action being monitored or studied.
- Select and use indicator variables that are ecologically important and broadly applicable. Incorporate these indicators in formal statements of conceptual ecological models.
- To achieve efficiency and to get results that are directly comparable with findings acquired through other studies or programs, maximize use of existing data, protocols, analytical tools, and expertise.

The following sections elaborate on some of the principal points above: the use of indicator variables, applicable protocols, and proper statistical design. Because it is impractical to evaluate most implementation actions through traditional controlled experiments, Section 3.6.4.1.4 presents a detailed discussion of the use of before-and-after assessments.

3.6.4.1.1 Indicators

Indicators can be used in many ways: to predict species richness (MacNally and Fleishman 2004), estimate biodiversity (Kati et al. 2004; Chase et al. 2000), assess levels of disturbance, or provide targeted information on a system or species (Caro and O'Doherty 1999; Carignan and Villard 2004). In general, indicators demonstrate changes or trends that are quantifiable. Landres et al. (1988) defined an indicator species as an organism whose characteristics are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species or environmental conditions of interest. Indicators may be species or physical, chemical, or ecological attributes (e.g., water velocity, dissolved oxygen level, or percent shrub cover). For the purposes of the BDCP, indicators may be selected to facilitate monitoring of systems or species that are otherwise difficult to examine. In some cases, indicators may be used to determine the availability of habitat for a species. In cases where an indicator is used to monitor an ecosystem or natural community, conceptual models identify the relevant indicator species or variable(s) and its/their relationship(s) to other important variables. Effective indicators have some or all of the following characteristics (Carignan and Villard 2002; Atkinson et al. 2004).

- They are relevant to program goals and objectives and can be used to assess program performance at appropriate spatial and temporal scales.
- They are sensitive to changes in the ecosystem, providing early warning of response to environmental or management effects.
- They indicate the cause of change, not just the existence of change.

- They provide a continuum of responses to a range of stressors such that the indicator will not quickly reach a minimum or maximum threshold.
- They have known statistical properties, with baseline data, references, or benchmarks available.
- They are technically feasible, easily understood, and cost-effective to measure by all personnel involved in the monitoring.

The annual monitoring plans will clearly present the rationale for using selected indicators.

3.6.4.1.2 Protocols

When available and appropriate, existing and accepted monitoring protocols will be adopted to help facilitate data integration with other studies. In cases where standardized protocols are not yet available, protocols will be developed with reference to relevant guidance, such as the National Park Service's Inventory and Monitoring Program guidelines for monitoring protocols (Oakley et al. 2003) or the Bureau of Land Management's monitoring guidelines for plants (Elzinga et al. 1998). Proposed protocols will be subject to review and approval by the fish and wildlife agencies. Designated monitoring protocols will be appropriate to the task, implemented precisely, and as cost-effective as possible. The BDCP will participate as a cooperating entity in efforts to standardize monitoring protocols for consistency with protocols used in neighboring and regional HCPs, NCCPs, and other conservation and environmental monitoring programs. Ongoing training by the Implementation Office or its contractors will ensure consistent protocol implementation.

3.6.4.1.3 Statistical and Sampling Design

Statistical and sampling design will vary with the goals and purposes of sampling or monitoring. Sampling design seeks to minimize extraneous variance in the measured values of indicators or variables. Selection of variables will be guided by a thorough knowledge of the ecological relationships that drive natural communities. Sampling intensity and probability of detection will be considered to ensure that all covered species are adequately inventoried and monitored. Methods of data analysis will be established prior to study design, and a statistician or biologist with sufficient statistical expertise will be consulted. Study designs, including methods of data analysis, will be subject to independent scientific review at the design stage to ensure that studies and monitoring that are implemented are appropriate and reliable. Some of the issues to consider in study design are listed below (Scheiner and Gurevitch 1993).

- Availability of sites on which treatments can be applied.
- Availability of reference sites.
- Site selection design (e.g., random, stratified random, nonrandom).
- Choice of systematic versus opportunistic sampling.
- Detection probability of the sampling protocol.
- Avoiding pseudoreplication (Hurlbert 1984).
- Sufficient statistical power to identify changes or differences of concern.

3.6.4.1.4 Before-and-After Assessments

The Delta reflects a highly altered ecosystem with a limited number of reference sites that provide long-term information on historical conditions (e.g., Rush Ranch [Suisun Marsh], Liberty Island, Franks Tract, Mildred Island, Decker Island). As such, the evaluation framework will rely wherever possible on the before/after and control/impact (BACI) design approaches to assess ecosystem change (Green 1979; Underwood 1992, 1994). The BACI approach is typically presented as a means for testing if an effect on the system has occurred as a result of an action that has been taken. The study design may also be used to evaluate conservation and restoration projects (Michener 1997; Lincoln-Smith et al. 2006) and test whether conditions are changing. This type of monitoring approach is commonly used in restoration ecology, particularly where numerous natural and anthropogenic disturbances represent unplanned, uncontrollable events that cannot be replicated or studied using traditional experimental approaches and statistical analyses.

Baseline Conditions in Before-and-After Experimental Design

Baseline and monitoring survey results will be used as the basis for BACI designs intended to evaluate program effectiveness. In some cases, baseline monitoring may involve monitoring at reference (control) sites inside or outside the Plan Area. Surveys to establish baseline conditions are used to compare biological and physical conditions before and after implementation of actions and to evaluate the effectiveness of those actions. The Adaptive Management Team will ensure that a sufficiently robust baseline monitoring program is established to measure the condition of the ecosystem at the time prior to the implementation of an action against which change can be compared. This will entail both assessing existing databases and determining what new measurements will be useful prior to the implementation of a conservation measure. A number of these surveys were needed in order to develop the Plan and have already been completed, but more local-scale surveys, and surveys conducted closer in time to the action, are likely to be needed in association with individual actions (e.g., restoration projects or predatory fish control plans). Baseline surveys will be performed prior to implementation of actions with sufficient lead time to allow future detection of changes in trajectories for the expected outcomes after implementation.

As described below (Section 3.6.4.2, *Integration of Existing Sources of Scientific Information*), a substantial number of monitoring programs currently exist in the Delta and surrounding area, and some current and historical data can be used to aid in establishing baseline conditions. Depending on the implementation action being planned, documenting baseline conditions may include the following types of tasks.

- Inventory and document resources and improve mapping.
- Conduct sampling to verify or better understand spatial/temporal variation in physical variables such as water quality and flow parameters, and in habitat use by terrestrial or aquatic organisms.
- Research and document historical data and trends, as appropriate.
- Use aerial photos and ground surveys, as needed, to assess quality and location of local and regional landscape linkages between unprotected natural areas and adjacent, existing conservation lands.

3.6.4.2 Integration of Existing Sources of Scientific Information

The Adaptive Management Team will need to rely on information obtained from existing monitoring and research efforts in the Delta. Under a variety of statutory mandates and/or cooperative agreements, multiple agencies and organizations are involved in resource management, monitoring, and research in the Delta. Several programs have some overlap with actions proposed by the BDCP. The Adaptive Management Team will coordinate its activities with implementation of the Delta Science Plan, the Delta Science Program, the IEP, and other entities involved in monitoring programs to ensure that efforts are not duplicated and are complementary. The Adaptive Management Team will use data collected through these programs, as appropriate, to support evaluation of the effectiveness of the conservation strategy in achieving the Plan's biological goals and objectives. Furthermore, the Implementation Office may fund these existing programs to conduct monitoring tasks on its behalf. The relationship between the adaptive management and monitoring program and these programs, as well as others, is discussed in Section 3.6.3, *Adaptive Management Process*; Section 3.6.4.3, *Compliance Monitoring*; Section 3.6.4.4, *Effectiveness Monitoring*; and Section 3.6.4.5, *Research*.

Several organizations and agencies monitor species and ecosystem conditions that are relevant to the BDCP implementation. The Ecosystem Restoration Program has supported and continues to support research actions, restoration projects, and other relevant activities in the Delta. A new regional monitoring program intended to coordinate Delta water quality monitoring in compliance with Clean Water Act permit conditions is currently under development by the Central Valley Water Board (Central Valley Regional Water Quality Control Board 2012). A similar regional monitoring program already exists for San Francisco Bay and is carried out by the San Francisco Estuary Institute, a nonprofit research organization. It will be crucial to the success of the adaptive management and monitoring program to regularly integrate with and review the data collected from the other research and monitoring efforts. The IEP and Delta Science Program will have unique roles in helping to implement the adaptive management and monitoring program, as discussed below.

3.6.4.2.1 Interagency Ecological Program

The IEP brings state and federal natural resource and regulatory agencies together to monitor and study ecological changes and processes in the Delta. The IEP consists of ten member entities: three state agencies (DWR, CDFW, and the State Water Resources Control Board), six federal agencies (USFWS, Reclamation, USGS, USACE, NMFS, and EPA), and one *ex officio* member (currently, the San Francisco Estuary Institute). These program partners work together to develop a better understanding of the estuary's ecology and the effects of the SWP/CVP operations on the physical, chemical, and biological conditions of the estuary.

The IEP has coordinated Bay-Delta monitoring and research activities conducted by state and federal agencies and other science partners for over 40 years (Table 3.6-2). IEP monitoring activities are generally carried out in compliance with water rights decisions and ESA/CESA permit and/or BiOp conditions. Most of the monitoring under the IEP focuses on open-water areas and the major Delta waterways conveying water to the SWP/CVP facilities in the south Delta and downstream, including the entire Bay-Delta area. The IEP produces publicly accessible data that include fish status and trends, water quality, estuarine hydrodynamics, and foodweb monitoring. Until recently, the IEP maintained and hosted the Bay Delta and Tributaries System or the HEC-DSS Time-Series Data System. These systems have been archived. Currently, DWR and IEP are working toward the migration to a standardized and modernized data system. This will make the data more easily accessible.

Table 3.6-2. Bay-Delta Fish Monitoring Programs Coordinated through the Interagency Ecological Program that are Relevant to the BDCP

Monitoring Program	Agency	Primary Purpose and Timeframe	Data Relevant to the BDCP
Spring Kodiak Trawl Survey	CDFW	Monitors spawning adult delta smelt distribution, relative abundance, and reproductive status, January–May, 2002–present.	• Delta smelt: spawning abundance index, distribution, sex ratios, reproductive status (e.g., prespawn, mature, or spent)
Delta Smelt 20 mm Survey (20 mm Survey)	CDFW	Monitors postlarval-juvenile delta smelt distribution and relative abundance, March–June, 1995–present.	• Delta smelt: postlarval and juvenile abundance index, distribution, length frequency
Summer Townet Survey (Townet Survey)	CDFW	Monitors striped bass and delta smelt abundance indices, July–August, 1959–present.	• Delta smelt: juvenile delta smelt abundance index, distribution, and length frequency • Longfin smelt: postlarval juvenile longfin smelt abundance index, distribution, and length frequency • Sacramento splittail: young-of-year splittail, distribution, and length frequency
Fall Midwater Trawl Survey	CDFW	Monitors striped bass and delta smelt abundance indices, September–December, 1967–present.	• Delta smelt: preadult delta smelt abundance index • Longfin smelt: preadult longfin smelt abundance index • Sacramento splittail: abundance of all size classes
Smelt Larval Study	CDFW	Monitors longfin smelt larvae distribution and relative abundance, January, 2009–present.	• Longfin smelt: larval abundance index and distribution
San Francisco Bay Study Survey (Bay Study Survey)	CDFW	Monitors abundance indices for a variety of species in South San Francisco and Suisun Bays, year-round, 1980–present.	• Delta smelt: juvenile and adult delta smelt abundance index • Longfin smelt: juvenile and adult longfin smelt abundance index • Sacramento splittail: young-of-year and older splittail abundance
Suisun Marsh Fish Community Survey (Suisun Marsh Survey)	UC Davis	Monitors abundance of all fish species in Suisun Marsh, year-round, 1979–present.	• Delta smelt: juvenile and adult delta smelt abundance, distribution in Suisun Marsh • Longfin smelt: juvenile and adult longfin smelt abundance, distribution in Suisun Marsh • Sacramento splittail: abundance of all size classes, distribution within Suisun Marsh
Fish Salvage Monitoring	DWR, CDFW, Reclamation	Monitors entrainment and salvage of all fish species, year-round, 1979–present.	• Delta and longfin smelt: 20-mm postlarvae and adult smelt abundance • Sacramento splittail: Abundance of all size classes >20 mm and length frequency • Salmonids: >20-mm larvae and adult abundance • Sturgeon: >20-mm juvenile sturgeon abundance

Monitoring Program	Agency	Primary Purpose and Timeframe	Data Relevant to the BDCP
Chipps Island, Mossdale, and Sacramento Trawl Survey	USFWS	Monitors fish abundance and distribution in midchannel at surface at Chips Island, Mossdale (RM 54), and Sacramento (RM 55), and survival through the Delta, targets Chinook salmon, year-round, 1976–present.	• Salmonids: juvenile abundance, distribution, length frequency, survival indices (of hatchery tagged fish) to Chipps Island • Delta smelt: >25-mm abundance, distribution, and length frequency • Longfin smelt: >25-mm abundance and distribution, and length frequency • Sacramento splittail: >25-mm abundance and distribution, and length frequency
Delta Juvenile Fishes Monitoring Beach Seine (Beach Seine Survey)	USFWS	Monitors fish abundance and distribution throughout the Delta, upstream Sacramento River, northern San Francisco and San Pablo Bays, targets Chinook salmon, year-round, 1976–present.	• Sacramento splittail: >25-mm young-of-year splittail abundance, distribution, and size frequency • Salmonids: juvenile salmonids, abundance, distribution, and size frequency
Chinook salmon escapement estimates (Grand tab database)	CDFW, DWR	Collects all races of Chinook salmon escapement.	• Salmonids: adult returns to spawning grounds by race and location
Suisun Marsh Otter Trawl	UC Davis	Monitors abundance of all fish species in Suisun Marsh, year-round, 1979–present.	• Chinook salmon: juvenile abundance and distribution within Suisun Marsh
Yolo Bypass Study	DWR	Monitors abundance of adult and juvenile fishes in Yolo Bypass, 1998–present.	• Salmonids: juvenile abundance, adult presence, distribution, length frequency • Delta smelt: >25-mm abundance, distribution, and length frequency • Longfin smelt: >25-mm abundance and distribution, and length frequency • Sacramento splittail: >25-mm abundance and distribution, and length frequency • White sturgeon: abundance, length frequency
Adult Sturgeon Tagging Survey	CDFW	Tag-recapture (via creel surveys) of green (prior to being listed) and white sturgeon for abundance and population dynamics.	• White and green sturgeon: abundance, distribution, population dynamics, length frequency, annual harvest rates, and migration rates

Notes:
CDFW = California Department of Fish and Wildlife; DWR = California Department of Water Resources; Reclamation = Bureau of Reclamation; USFWS = U.S. Fish and Wildlife Service; UC = University of California; mm = millimeters

3.6.4.2.2 Delta Science Program

Research actions are also supported through the Delta Science Program, whose mission is to provide the best possible unbiased scientific information to inform water and environmental decision making in the Bay-Delta region. The Delta Science Program's objectives are listed below.

- Initiate, evaluate and fund research that will fill critical gaps in the understanding of the current and changing Bay-Delta system.
- Facilitate analysis and synthesis of scientific information across disciplines.
- Promote and provide independent, scientific peer review of processes, plans, programs, and products.
- Coordinate with agencies to promote science-based adaptive management.
- Interpret and communicate scientific information to policy- and decision-makers, scientists, and the public.
- Foster activities that build the community of Delta science.

The Delta Science Program has particular expertise and experience organizing and facilitating independent scientific reviews. It also has primary responsibility for developing and implementing the Delta Science Plan (see Section 3.6.2.4, *Integration with the Delta Science Plan*, for details).

3.6.4.3 Compliance Monitoring

The purpose of compliance monitoring is to track progress of BDCP implementation in accordance with established timetables and to ensure compliance with terms and conditions of the BDCP and its associated permits. Compliance monitoring actions are identified in the respective conservation measures (Section 3.4) and listed by conservation measure in Table 3.D-1 of Appendix 3.D, *Monitoring and Research Actions*. As noted in Chapter 7, Section 7.1.1.3, *Implementation Office: Function, Establishment, and Organization*, fulfillment of compliance monitoring and reporting requirements, including the preparation of the Annual Progress Report, is solely the responsibility of the Implementation Office, and thus is not a responsibility of the Adaptive Management Team. Compliance monitoring activities will be conducted in accordance with guidance provided by the Adaptive Management Team. Compliance monitoring will be conducted for all conservation measures, whether implemented directly by the Implementation Office or by other supporting entities through contracts, memoranda of agreement, or other agreements with the Implementation Office.

The Implementation Office will track and ensure compliance monitoring is conducted in accordance with provisions of the BDCP and its associated regulatory authorizations, and will provide results to the fish and wildlife agencies as part of the Annual Progress Report. Compliance monitoring will comprise two main categories.

- **Construction monitoring**. Construction monitoring will be used to ensure that constructed features and structures, as well as the avoidance and minimization measures associated with construction activities, are implemented in a manner consistent with the BDCP.
- **Conservation measure implementation monitoring**. The Implementation Office will gather the necessary information and prepare annual reports that are sufficient to demonstrate compliance with the BDCP and its associated authorizations and to help facilitate interagency

coordination. Annual progress reports will include a description and accounting of compliance with water operations criteria, land acquisitions, and habitat restoration requirements. The compliance monitoring program will also allow for transparent, real-time operational decisions by the fish and wildlife agencies to ensure that biological performance measures are being met, consistent with the requirements of the Delta Reform Act (Water Code Section 85321).These activities are further described in Section 3.6.5, *Data Management and Reporting*, and in Chapter 6, Section 6.3, *Planning, Compliance, and Progress Reporting*.

3.6.4.3.1 Construction Monitoring

Monitoring will be conducted during construction activities (both covered activities and conservation measures), including those related to water facilities, restoration projects, projects constructed under *CM2 Yolo Bypass Fisheries Enhancement*, smelt hatcheries, and remediation of nonproject diversions. Construction monitoring is required to ensure that avoidance and minimization measures are properly implemented. The Implementation Office will monitor implementation of covered activities to ensure that applicable avoidance and/or minimization measures (*CM22 Avoidance and Minimization Measures*) are properly implemented. It also will ensure that construction occurs in accordance with specifications and plans. Construction compliance monitoring will include the following potential actions.

- Avoidance and demarcation of sensitive habitats and natural communities.
- Documenting compliance with project design criteria, as appropriate.
- Documenting compliance with construction BMPs.

Construction BMPs and monitoring (AMM2) are presented in Appendix 3.C, *Avoidance and Minimization Measures*.

3.6.4.3.2 Conservation Measure Implementation Monitoring

Compliance monitoring regarding the implementation of conservation measures will be conducted during the implementation phase and throughout the permit term. Compliance monitoring is required to ensure that conservation measures and their associated actions are properly carried out within the specifications and timeframe of the BDCP, and to document compliance with identified restoration targets. Annual Progress Reports will include a description and accounting of compliance monitoring results. The Implementation Office will be responsible for implementing compliance monitoring. Compliance monitoring actions are listed in Appendix 3.D, *Monitoring and Research Actions*.

3.6.4.4 Effectiveness Monitoring

3.6.4.4.1 Principles of Effectiveness Monitoring

Effectiveness monitoring is undertaken to determine whether an action is effective. Effectiveness of the conservation measures ultimately is measured by how well they achieve the plan objectives they are designed to achieve. As an interim step, effectiveness may also be assessed in terms of responses predicted by conceptual models or other pragmatic considerations. These three topics are not entirely distinct, but they emphasize different aspects of how implementation actions are planned and implemented.

Effectiveness monitoring may be used to directly measure whether a conservation measure achieves the expected biological objectives. If an objective is not being achieved, then additional study of relevant processes captured in the conceptual model underlying the conservation measure likely is needed. If an objective is being achieved, additional study may reveal more efficient approaches to achieving the same result.

Effectiveness monitoring can be used as part of a scientific investigation to evaluate processes described in conceptual models, because the conceptual model predicts that a given action will cause a particular array of changes in the modeled system. If effectiveness monitoring verifies that this occurs, this outcome is consistent with a hypothesis that the conceptual model is accurate. If effectiveness monitoring does not verify the expected outcome, then one possible explanation is that the conceptual model is flawed. Additional study may be needed to distinguish between various alternative explanations; the approach may entail a research action, as described below in Section 3.6.4.5, *Research*.

Assuming that effectiveness monitoring does not identify inconsistencies in conceptual models, it can then be used to verify progress towards meeting biological goals and objectives. Each conservation measure is based on a conceptual ecological model of how the measure will affect some aspect of the Bay-Delta ecosystem. If the model is accurate, implementation of the measure will result in meeting the biological objectives that the measure has been designed to achieve. Effectiveness monitoring can be used to measure that progress and to assess whether the objectives are being achieved or progress is adequate. For this reason, effectiveness monitoring results are expected to weigh heavily in decisions about which conservation measures are effective as they are and which should be modified to perform more effectively.

Thus, effectiveness monitoring can be used to evaluate pragmatic considerations in conservation measure implementation. Pragmatic considerations are those which deal with how implementation actions are performed. Examples include using effectiveness monitoring results to answer questions such as “How can we modify nonphysical barriers to be easier to install and maintain?” or “How can the invasive species inspection program be modified to maximize the number of watercraft inspected?” or “Which channel margin enhancement projects have been most effective, and why?”

3.6.4.4.2 Implementing Effectiveness Monitoring

Effectiveness monitoring will be performed *in perpetuity* per the terms of the Plan under the guidance of the Adaptive Management Team, in coordination or collaboration with the IEP, Delta Science Program, and others, as appropriate. Initial effectiveness monitoring actions are identified in the respective conservation measures (Section 3.4) and listed by conservation measure in Table 3.D-2 of Appendix 3.D, *Monitoring and Research Actions*. Metrics and protocols for effectiveness monitoring will be developed early in Plan implementation and periodically revised in response to factors such as improvements in scientific understanding, improved technology, and the needs of integrated regional monitoring programs. It is anticipated that the extent of effectiveness monitoring will be reduced over time as causal relationships between the conservation measures and the responses of covered species and natural communities are better understood. However, continued effectiveness monitoring will be required to continue to verify progress toward achieving biological goals and objectives that cannot be tracked with simple compliance monitoring, and the need for effectiveness monitoring will be periodically renewed as conceptual ecological models are improved and new techniques for implementation are tried via the adaptive management process.

Effectiveness monitoring will occur on a variety of scales, including landscape, natural community, and species scales, for multiple purposes. In some cases, data will be used to monitor effectiveness in multiple analytical scales. As a result, some monitoring actions and metrics may occur at more than one of these scales.

Landscape Scale

Landscape-scale monitoring actions will be directed at tracking large areas, ecosystem processes, and regional issues that affect the Plan Area. Monitoring at this scale will provide the information necessary to ascertain the effectiveness of implementation actions designed to achieve, or contribute to achieving, the biological goals and objectives described in Section 3.3.5, *Landscape-Scale Biological Goals and Objectives*. Monitoring of ecosystem processes and conditions will provide the Adaptive Management Team with information necessary to track long-term changes affecting the Delta ecosystem and to document the contribution of the BDCP toward maintaining and improving ecosystem attributes in support of the covered species and natural communities.

Natural Communities

The extent and distribution of natural communities within the reserve system and within the Plan Area will be monitored at appropriate intervals over the term of the BDCP. This monitoring will provide the Adaptive Management Team with information sufficient to track long-term changes in the distribution and extent of natural communities. These monitoring data will also help to document the BDCP's contribution toward maintaining and improving the extent, distribution, and continuity of natural communities. The baseline conditions from which changes in the range and distribution of natural communities will be assessed are the conditions described in Chapter 2, *Existing Ecological Conditions,* and in additional baseline data collected by the Adaptive Management Team early in the permit term.

Where protection of biological diversity is a goal, natural community monitoring is needed to evaluate success. Effectiveness monitoring at this scale will provide the information necessary to verify progress toward achieving the biological goals and objectives described in Section 3.3.6, *Natural Community Biological Goals and Objectives*. The monitoring plan will focus on the degree of progress in the following areas.

- Effectiveness of actions to protect, enhance, create, and restore natural communities that contribute to the conservation of associated covered and other native species.
- Maintenance and enhancement of habitat functions to increase the abundance and distribution of associated covered and other native species.
- Provision of conservation benefit to covered species and native plants.
- Promotion of native biological diversity (e.g., species richness, presence or abundance, biomass) through restoration or creation of natural communities to increase the extent and availability of covered and other native species habitat.

Specific metrics and protocols for effectiveness monitoring of natural communities will be developed during Plan implementation.

Covered Species

The status and distribution of covered fish, wildlife, and plant species will be monitored in the Plan Area over the term of the BDCP. This monitoring will provide the Adaptive Management Team with information sufficient to track long-term changes attributable to factors such as covered activities, physical and chemical changes, climate change. The results of these monitoring efforts will document the contribution of the BDCP to the conservation and management of covered species and inform system-level assessments of status, trends, and distribution. The baseline conditions from which changes in the range and distribution of covered species will be assessed are the conditions described in Chapter 2, *Existing Ecological Conditions,* and Appendix 2.A, *Covered Species Accounts,* and in additional baseline data collected by the Adaptive Management Team early in the implementation period. Monitoring will be performed for the permit's duration and *in perpetuity* per the terms of the Plan. The Adaptive Management Team will develop specific metrics and protocols for species effectiveness monitoring during Plan implementation, in coordination with IEP, the fish and wildlife agencies, and Delta Science Program, as appropriate.

As part of the covered species monitoring, the Adaptive Management Team, will also review relevant scientific information documenting improved knowledge of covered species biology, including such topics as behavior, habitat needs, and ecological interactions. Review of this information will further inform assessments of the status of covered species within the Plan Area and decisions concerning whether to modify species management and monitoring through the adaptive management process.

The following represent examples of the types of issues species-specific monitoring will address.

- Perform field surveys work with other programs to document and monitor species status.
- Evaluate covered species response to flow management implemented per *CM1 Water Facilities and Operation*.
- Evaluate covered species response to restoration actions implemented under *CM3 Natural Communities Protection and Restoration, CM4 Tidal Natural Communities Restoration, CM5 Seasonally Inundated Floodplain Restoration, CM6 Channel Margin Enhancement, CM7 Riparian Natural Community Restoration, CM8 Grassland Natural Community Restoration, CM9 Vernal Pool and Alkali Seasonal Wetland Complex Restoration, CM10 Nontidal Marsh Restoration, CM11 Natural Communities Enhancement and Management*.
- Evaluate covered fish species response to stressor reduction actions implemented under *CM12 Methylmercury Management*, *CM13 Invasive Aquatic Vegetation Control*, *CM14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels*, *CM15 Localized Reduction of Predatory Fishes*, *CM16 Nonphysical Fish Barriers*, *CM17 Illegal Harvest Reduction*, *CM19 Urban Stormwater Treatment,* and *CM21 Nonproject Diversions*.
- Evaluate covered fish species response to conservation hatchery programs implemented under *CM18 Conservation Hatcheries*.

In some cases, conservation of covered species is addressed primarily through monitoring actions at the landscape scale and the natural community scale. For some species, additional species-specific biological goals and objectives were deemed necessary for conservation, and monitoring actions specific to these objectives will be implemented.

3.6.4.5 Research

Research is generally not a requirement of HCPs and NCCPs. However, given the ecological complexity of the Delta and the level of uncertainty regarding anticipated beneficial outcomes from implementation of the conservation strategy, there is a need for research to address key uncertainties. Many key uncertainties, along with examples of relevant research actions, have been identified for the individual conservation measures (Section 3.4, *Conservation Measures,* and Table 3.D-3 in Appendix 3.D, *Monitoring and Research Actions*). Existing research programs in the Delta have produced a broad range of valuable products. Many of these efforts are ongoing under the IEP, Ecosystem Restoration Program, and Delta Science Program (Section 3.6.4.2, *Integration of Existing Sources of Scientific Information*).

Example research actions are identified to address each of the key uncertainties, but the Adaptive Management Team will identify and prioritize research needs necessary to inform implementation actions, taking into consideration existing research programs and the science priorities identified through implementation of the Delta Science Plan. Guided by the Adaptive Management Team, the Science Manager will administer a process to solicit proposals to address specific uncertainties, with qualified proposers identifying the precise research actions that are expected to resolve the uncertainties. It is expected that new data and information will be developed during implementation that will increase knowledge and help reduce uncertainties regarding implementation and outcomes of the conservation measures. Research principally involves the following approaches.

- Testing and refining conceptual ecological models that define the needs of covered species, the structure and functions of natural communities, the expected effects of achieving biological objectives, the expected mechanisms and effects of conservation measure implementation, and other aspects of Delta ecosystem processes such as responses to climate change.
- Developing and refining life-history models for covered fish species to facilitate Plan implementation and guide adaptive management.
- Developing new and more sensitive indicators and metrics.
- Identifying and evaluating tradeoffs among and within conservation measures.

The Adaptive Management Team will follow the process described in Section 3.6.4.4.2, *Implementing Effectiveness Monitoring*, when implementing research actions. Research conducted under the BDCP will have the following attributes.

- Be directly relevant to uncertainties associated with BDCP implementation.
- Have clear objectives, hypotheses, methods, analytical approaches, and deliverable schedules.
- Be subjected to independent scientific peer review, as appropriate.
- Make data and results available to the fish and wildlife agencies and to the public and ensure timely publication of results where appropriate.

The BDCP will consider these efforts when identifying and prioritizing key research needs to fill data gaps and address uncertainty relevant to the BDCP.

Contents of a research action report will focus on responding to the questions framed during action design (Section 3.6.3.4.4, *Step 4: Plan and Design Implementation Actions*) but will in all cases include a detailed, explicit statement of how the action has addressed relevant key uncertainties and how those findings have modified relevant conceptual ecological models. The report will also present a fully detailed explanation of the background, methods, results, and implications of the research, and will identify new or residual sources of uncertainty. Reports will receive independent peer review by reviewers chosen by the Adaptive Management Team.

3.6.5 Data Management

A spatially linked database of BDCP actions and decisions will be developed and maintained by the Implementation Office. This information will be used to track Plan implementation, document permit compliance and progress toward meeting the biological goals and objectives; and for reporting of BDCP progress to the Authorized Entity Group, the Permit Oversight Group, the Stakeholder Council, and the public (reporting requirements are described in Chapter 6, Section 6.3, *Planning, Compliance, and Progress Reporting*).

The database will be structured to allow for future expansion and integration with external databases (e.g., linkage and interoperability to the databases of the Delta Science Program, California Environmental Data Exchange Network, California Water Quality Monitoring Council, and EPA's STORET Data Warehouse and Water Quality Exchange). The database design will look to other recognized database management examples, such as the new IEP database under development and the California Environmental Data Exchange Network. The database will support the following functions.

- Metadata (data documentation) showing how, where, and by whom the data were collected.
- Data entry quality assurance and quality control.
- Access to and use of the most current information for analysis and decision making.
- Corrections and improvements in the data.

The database is expected to maintain the following information.

- Metadata.
- Quality assurance data.
- Data and analysis from compliance and effectiveness monitoring and directed research.
- Modeling inputs, outputs, and results.
- Status of covered activities, including implementation and effects.
- Implementation status of conservation measures.
- Implementation status of research and adaptive management experiments.
- Adopted changes to conservation measures and biological objectives through the adaptive management process.
- All reports and documents generated by the Implementation Office and relevant data and reports generated by other entities.

The database will incorporate controls and monitoring to ensure database integrity. It may be accessible via the Internet, but if not, a large fraction of the reporting documents produced under the BDCP will be so available.

The Science Manager will ensure quality control of all monitoring data and will adopt procedures to maintain high standards of quality, following protocols established by the Adaptive Management Team. Steps will be instituted to maintain the accuracy and functionality of gages, meters, and other devices, and protocols will be established to govern the collection, transcription, and storage of data. All monitoring data will be entered into database software and will be made available online once quality control analyses have been conducted.

3.6.6 References Cited

Allen, C. R., and L. H. Gunderson. 2011. Pathology and failure in the design and implementation of adaptive management. Journal of Environmental Management 92(5):1379-1384.

Atkinson, A. J., P.C. Trenham, R. N. Fisher, S. A. Hathaway, B. S. Johnson, S. G. Torres, and Y. C. Moore. 2004. *Designing Monitoring Programs in an Adaptive Management Context for Regional Multiple Species Conservation Plans.* U.S. Geological Survey Technical Report, USGS Western Ecological Research Center, Sacramento, CA.

Briceño-Linares, J. M., J. P. Rodríguez, K. M. Rodríguez-Clark, F. Rojas-Suárez, P. A. Millán, E. G. Vittori, and M. C. Carrasco-Muñoz. 2011. Adapting to Changing Poaching Intensity of Yellow-Shouldered Parrot (*Amazona Barbadensis*) Nestlings in Margarita Island, Venezuela. *Biological Conservation* 144(4):1188–1193.

CALFED Bay-Delta Program. 2000. *Ecosystem Restoration Program Plan. Volume II: Ecological Management Zone Visions*. Final Programmatic EIS/EIR Technical Appendix. Available: <http://www.delta.dfg.ca.gov/erp/docs/reports_docs/ERPP_Vol_2.pdf>.

Carignan, V., and M-A. Villard. 2002. Selecting Indicator Species to Monitor Ecological Integrity: A Review. *Environmental Monitoring and Assessment* 78:45–61.

Carignan, V., and M-A. Villard. 2004. Indicator species in environmental monitoring programs: conceptual and operational considerations. Pages 567-582 in: Wiersma, G. B. (ed.). *Environmental Monitoring*. CRC Press, Boca Raton, FL.

Caro, T. M., and G. O'Doherty. 1999. On the Use of Surrogate Species in Conservation Biology. *Conservation Biology* 13:805–814.

Chase, J. M., P. A. Abrams, J. P. Groverm, S. Diehl, P. Chesson, R. D. Holt, S. A. Richards, R. M. Nisbet, and T. J. Case. 2000. The Interaction between Predation and Competition: A Review and Synthesis. *Ecology Letters* 5:302–315.

Christensen, N. L., A. Bartuska, J. H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J. F. Franklin, J. A. MacMahon, R. F. Noss, D. J. Parsons, C. H. Peterson, M. G. Turner, and R. G. Moodmansee. 1996. The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. *Ecological Applications* 6:665–691.

Dahm, C., T. Dunne, W. Kimmerer, D. Reed, E. Soderstrom, W. Spencer, S. Ustin, J. Wiens, I. Werner. 2009. *Bay Delta Conservation Plan Independent Science Advisors' Report on Adaptive Management*. February. Prepared for the BDCP Steering Committee.

Dahm, C., D. Reed, E. Soderstrom, and J. Wiens. 2010. *Bay-Delta Conservation Plan Delta Science Program Panel Review of the Logic Chain Approach*. Prepared for the BDCP Steering Committee. Available:

<http://archive.deltacouncil.ca.gov/delta_science_program/pdf/BDCP_Logic_Chain_report_final.pdf>.

Delta Stewardship Council. 2013. *Delta Plan*. Available: <http://deltacouncil.ca.gov/delta-plan-0>.

DiGennaro, B., D. Reed, C. Swanson, L. Hastings, Z. Hymanson, M. Healey, S. Siegel, S. Cantrell, and B. Herbold. 2012. Using Conceptual Models in Ecosystem Restoration Decision Making: An Example from the Sacramento-San Joaquin River Delta, California. *San Francisco Estuary and Watershed Science* 10(3).

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. *Measuring and Monitoring Plant Populations*. Technical Reference 1730–1. Denver, CO: Bureau of Land Management.

Green, R. H. 1979. *Sampling Design and Statistical Methods for Environmental Biologists*. Chichester, UK: John Wiley & Sons, Inc.

Gregory, R., D. Ohlson, and J. Arvai. 2006. Deconstructing adaptive management: criteria for applications to environmental management. Ecological Applications 16(6):2411-2425.

Gunderson, L., and S. Light. 2006. Adaptive Management and Adaptive Governance in the Everglades Ecosystem. *Policy Science* 39:323–334.

Habron, G. B. 2003. Role of Adaptive Management for Watershed Councils. *Environmental Management* 31(1):29–41.

Healey, M. 2008. Science in Policy Development for the Bay-Delta. Page 174 in M. C. Healey, M. D. Dettinger, and R. B. Norgaard (eds.), *The State of Bay-Delta Science, 2008*. Sacramento, CA: The CALFED Science Program.

Holling, C. S. 1978. *Adaptive Environmental Assessment and Management*. New York, NY: John Wiley & Sons, Inc.

Hurlbert, Stuart H. 1984. Pseudoreplication and the Design of Ecological Field Experiments. *Ecological Monographs* 54(2):187–211.

Kaplan, R. S., and D. P. Norton. 2008. Mastering the Management System. *Harvard Business Review* 86(1):62–77.

Kati, V., P. Devillers, M. Dufrene, A. Legakis, D. Vokou, and P. Lebrun. 2004 Testing the Value of Six Taxonomic Groups as Biodiversity Indicators at a Local Scale. *Conservation Biology* 18(3):667–675.

Keith, D. A., T. G. Martin, E. McDonald-Madden, and C. Walters. 2011. Uncertainty and Adaptive Management for Biodiversity Conservation. *Biological Conservation* 144:1175–1178.

Landres, P. B., J. Verner, and J. W. Thomas. 1988. Ecological Use of Vertebrate Indicator Species: A Critique. *Conservation Biology* 2:316–328.

Lee, K. N. 1999. Appraising Adaptive Management. *Conservation Ecology* 3(2):3. Available: <http://www. consecol.org/Journal/vol3/iss2/art3>.

Lincoln-Smith, M. P., K. A. Pitt, J. D. Bell, and B. D. Mapstone. 2006. Using Impact Assessment Methods to Determine the Effects of a Marine Reserve on Abundances and Sizes of Valuable Tropical Invertebrates. *Canadian Journal of Fisheries and Aquatic Sciences* 63(6):1251–1266.

Lyons, J. E., M. C. Runge, H. P. Laskowski, and W. L. Kendall. 2008. Monitoring in the Context of Structured Decision-Making and Adaptive Management. *Journal of Wildlife Management* 72:1683–92.

Mackenzie, B. D. E., and D. A. Keith. 2009. Adaptive Management in Practice: Conservation of a Threatened Plant Population. *Ecological Management and Restoration* 10:S129–S135.

MacNally, R., and E. Fleishman. 2004. A Successful Predictive Model of Species Richness Based on Indicator Species. *Conservation Biology* 18:646–634.

Michener, W. K. 1997. Quantitatively Evaluating Restoration Experiments: Research Design, Statistical Analysis, and Data Management Considerations. *Restoration Ecology* 5(4):324–337.

National Research Council. 1999. *Sustaining Marine Fisheries*. Committee on Ecosystem Management for Sustainable Marine Fisheries, Ocean Studies Board, Commission on Geosciences, Environment and Resources. Washington D.C.: National Academy Press.

National Research Council. 2002. *Riparian Areas: Functions and Strategies for Management*. Committee on Riparian Zone Functioning and Strategies for Management, Water Science, and Technology Board. Washington, D.C.: The National Academies Press.

National Research Council. 2004a. *Adaptive Management for Water Resources Project Planning.* Washington, D.C.: The National Academies Press.

National Research Council. 2004b. *Managing the Columbia River: Instream Flows, Water Withdrawals, and Salmon Survival*. Washington, D.C.: The National Academies Press.

National Research Council. 2010. *A Scientific Assessment of Alternatives for Reducing Water Management Effects on Threatened and Endangered Fishes in California's Bay Delta*. Washington, D.C.: The National Academies Press.

National Research Council. 2011. *A Review of the Use of Science and Adaptive Management in California's Draft Bay Delta Conservation Plan*. Washington, D.C.: The National Academies Press.

Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for Long-Term Monitoring Protocols. *Wildlife Society Bulletin* 31(4):1000–1003.

Oglethorpe, J. (ed.). 2002. *Adaptive Management: From Theory to Practice*. Gland, Switzerland, and Cambridge, UK: IUCN.

Pahl-Wostl, C. 1995. *The Dynamic Nature of Ecosystems: Chaos and Order Entwined*. Chichester, UK: Wiley & Sons, Inc.

Parker, A., C. Simenstad, T. L. George, N. Monsen, T. Parker, G. Ruggerone, and J. Skalski. 2011. *Bay Delta Conservation Plan (BDCP) Effects Analysis Conceptual Foundation and Analytical Framework and Entrainment Appendix: Review Panel Summary Report.* Delta Science Program. Independent Scientific Review Panel. November. Available: <http://deltacouncil.ca.gov/sites/default/files/documents/files/BDCP_Effects_Analysis_Review_Panel_Report_FINAL.pdf>.

Parker, A., C. Simenstad, T. L. George, N. Monsen, T. Parker, G. Ruggerone, and J. Skalski. 2012. *Bay Delta Conservation Plan (BDCP) Effects Analysis Phase 2 Partial Review. Review Panel Summary Report.* Delta Science Program.

Reed, D., J. Anderson, E. Fleishman, D. Freyberg, W. Kimmerer, K. Rose, M. Stacey, S. Ustin, I. Werner, B. DiGennaro, and W. Spencer. 2007. *Bay Delta Conservation Plan Independent Science Advisors Report*. November 16.

Reed, D., K. D. Fausch, G. D. Grossman, and K. A. Rose. 2010. *Bay-Delta Conservation Plan. Delta Science Program Panel, Second Review of the "Logic Chain" Approach*. August 23. Available: <http://www.essexpartnership.com/wp-content/uploads/2010/10/Logic_Chain_review_August_2010_KB-revised-090710.pdf>.

Rumpff, L., D. H. Duncan, P. A. Vesk, D. A. Keith, and B. A. Wintle, 2011. State and Transition Modelling for Adaptive Management of Native Woodlands*. Biological Conservation* 144, 1224–1236.

Scheiner, S. M., and J. Gurevitch. 1993. *Design and Analysis of Ecological Experiments*. London: Chapman and Hall.

Stanford, J. A., and G. C. Poole. 1996. A protocol for ecosystem management. *Ecological Applications* 6:741–744.

State Water Resources Control Board. 2012. *Delta Water Quality - Delta Regional Monitoring Program*. Available: <http://www.swrcb.ca.gov/rwqcb5/water_issues/delta_water_quality/comprehensive_monitoring_program>. Accessed: November 16, 2012.

Underwood, A. J. 1992. Beyond BACI: The Detection of Environmental Impacts on Populations in the Real, but Variable, World. *Journal of Experimental Marine Biology and Ecology* 161:145–178.

Underwood, A. J. 1994. On Beyond BACI: Sampling Designs that Might Reliably Detect Environmental Disturbances. *Ecological Applications* 4:3–15.

Vail, L. W., and R. Skaggs. 2002. *Adaptive Management Platform for Natural Resources in the Columbia River Basin*. PNNL-13875. Richland, WA: Pacific Northwest National Laboratory. Available: <http://www.pnl.gov/main/publications/external/technical_reports/PNNL-13875.pdf>. Accessed: December 13, 2012.

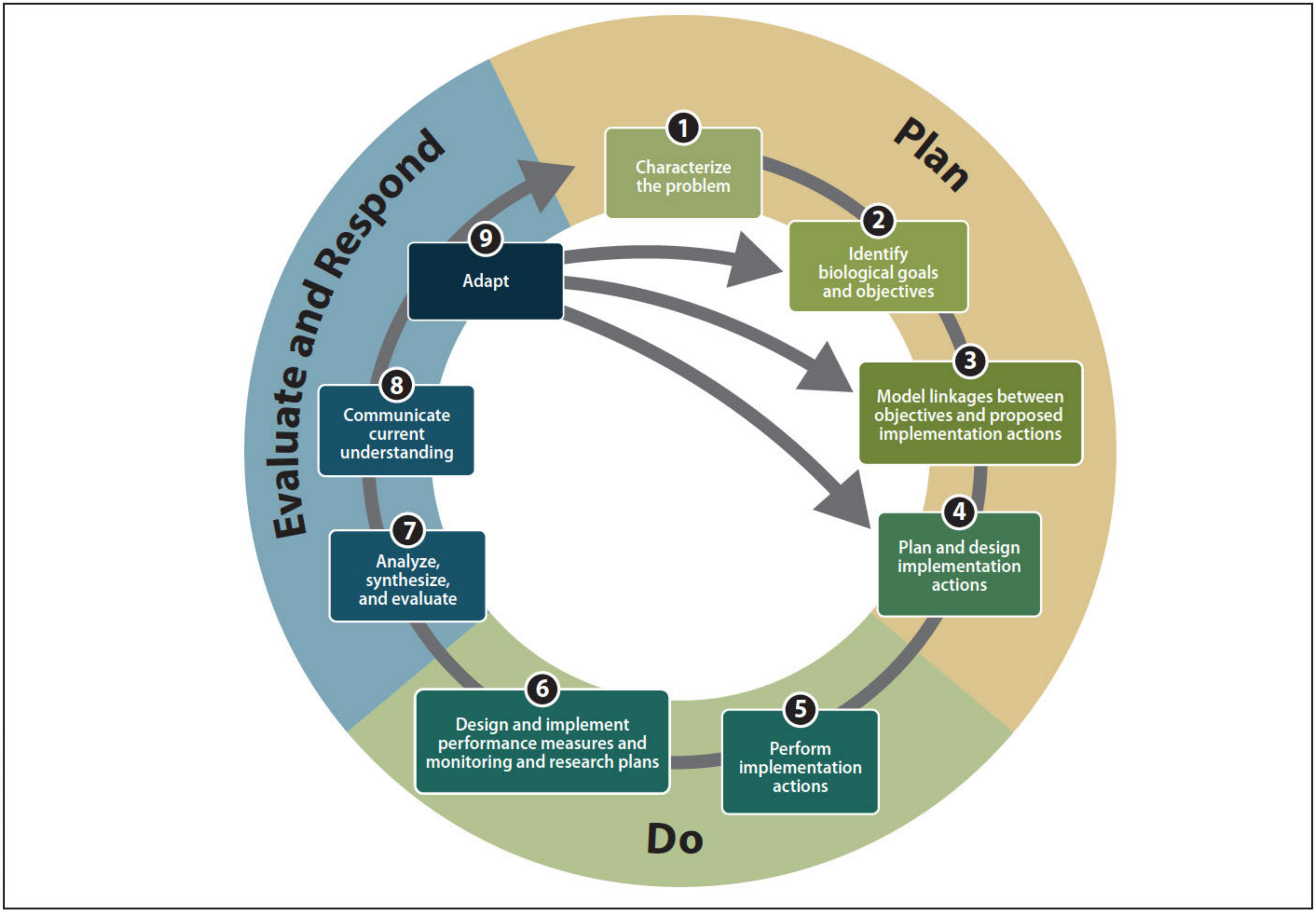
Walters, C. J. 1986. *Adaptive Management of Renewable Resources*. Caldwell, NJ: Blackburn Press.

Walters, C. J. 2007. Is adaptive management helping to solve fisheries problems? *Ambio* 36(4):304-307.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. *Adaptive Management: The U.S. Department of the Interior Technical Guide*. Washington, D.C.: Adaptive Management Working Group, U.S. Department of the Interior.

Williams, B. K. 2011a. Adaptive management of natural resources - framework and issues. Journal of Environmental Management 92(5):1346-1353.

Williams, B. K. 2011b. Passive and active adaptive management: Approaches and an example. Journal of Environmental Management 92(5):1371-1378.



Graphics... BDCP HCP 00343.12 (9/19/13) AB

Figure 3.6-1
Steps in the Adaptive Management Process