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Riders on the Storm: Selective Tidal Movements Facilitate the Spawning Migration of Threatened Delta Smelt in the San Francisco Estuary

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Abstract Migration strategies in estuarine fishes typically include behavioral adaptations for reducing energetic costs and mortality during travel to optimize reproductive success. The influence of tidal currents and water turbidity on individual movement behavior were investigated during the spawning migration of the threatened delta smelt, *Hypomesus transpacificus*, in the northern San Francisco Estuary, California, USA. Water current velocities and turbidity levels were measured concurrently with delta smelt occurrence at sites in the lower Sacramento River and San Joaquin River as turbidity increased due to first-flush winter rainstorms in January and December 2010. The presence/absence of fish at the shoal-channel interface and near the shoreline was quantified hourly over complete tidal cycles. Delta smelt were caught consistently at the shoal-channel interface during flood tides and near the shoreline during ebb tides in the turbid Sacramento River, but were rare in the clearer San Joaquin River. The apparent selective tidal movements by delta smelt would facilitate either maintaining position or moving upriver on flood tides, and minimizing advection down-estuary on ebb tides. These movements also may reflect responses to lateral gradients in water turbidity created by temporal lags in tidal velocities between the near-shore and mid-channel habitats. This migration strategy can minimize the energy spent swimming against strong river and tidal currents, as well as predation risks by remaining in turbid water. Selection pressure on individuals to remain in turbid water may underlie population-level observations suggesting that turbidity is a key habitat feature and cue initiating the delta smelt spawning migration.

Keywords Selective tidal movements · Tidal currents · Turbidity · Migration · Endangered species · San Francisco Estuary

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Introduction

Migration is a widespread life history strategy that optimizes the use of spatial and temporal variability in habitat quality to increase reproductive success and fitness of individuals (Dingle 1996). Characterizing this fascinating and complex phenomenon involves perspectives at various levels of biological organization, such that migration is most readily defined by the behavior of individuals, but then only fully understood in terms of population outcomes or consequences (Roff 1992; Dingle 1996). For fishes in estuarine and river systems, recent work has focused on quantifying cost/benefit trade-offs underlying the evolution of migration strategies. For any specific strategy to persist, the potential benefits (e.g., foraging and reproductive success) must outweigh the substantial costs in time and metabolic energy expended, as well as the added risks of mortality (e.g., predation) during migration (Jonsson and Jonsson 1993; Bronmark et al. 2008; Chapman et al. 2013). Theoretical and empirical studies (Roff 1988; Jorgensen et al. 2008) suggest migrants ameliorate costs through adaptive responses in various traits, including ecological (Schaffer and Elson 1975; Jonsson and Jonsson 2006), morphological (Crossin et al. 2004; Jonsson and Jonsson 2006), and behavioral (Hinch and Rand 2000;

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McElroy et al. 2012; Keefer et al. 2013). Accordingly, selection pressure to conserve energy for reproduction is more likely to be stronger on smaller or long-distance migrants and when spawning occurs soon after migrating (Kinnison et al. 2001; Crossin et al. 2004; Jonsson and Jonsson 2006).

Behavioral responses used by fishes to optimize cost/benefit trade-offs are often triggered by external cues and can include individual assessments of body condition and maturity level, as well as strategies for swimming against strong river and tidal currents (Brodersen et al. 2008a, b; Forsythe et al. 2012). Typically, external cues signal optimal times and routes for traveling that minimize predation risks and promote reproductive success. Thus, cues initiating migration are often somewhat predictable, including annual and monthly lunar cycles (Forsythe et al. 2012), seasonal water temperatures (Quinn and Adams 1996; Dahl et al. 2004), as well as tidal currents and river outflows (Anderson and Beer 2009; Forsythe et al. 2012). For many species, the energetic costs of swimming are tremendous. Atlantic salmon (*Salmo salar*) have been estimated to lose between 60 and 70 % of their energy reserves during migration and spawning (Jonsson et al. 1997), whereas sockeye salmon (*Onchorynchus nerka*) can use up to 84 % of their total energy reserves for swimming (Hinch and Rand 1998). This suggests that there is strong selection pressure to adjust travel speeds and distances, as well as position in tidal currents to conserve energy for reproduction. For example, sockeye salmon travel upriver in narrow bands near the shoreline where current speeds are lower than mid-channel (Hinch and Rand 2000), and Pallid sturgeon (*Scaphirhynchus albus*) appear to zigzag across river channels taking advantage of weaker currents on the inside of river bends as they migrate (McElroy et al. 2012).

In the present study, we investigate the effect of tidal currents and water quality variables (e.g., turbidity) on the individual movement behaviors used during the spawning migration by the threatened delta smelt, *H. transpacificus*, endemic to the northern San Francisco Estuary (SFE), California, USA. (Fig. 1). This small (<90 mm) semi-anadromous species is primarily an annual with a few individuals living to spawn in a second spring. Delta smelt was abundant historically, but declined dramatically over the last three decades, such that it is now protected under the California state and federal Endangered Species Act (ESA, USFWS 1993). Relatively little is known about spawning and reproduction in nature; adhesive embryos spawned by delta smelt have never been found (Moyle et al. 1992; Bennett 2005). Spawning in most years occurs primarily in the upper freshwater portions of the northern Delta during spring (March–June), with larvae and juveniles dispersing and rearing in the tidal freshwater to the low-salinity zone (<12) of the system (Fig. 1). This region expands to encompass Suisun Bay in years with moderate to high freshwater outflow and contracts in dry, or drought, conditions to include only the Delta (Bennett 2005, Fig. 1). During fall (September–November), maturing adults reside primarily in the low-salinity zone which also maintains elevated water turbidity relative to elsewhere due to wind-wave resuspension occurring over two large shallow (<3 m) sub-embayments, Grizzly and Honker Bays (Ruhl et al. 2001, Fig. 1).

Delta smelt undertake an annual spawning migration that appears to begin immediately following the arrival of turbid water from land runoff mobilized by the first major winter (December–February) rainstorm, the so-called first flush (Bergamaschi et al. 2001; Grimaldo et al. 2009; Sommer et al. 2011). The sudden increase in turbidity may reduce predation risks, signaling the optimal time for traveling upriver (about 15–20 km) to spawning habitat in the northern Delta (Grimaldo et al. 2009; Sommer et al. 2011). Although turbidity is a readily apparent cue associated with the delta smelt migration, other potentially co-occurring and interactive processes also may be involved (Rakowitz et al. 2008).

Our objectives were to (1) evaluate individual movement behavior in relation to the prevailing hydrodynamics at tidal time scales to understand how this small pelagic fish is able to travel upriver against strong river and tidal flows (ca. 1,800 m^3 s^{-1}) and (2) explore if processes observed at the individual and tidal scales can help to explain the apparent roles of turbidity as a habitat feature (Feyrer et al. 2007) and a cue for the spawning migration at the population level (Grimaldo et al. 2009; Sommer et al. 2011). Here, we distinguish *movements* as those made by individuals over a few meters at tidal time scales, and *migration* as a distributional shift occurring annually over kilometers and months at the population level. Our study occurred in two consecutive winters, integrating monitoring of hydrodynamics, water turbidity, salinity, and temperature, concurrently with sampling for fish. Understanding how individual behaviors interact with tidal currents and water quality is essential to gain insight into the processes promoting pelagic habitat for estuarine species and the evolution of migration.

Methods

Study Area

The Delta region of the SFE is composed of a complicated network of tidally forced channels and canals that is considered one of the most highly altered terminal floodplain ecosystems (Lund et al. 2010, Fig. 1). The Delta is used primarily to transfer freshwater from the Sacramento River in the north and San Joaquin River in the south to central and southern California via canals of the State Water Project and Central Valley Project (Lund et al. 2010, Fig. 1). The diverted freshwater supports production of about one half of the fruits and vegetables in the USA and provides drinking water for about 25 million Californians. Water-exporting operations, however,

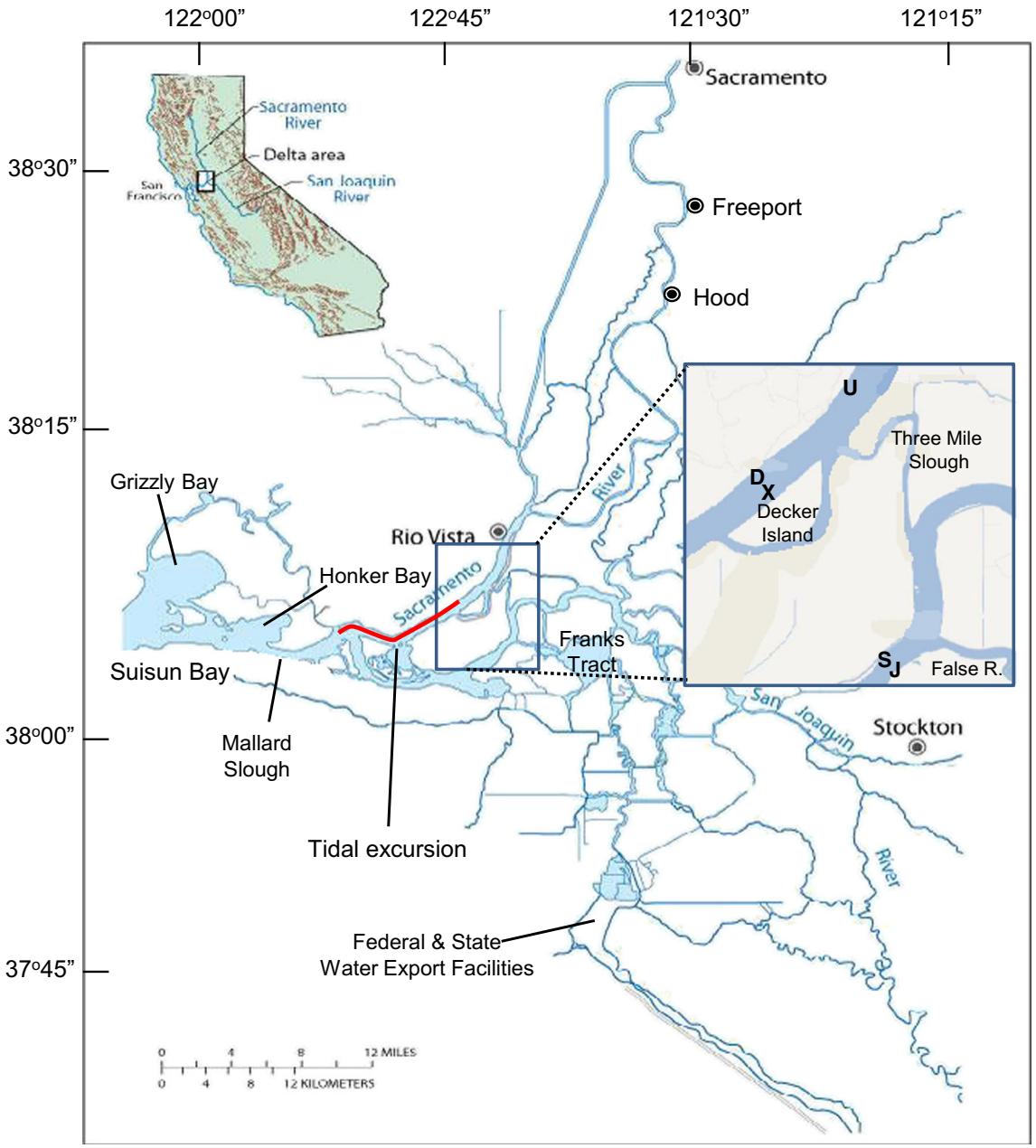


Fig. 1 Map of study area in the lower Sacramento River and San Joaquin River in the northern San Francisco Estuary, CA, USA. *Letters* show location of sampling stations and typical tidal excursion (*thick line*)

also kill large numbers of fish, including delta smelt (Kimmerer 2008; Grimaldo et al. 2009). ESA regulations intended to minimize entrainment mortality of delta smelt often restrict water-exporting operations and interfere with allocations of freshwater throughout California, which has unfortunately intensified controversy and litigation focusing on this imperiled species.

Study Design

Our study was conducted in the lower Sacramento River and San Joaquin River, two potential migration routes for delta smelt in the western Delta (Fig. 1). While the Sacramento River is likely the primary route, in some years, individuals enter the San Joaquin River and travel through the central Delta, which increases the chance of entrainment in the water export facilities (Grimaldo et al. 2009). Our fieldwork coincided with the first major winter storms producing the first flush and occurred on January 27–28, 2010 and then December 21, 2010 to January 1, 2011. Sampling integrated continuous monitoring of hydrodynamics, water turbidity, salinity, and temperature, concurrently with sampling for fish to quantify the pelagic microhabitat typically used by delta smelt at tidal time scales. Based on velocity measurements

taken at this location using a horizontal acoustic Doppler profiler (Burau, unplublished data), we decided to sample hourly at fixed locations. This would enable sampling of 8–12 km of river water and fish habitat as it moved past our position by strong tidal currents (ca. 85 cm s^{-1}) over a complete tidal cycle, depending on the spring/neap lunar phase (Fig. 1).

During the January 2010 study, hereafter referred to as the Pilot Study, sampling occurred only near Decker Island in the lower Sacramento River (D, Fig. 1), whereas during the following winter (December 2010), sampling alternated daily between sites in the Sacramento River and those near Jersey Point in the San Joaquin River (Fig. 1). The bathymetry in this reach of the Sacramento River is relatively prismatic (i.e., uniform in cross section) within about 18 km of our sampling location, because it was completely man-made by dredging during the late 1800s for flood control. Thus, because this reach of the river is wide (ca. 900 m), relatively shallow (ca. 10 m), and prismatic, it has very weak lateral mixing and other potential complicating hydrodynamic factors; particles released in this region tend to return to their original release point on subsequent tide (Fischer et al. 1979; Nidzieko et al. 2009). This facilitates separating behavioral responses from hydrodynamic influences on responses of fish to changes in tidal current direction and water clarity. In contrast, the hydrodynamics at the San Joaquin location are more complex, with water mixed by secondary currents in nearby bends and exchanging with side channels such that it can come from different regions of the Delta (Fig. 1).

In the Sacramento River, we chose our sampling sites along the northwestern side of the river just inside the channel marker buoys, where tidal fronts regularly occur at the shoal-channel interface (Fig. 1). Our rationale was based on the well-documented observation that a variety of pelagic organisms, including small fishes, tend to exploit open-water habitat by aggregating at tidal fronts (Owen 1981; Maravelias and Reid 1997; Marchand et al. 1999). A horizontal acoustic Doppler current profiler (H-ADCP, ChannelMaster, Teledyne RD Instruments) calibrated using the index velocity method (Ruhl and Simpson 2005; Coz et al. 2008) was deployed from a channel marker and continuously monitored river discharge and tidal current velocity distribution at mid-depth; electrical conductivity, temperature, and turbidity were also measured using a 6,600 V2-4 MultiSonde (YSI, Inc.) and available in real-time throughout the study via a RavenXTV CDMA Sierra Wireless Cellular Modem (Campbell Scientific, Inc.). Additional water current velocity and turbidity data (e.g., used in Fig. 2) collected by the U.S. Geological Survey were measured as part of the Interagency Ecological Program's continuous monitoring program (http://www.water.ca.gov/iep/).

Overall, sampling for fish occurred hourly over 12–16 h, to encompass complete tidal cycles which varied in duration

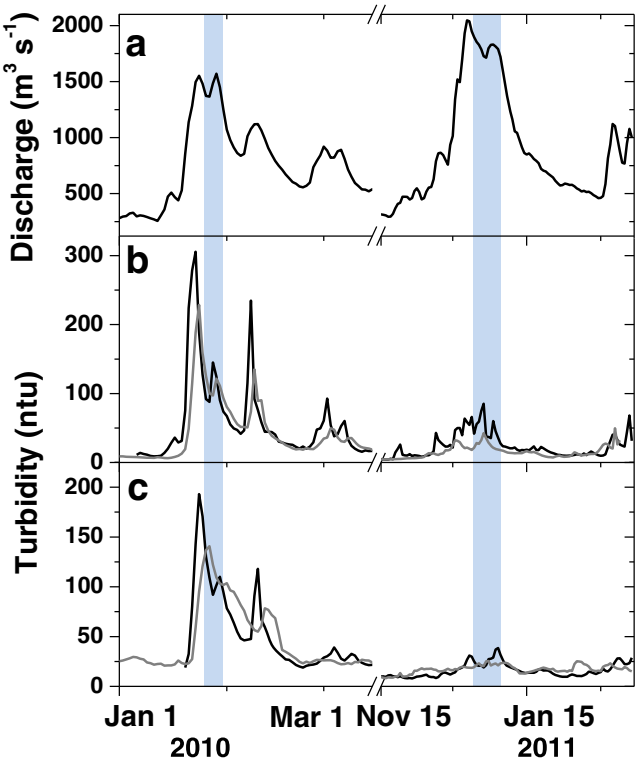


Fig. 2 Sacramento River flow (*a*) and turbidity levels at Freeport (*black line*) and Rio Vista (*gray line*) (*b*), as well as Decker Island (*black*) and Mallard Slough (*gray*) in the lower San Joaquin River (*c*) from January 2010 to March 2011. *Vertical shading* shows both study periods

with the magnitudes of river flow and the tides. Each day of sampling required several field crews working concurrently at different locations and began at the top of the hour nearest time of slack water estimated using the real-time data from the hydrodynamic instruments. Fish were sampled in the upper 4 m of the water column using Kodiak trawls, which involves towing a 7.6×1.8-m net with mesh that tapers from 50 mm at the mouth to 6 mm at the cod end. This presents a cross-sectional area of about 14 m^2 when the net is stretched between two boats running in parallel. During each winter study, a crew with a Kodiak trawl sampled hourly at station D near Decker Island in the lower Sacramento River (Fig. 1). In the December 2010 study, another crew also sampled concurrently with a 15.2×1.2-m beach seine with a 3-mm mesh along the adjacent shoreline at station D, with an additional Kodiak trawl and beach seine crews also sampling immediately upriver, near Three Mile Slough (station U, Fig. 1). Station U was located about one third of the distance of the maximum tidal excursion from station D (Fig. 1). If delta smelt were caught at station D during the flood tide, we might expect to detect them at station U after a few hours if fish were moving upriver with the incoming tide. The crew sampling at station U alternated hourly with station X, located mid-channel directly offshore from station D to assess the extent to which delta smelt were distributed laterally (Fig. 1).

Table 1 Numbers of fish caught in Kodiak trawl and beach or purse seines in the Sacramento and San Joaquin Rivers on January 27–28, 2010 (1/10) and from December 21, 2010 to January 1, 2011 (12/10–1/11)

Species	Sacramento River			San Joaquin River		
	Kodiak Trawl 1/1012/10-1/11		Beach Seine	Kodiak Trawl	Purse seine	Total
Delta smelt *Hypomesus transpacificus*[a]	225	479	176	3	0	883
Threadfin shad *Dorosoma petenense*	73	359	182	38	13	665
Chinook salmon *Oncorhyncus tshawytscha*[a]	129	237	1,594	13	5	1,978
Mississippi silverside *Menidia beryllina*	35	151	821	5	55	1,067
Pacific lamprey *Lampetra tridentata*[a]	7	59	0	0	0	66
Longfin smelt *Spirinchus thaleichthys*[a]	20	48	7	0	0	75
American shad *Alosa sapidissima*	6	27	0	15	0	48
Bluegill *Lepomis macrochirus*	5	9	8	7	1	30
River lamprey *Lampetra ayresi*[a]	1	11	0	0	0	12
Tule perch *Hysterocarpus traski*[a]	1	1	20	4	62	88
Striped bass *Morone saxatilis*	2	3	639	0	293	937
Splittail *Pogonichthys macrolepidotus*[a]	13	4	59	0	24	100
Sacramento pikeminnow *Ptychocheilus grandis*[a]	15	0	26	1	1	43
Yellowfin goby (*Acanthogobius flavimanus*)	0	3	21	2	8	34
Wakasagi *Hypomesus nipponensis*	3	3	17	0	1	24
Bigscale logperch *Percina macrolepida*	0	0	1	0	46	47
Hitch *Lavinia exilicauda*[a]	0	0	12	0	11	23
Redear sunfish *Lepomis microlophis*	0	0	4	0	3	7
Shimofuri goby *Tridentiger bifasciatus*	2	3	7	0	0	12
Rainbow trout *Oncorhynchus mykiss*[a]	7	2	0	0	0	9
Largemouth bass *Micropterus salmoides*	0	1	0	1	2	4

Only Kodiak trawls were used during the 1/10 sampling

[a] Denote 513 native species

Every other day during the December 2010 study, we sampled in the San Joaquin River with a Kodiak trawl crew that alternating hourly between station S, at the shoal-channel interface, and station J, located on the opposite side of the main channel (Fig. 1). These two locations were chosen so that we sampled water that exchanged into different regions of the central Delta. For example, on ebb tides, water at station S is transported from the San Joaquin River, whereas at station J, water arrives from the southern Delta via the False River (Fig. 1). Thus, by sampling laterally at this single location, we could compare and contrast two distinct routes of potential fish transport, assuming fish move with the water. If delta smelt were detected at station J, the prevailing hydrodynamics associated with dispersive mixing in Franks Tract would substantially increase the probability for these fish to become vulnerable to the major water export facilities in the south Delta (Fig. 1). At station S, a separate crew used a 30-m purse seine with a 5-mm mesh to sample near the shoreline because of the logistical difficulties associated using a beach seine at this location.

Given that both delta smelt and winter run Chinook salmon, *Oncorhynchus tshawytscha*, co-occurred in our study area and are both protected under the federal ESA, strict fish-take limits were imposed with catch reported daily to the regulatory agencies. Although delta smelt occur in very low densities, we closely monitored catch and adjusted sampling effort (tow durations) in real time to avoid excessive take of these species. Thus, we tailored sampling to reliably detect delta smelt presence/absence rather than quantify overall density. All fish caught during sampling were first identified and measured for length. The majority of juvenile Chinook salmon were then released immediately unharmed, as were other fishes in the catch. About 30 % of the delta smelt in the catch appeared unharmed and were swimming normally after capture, thus were also released. Although fewer individuals of this fragile species survived relative to others, the proportion released was higher than anticipated and likely due to reducing trawl durations from 15 to 10 min. The remaining delta smelt were then coded and individually rolled up in aluminum foil and placed into a dewar containing liquid nitrogen and archived. Hydrodynamic and delta smelt catch data were initially explored using various graphical techniques. Generalized linear modeling (GLM) was then used to evaluate an apparent association between tidal current direction and delta smelt catch.

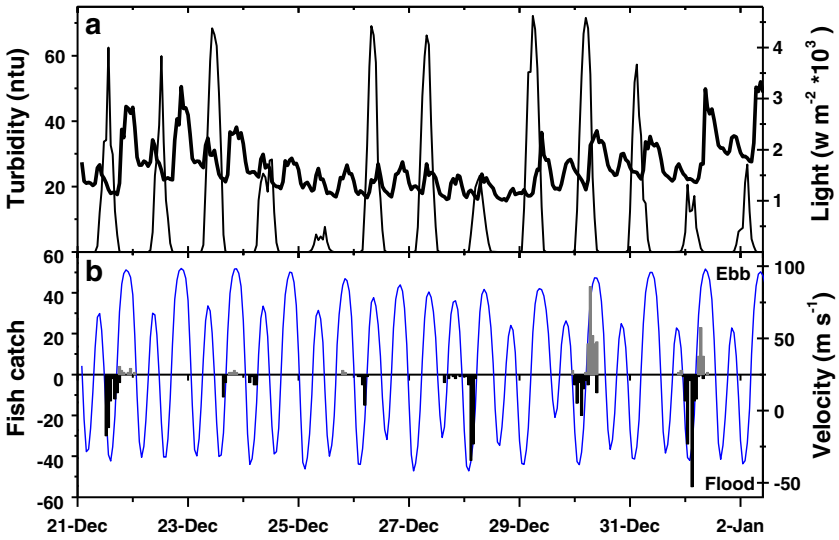


Fig. 3 Trends in turbidity (*thick line*) and light intensity (*a*) with delta smelt catch at shoal-channel margin (*dark bars*) and near the shoreline (*gray bars*) in relation to tidal and river flows (*b*), from the December 2010 field sampling in the Sacramento River. Negative water velocity represents flood tides

Results

Physical Conditions

Patterns of rainfall, river discharge, and turbidity differed substantially between the two winter study periods (Fig. 2). During the 2009–2010 winter of the Pilot Study, river flows were relatively low, peaking at only about 1,557 m^3 s^{-1} (Fig. 2(a)), but were apparently sufficient to mobilize higher levels of turbidity (~350 nephelometric turbidity units (NTU) at Freeport, Fig. 2(b)) than those observed in the following winter season. After the December 2010 "first flush" rainstorm, however, turbidity levels were far lower than anticipated (~50–80 NTU) at our Sacramento River study area and did not increase in the San Joaquin River (Fig. 2(b, c)). This was surprising given that flows in the Sacramento River peaked at 2,124 m^3 s^{-1} (Fig. 2). These unusually low turbidity levels likely resulted from intentional releases of relatively clear water from reservoirs in the upper watershed to accommodate the large volumes of runoff projected from this storm. The reservoir releases were substantial, constituting 30–80 % of the flow in the Sacramento River during December–January, whereas they typically only make up about 10 % of the river flow. As a result, the slight increases in turbidity observed in the lower Sacramento River were derived from turbid water extending upriver on flood tides to our study area from Suisun Bay, given that the highest levels occurred primarily during flood tides.

Table 2 Results of alternative generalized linear models associating delta smelt occurrence with environmental conditions at the shoal-channel margin versus the near the shoreline, including *z*-statistics, probabilities of significance, and Akaike Information Criteria (AIC)

Model	Variable					
	Velocity (CMS)	Turbidity (NTU)	Hour (h)	Year	CMS×NTU	AIC
Channel margin						
CMS	−5.78***					127
NTU		−3.98***				153
CMS+NTU	−5.09***	−2.39*				122
CMS+NTU+h	−4.37***	−2.41*	−0.813			124
CMS+NTU+Year	−4.15***	−2.41*		1.16		123
CMS+NTU+CMS×NTU	−2.59**	−2.09*			1.19	123
Shoreline						
CMS	4.24***					76
NTU		3.96***				92
CMS+NTU	3.22**	0.36				78
CMS+h	3.82***		1.03			77

*p<0.05; **p<0.01; ***p<0.001

Fish Catch

Overall, 21 fish species were collected during the two winter sampling periods, with catch composition varying greatly between the Sacramento River and San Joaquin River, as well as in the Kodiak trawls versus the beach or purse seines (Table 1). Pelagic species, such as delta smelt and threadfin shad, *Dorosoma petenense*, were most abundant in the Kodiak trawls, whereas juvenile Chinook salmon and Mississippi silversides, *Menidia beryllina*, dominated the catch in the shoreline sampling. During the Pilot Study, 225 delta smelt and 129 juvenile Chinook salmon were caught in the Pilot Study, with 655 and 1,831 of each species respectively caught during the December 2010 sampling period. Juvenile Chinook salmon and Mississippi silversides, *M. beryllina*, dominated the catch in the shoreline sampling. In contrast, only 3 delta smelt and 18 juvenile Chinook salmon were caught at the San Joaquin River locations (Table 1).

Delta smelt were caught fairly consistently by focusing our sampling near the shoal-channel interface during both the Pilot Study and the December 2010 study period. At this location (D, Fig. 1), 82 % of net tows occurring on flood tides detected delta smelt relative to 67 % of samples taken nearby at the mid-channel station (X, Fig. 1). The higher detection of delta smelt at the interface facilitated identifying a clear tidal signal in the catch time series, such that during flood tides, delta smelt were caught almost exclusively in the Kodiak trawls, whereas on ebb tides, they were primarily caught in the beach seines at the shoreline stations (Fig. 3). Delta smelt catch in the Kodiak trawls was also somewhat higher when turbidity levels were elevated and in the morning (Fig. 3).

Generalized linear models with a binomial error distribution and a logit link function (i.e., logistic regression) were used to associate delta smelt occurrence (i.e., presence/absence) in the Kodiak trawls and beach seines with tidal velocity, water turbidity, time of day, and calendar year sampled as predictor variables (Table 2). Overall, variability in water temperatures and specific conductance was low, averaging 10 °C (range=1.8 °C) and 116 μS cm^{-1} (range=149 μS cm^{-1}), respectively. In preliminary analyses, both factors were not significant predictors, thus were not included in the final analyses. For the Kodiak trawl samples, the optimal model explaining fish occurrence included water current velocity (t=−5.36, df=90, P<0.0001) and turbidity (t=−5.36, df=90, P<0.0001), whereas for the beach seine samples, only current velocity (t=4.24, df=90, P<0.0001) was retained as a significant predictor (Table 2). Hour of the day and winter sampled as well as an interaction term with velocity and turbidity were not significant (Table 2). The best-fit models for fish presence/absence by gear type exhibit inverse relationships with water current velocity; during flood tides, probabilities of occurrence increased on flood tides in the Kodiak trawls and during ebb tides in the beach seines (Fig. 4a). While the flood-ebb tidal asymmetry in delta smelt occurrence was also apparent during the nighttime, the overall catch was much lower. Cumulative frequency distributions of fish catch over time indicate that more delta smelt were caught in the Kodiak trawls before mid-day, whereas they more frequently appeared in the beach seines later in the afternoon and evening (Fig. 4b).

Discussion

Our results from two sampling periods in consecutive years indicate that during winter, delta smelt aggregate near frontal zones at the shoal-channel interface moving laterally into the shoals on ebb tides and back into the channel on flood tides. For a small pelagic fish attempting to migrate upriver against strong river flows and tidal currents, this behavioral strategy would facilitate either maintaining position or moving upriver during flood tides, whereas on ebb tides, it would help to minimize advection down-estuary. Delta smelt have been shown to prefer modest swimming velocities and a discontinuous stroke and glide behavior in the laboratory, prompting Swanson et al. (1998) to suggest that selective tidal stream transport would be likely employed during the spawning migration. Sommer et al. (2011) using a particle-tracking

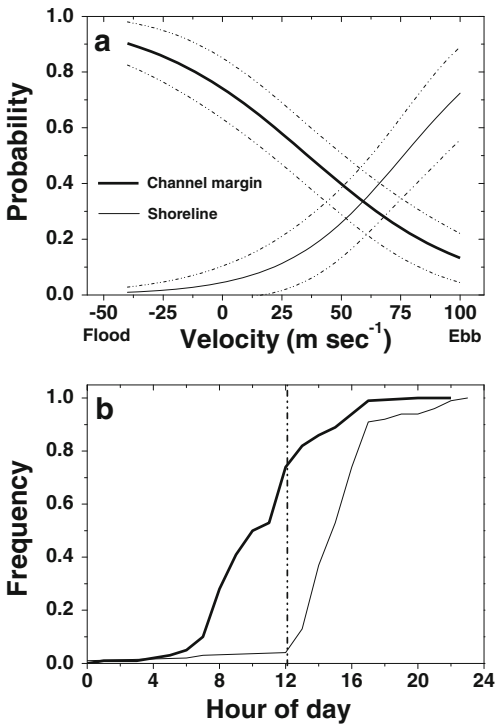


Fig. 4 Generalized linear model fits of delta smelt occurrence to tidal velocity (**a**) and cumulative distributions of catch relative to sampling hour of the day (**b**) at the shoal-channel margin (*thick line*) and near the shoreline (*thin line*) with 95 % confidence limits, respectively, from the December 2010 field sampling in the Sacramento River

model showed that moving upriver was only plausible if fish exhibited tidally selective vertical movements; simulating lateral migration was not possible with their one-dimensional vertically averaged model. Indeed, given the small body size, observed swimming behaviors, and extreme flow velocities typically observed on ebb tides during storms (>1,500 $m^3 s^{-1}$), it is unlikely that vertical tidal movements would facilitate migration. Although fewer delta smelt were caught during the night, the same tidal asymmetry was evident in the catch. Delta smelt are visual foragers, thus are more highly aggregated nearer the surface during the daytime (Hobbs et al. 2006). Lower catch at night is likely due to these fish being more dispersed throughout the water column in darkness, a pattern also observed for larval smelt in the low-salinity zone (Bennett et al. 2002). Such higher dispersion is sufficient to lower catch efficiency of the Kodiak trawl net at night which samples only the upper portion of the water column.

These results also indicate the effectiveness of tuning our sampling routine closely to the scales of the processes in question. Standard monitoring surveys that sample monthly across a fixed sample grid, irrespective of the tides, may be useful for detecting trends in distribution or abundance over many years, but they are hampered by considerable observational bias due to tidal aliasing and are thus not sufficient for addressing finer-scale or process-oriented questions. By focusing our sampling close to the shoal-channel interface, we detected (caught) delta smelt in 82 % (station D, Fig. 1) of net tows during flood tides, whereas detections declined to 67 % at the nearby mid-channel station (X, Fig. 1). Moreover, improving our understanding of how these fish interact with the tides also provides key information on the microhabitat preferences and behaviors essential for adapting monitoring programs, and management options for delta smelt and other pelagic fishes in tidally dominated systems.

The apparent selective tidal movements may also be in response to lateral turbidity gradients that can develop near slack water (Yu et al. 2012). In the shoals, shallow depths and slower tidal currents due to increased friction with the shoreline substantially reduces momentum, such that currents switch direction in the shallows before changing in the center of the river channel (by as much as about an hour) where it is deeper and currents are stronger. This temporal asynchrony in tidal timing, in the presence of a prominent along-channel turbidity gradient in the Sacramento River, can produce lateral turbidity gradients near slack water (Fig. 5). When the turbidity source for the along-channel gradient switches from down-estuary in Suisun Bay before the first flush to upriver in the Delta afterwards, inverse patterns in these lateral turbidity gradients are produced with respect to the tides (Fig. 5). Before first flush, as the ebb tide begins, relatively clear water moves downriver along the shoals before it appears in the channel (Fig. 5(a)); on the flood, the reverse occurs with water of higher turbidity moving upriver near shore before the channel (Fig. 5(b)). Thus, if fish attempt to remain with turbid water, they are likely to move upriver near the shoals first and then in the channel as the flood develops, but then travel back down-estuary on the ebb, because clearer water arrives in the shoals first which discourages lateral movement. After first flush,

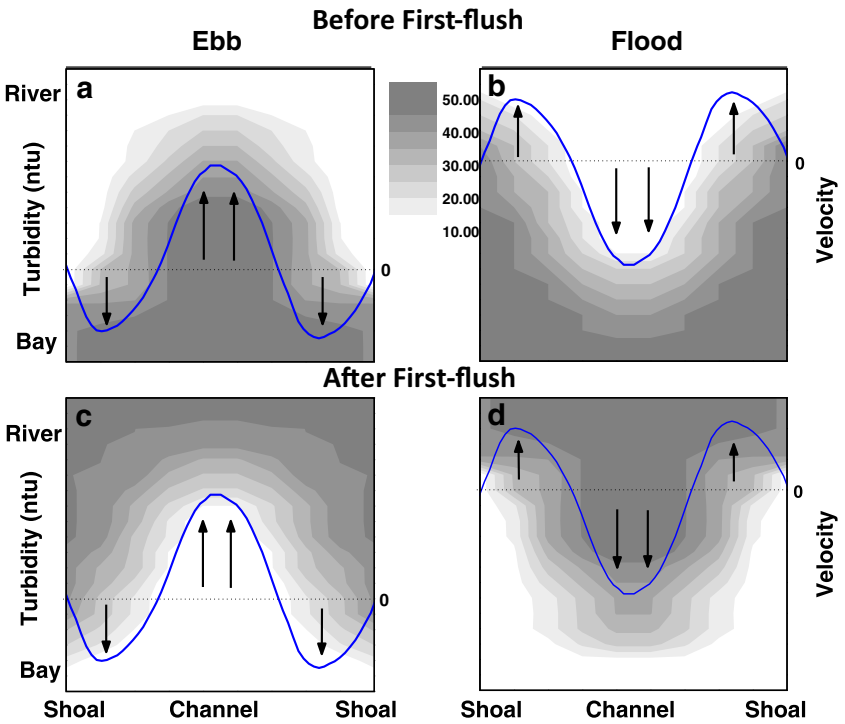


Fig. 5 Conceptual diagram showing how cross-channel gradients in water turbidity (*shaded*) develop from temporal asynchronies in near-shore versus mid-channel tidal velocities near slack water (*line*, *vector arrows*), as well as how these gradient patterns reverse when the source of turbidity along-channel switches from down-estuary to upriver, before (**a**, **b**) and after (**c**, **d**) the first-flush winter rainstorm

the turbidity source is from upriver, which then reverses both the along-channel and lateral gradients (Fig. 5(c, d)). Now, as the flood tide begins, water in the channel remains turbid while clearer water from down-estuary arrives in the shoals first which discourages onshore movements by fish such that they remain in the turbid channel and move upriver with the tide (Fig. 5(d)). Thus, after the first flush, the coherence of lateral turbidity gradient and tidal current allows fish to greatly reduce the energy needed to swim upriver, even if they are only attempting to remain in turbid water as the tide changes direction.

Our results, thus far, cannot distinguish the relative importance of turbidity versus changing tidal direction as cues for moving laterally or for the spawning migration. Selective tidal movements are a common strategy among marine and estuarine organisms (e.g., review by Forward and Tankersley 2001); however, little is known concerning if or how individuals detect tidal currents and direction (Chapman et al. 2013), with the possible exception of blue crab (*Callinectes sapidus*) larvae (Forward et al. 2003). Related strategies for migrating have been reported for sockeye salmon (Hinch and Rand 2000) and Pallid sturgeon (McElroy et al. 2012). For delta smelt with a primarily annual life cycle, the advantages of moving laterally are likely to vary greatly given the high interannual variability in freshwater outflows. Extremely high outflow in wet years can weaken or completely overwhelm the flood tidal signal in the Sacramento River and thus preclude or impair maturation and the reproductive output of spawning individuals (Kinnison et al. 2001; Bronmark et al. 2008). In such years, fish may choose to reproduce in suboptimal habitat or migrate up the San Joaquin River which has lower outflows, but this increases potential mortality by moving fish toward the water export facilities (Grimaldo et al. 2009). Nonetheless, there is likely strong selection pressure to use both cues for moving laterally, such that adaptive responses to turbid water by individuals may underlie observations at the population level suggesting that it is a cue for the spawning migration (Grimaldo et al. 2009). When considered in the cost-benefit trade-off proposed by Bronmark et al. (2008), turbidity may sufficiently reduce predation risks relative to potential growth and reproductive benefits, tipping the balance in favor of migrating. Understanding these processes may facilitate development of management tools using turbidity to reduce entrainment impacts not only on imperiled species, such as delta smelt, but also on others occurring in highly dynamic systems subjected to human interventions and future changes in climate.

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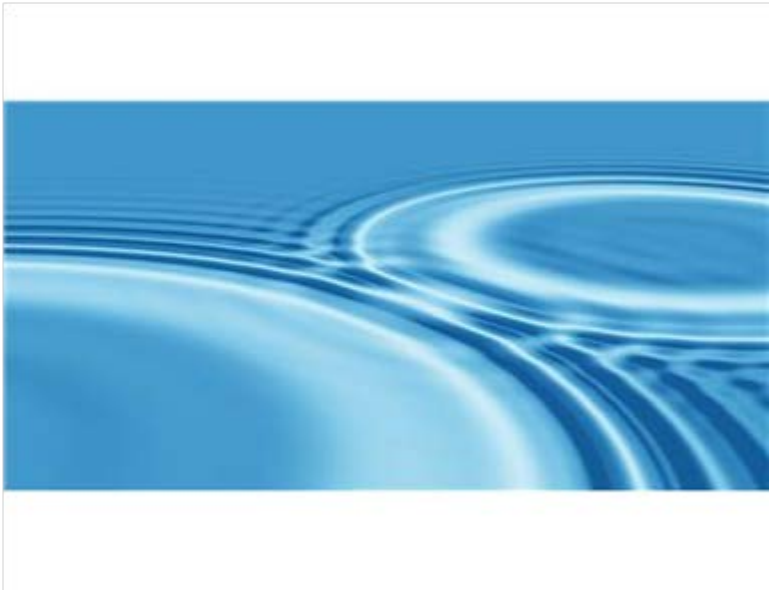
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California Water Action Plan



CALIFORNIA natural resources AGENCY

cdfa CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY (CAL/EPA)

Among all our uncertainties, weather is one of the most basic. We can't control it. We can only live with it, and now we have to live with a very serious drought of uncertain duration.

Right now, it is imperative that we do everything possible to mitigate the effects of the drought. I have convened an Interagency Drought Task Force and declared a State of Emergency. We need everyone in every part of the state to conserve water. We need regulators to rebalance water rules and enable voluntary transfers of water and we must prepare for forest fires. As the State Water Action Plan lays out, water recycling, expanded storage and serious groundwater management must all be part of the mix. So too must be investments in safe drinking water, particularly in disadvantaged communities. We also need wetlands and watershed restoration and further progress on the Bay Delta Conservation Plan.

It is a tall order.

But it is what we must do to get through this drought and prepare for the next.

Edmund G. Brown Jr.
State of the State Speech, January 22, 2014

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California Water Action Plan: Actions for Reliability, Restoration and Resilience

Introduction

California has seen many flood events, including the most recent flood of 1995 when 48 of 58 counties declared a state of emergency. After two years of dry weather and shrinking reservoir supplies, we are reminded once again that nothing focuses Californians' attention on our limited water resources like drought.

There is broad agreement that the state's water management system is currently unable to satisfactorily meet both ecological and human needs, too exposed to wet and dry climate cycles and natural disasters, and inadequate to handle the additional pressures of future population growth and climate change. Solutions are complex and expensive, and they require the cooperation and sustained commitment of all Californians working together. To be sustainable, solutions must strike a balance between the need to provide for public health and safety (*e.g.*, safe drinking water, clean rivers and beaches, flood protection), protect the environment, and support a stable California economy. This action plan lays out our challenges, our goals and decisive actions needed now to put California's water resources on a safer, more sustainable path. While this plan commits the state to moving forward, it also serves to recognize that state government cannot do this alone. Collaboration between federal, state, local and tribal governments, in coordination with our partners in a wide range of industry, government and nongovernmental organizations is not only important—it is essential. The input and contributions received from all of these partners throughout the drafting of this action plan have resulted in a comprehensive and inclusive plan.

Challenges for Managing California's Water Resources

Water has always been a scarce resource in California. Most of the precipitation falls on the west-facing slopes of Northern California mountain ranges, yet most of the population and irrigated farmland is located in the drier southern half of the state. Precipitation is highly variable year-to-year, but the long warm summers are always dry. In the mid-20th century, state, federal and local agencies vastly expanded the state's system of reservoirs, canals, pumps and pipelines to store water and deliver it to agricultural and urban users in dry areas. Also, in the late 20th century, significant investments were made in the state's flood protection system, including levees and bypasses. These changes to the physical infrastructure have resulted in unintended consequences to the natural world. In general, there is broad consensus about our challenges.

> ***Uncertain water supplies –*** Reductions in water from major watersheds like the Colorado River watershed and the Sacramento-San Joaquin Delta (Delta) watershed—due to hydrologic and declining environmental conditions—have made these water supplies less reliable. Moreover, climate change impacts to these sources and the Cascade and Sierra headwaters will further strain supply reliability throughout the state. These sources are foundational supplies around which communities develop and manage local resources through strategies such as water use efficiency, recycled water, and groundwater recharge. The unreliable nature of these supplies threatens local, regional and statewide economies. **Collectively, the actions in this plan will contribute to more reliable water supplies**.

Water scarcity/drought – California's hydrology has always included extended dry periods. Much of California's water system was originally designed to withstand a seven-year dry period without severe damage to the economy and environment. Today some regions and many communities struggle to maintain adequate water supplies after only a year or two of dry conditions. Climate change makes this situation even more challenging. Less outflow of water coming from the Cascades and Sierras during periods of drought increases seawater intrusion into the Delta. Improving our ability to manage scarce water supplies and over-stressed groundwater basins and better coordination of major reservoir operations is essential to economic and environmental sustainability. Taking action to address drought is especially urgent for agriculture where crops wither without water, and the world's growing population and food demand create food security concerns. **This action plan includes both immediate steps for 2014 as well as actions that will better prepare California for future droughts.**

Declining groundwater supplies – Groundwater accounts for more than one-third of the water used by cities and farms – much more in dry years, when other sources are cut back. Some of California's groundwater basins are sustainably managed, but unfortunately, many are not. Inconsistent and inadequate tools, resources and authorities make managing groundwater difficult in California and impede our ability to address problems such as overdraft, seawater intrusion, land subsidence, and water quality degradation. Pumping more than is recharged lowers groundwater levels – which makes extracting water more expensive and energy intensive. Under certain conditions, excessive groundwater pumping could mobilize toxins that impair water quality and cause irreversible land subsidence which damages infrastructure and diminishes the capacity of aquifers to store water for the future. When properly managed, groundwater resources will help protect communities, farms and the environment against the impacts of prolonged dry periods and climate change. **The strategies identified in this action plan will move California toward more sustainable management of our groundwater resources.**

Poor water quality – It is a fact that millions of Californians rely, at least in part, on contaminated groundwater for their drinking water. While most water purveyors blend or treat water to meet public health standards, many disadvantaged communities cannot afford to do so. In addition, domestic wells are drying up in many areas. All Californians have a right to safe, clean, affordable and accessible water adequate for human consumption, cooking and sanitary purposes. Safe water is necessary for public health and community prosperity. **The methods set forth in this action plan will improve the organization of our water quality programs and create new tools to help ensure that every Californian has access to safe water.**

Declining native fish species and loss of wildlife habitat – California's once robust native fish populations are at or near historic lows. Federal and state fish agencies now list many species of salmon and other fish as endangered and threatened. Wildlife habitat is also being lost at a rapid pace. Climate change further threatens the state's natural biodiversity. Many do not understand that our fish and wildlife are part of the complex system that provides and protects California's water resources. Tourism and fishing which provide economic benefits to local communities and to the state are also reliant on healthy ecosystems. Declining species and lost habitat disrupt the cultural, spiritual and ecological practices of California's Native American tribes. Simply put, California's diverse and unique ecosystems are irreplaceable and their loss threatens the sustainability of all of California's communities. **The objectives in this action plan include aggressive ecosystem restoration and other steps that will restore fish populations and benefit wildlife.**

Floods – Over 7 million Californians live in a floodplain. Historically, flooding has occurred in all regions of the state. Our state's capital, Sacramento, has one of the lowest levels of flood protection of any major city in the nation. Climate change will only exacerbate this problem. More precipitation will fall as rain rather than snow, snowmelt will occur earlier, and there will be more extreme weather events. **This action plan will serve to coordinate and streamline flood control efforts and result in multi-benefit flood projects, helping to mitigate the significant investments needed to improve flood protection for existing communities and infrastructure.**

Supply disruptions – Many parts of California's water system are vulnerable to earthquakes and flooding, particularly the Delta, which serves as the conveyance hub for a substantial percentage of all water supplies in the Bay Area, the San Joaquin Valley, and Southern California. A large earthquake along any of five major faults or a major storm-induced levee failure could render this water supply unreachable or unusable for urban and agricultural needs for months. **The combined benefits of many of the actions in this plan will better prepare us to manage through potential disruptions in the system.**

Population growth and climate change further increase the severity of these risks – The state's population is projected to grow from 38 million to 50 million by 2049.[1] The effects of climate change are already being felt and will worsen. The Sierra snowpack is decreasing, reducing natural water storage and altering winter and spring runoff patterns. This is most likely the result of higher temperatures and may also be related to air pollution that deposits fine particulate on the surface of snow, changing its reflectivity and causing it to absorb more heat and melt faster. Higher river and ocean water temperatures will make it harder to maintain adequate habitat for native fish species. Higher ocean temperatures will alter the already changing weather patterns. Sea level rise threatens coastal communities and islands in the Delta. Sea level rise also amplifies the risk that the pumps that supply cities and farms with Delta water will be inundated with seawater in a large earthquake or storms that breach levees. **The strategies identified in this action plan will help protect our resources from more frequent and more severe dry periods which threaten the health of our natural systems and our ability to meet our diverse water supply and water quality needs**.

Goals: Reliability, Restoration and Resilience

The California Water Action Plan has been developed to meet three broad objectives: more reliable water supplies, the restoration of important species and habitat, and a more resilient, sustainably managed water resources system (water supply, water quality, flood protection, and environment) that can better withstand inevitable and unforeseen pressures in the coming decades. Over the next five years, the actions discussed below will move California toward more sustainable water management by providing a more reliable water supply for our farms and communities, restoring important wildlife habitat and species, and helping the state's water systems and environment become more resilient.

[1] http://www.dof.ca.gov/research/demographic/reports/projections/view.php California's population will cross the 50 million mark in 2049 and grow to nearly 52.7 million by 2060.

Working Together and Continued Collaboration is Essential

Despite the many challenges for water management in California, there is good progress to report. There are thousands of important projects that are being planned or implemented by all levels of government as well as by conservationists, tribes, farmers, water agencies and others. State, regional and local agencies have increasingly been pursuing a strategy of making regions more self-reliant by reducing water demand and by developing new or underused water resources locally. In the future, most new water will come from a combination of improved conservation and water use efficiency, conjunctive water management (i.e., coordinated management of surface and groundwater), recycled water, drinking water treatment, groundwater remediation, and brackish and seawater desalination. There is increased focus on projects with multiple benefits, such as stormwater capture and floodplain reconnection, that can help simultaneously improve the environment, flood management and water supplies. These diversified regional water portfolios will relieve pressure on foundational supplies and make communities more resilient against drought, flood, population growth and climate change.

This Water Action Plan does not replace these local efforts. It complements and leverages them. Collaboration is essential. Successful implementation of this plan will require increased collaboration between state, federal and local governments, regional agencies, tribal governments, and the public and the private sectors. The Legislature is also a key partner.

Water has shaped California's past, its present, and will help define its future. Water has always been among the state's most contentious issues. California is at its best when people come together in the face of adversity to solve difficult problems. Only by working together can we improve and sustain the state's water future for generations to come.

Actions

1. Make conservation a California way of life;
2. Increase regional self-reliance and integrated water management across all levels of government;
3. Achieve the co-equal goals for the Delta;
4. Protect and restore important ecosystems;
5. Manage and prepare for dry periods;
6. Expand water storage capacity and improve groundwater management;
7. Provide safe water for all communities;
8. Increase flood protection;
9. Increase operational and regulatory efficiency;
10. Identify sustainable and integrated financing opportunities.

Together, these actions address the most pressing water issues that California faces while laying the groundwork for a sustainable and resilient future and are critical to moving the state forward now. They reflect an integration of new ideas with the ongoing important work that the state and federal government, local agencies, and others are already engaged in and require coordination and collaboration across levels of government. They will not address all of our challenges. Some of these actions are new proposals. Some are currently being planned and should be completed more rapidly, implemented in a better way, or on a larger scale. Success will require the cooperation of many partners; the state's role is to lead, help others, and remove barriers to action.

1. MAKE CONSERVATION A CALIFORNIA WAY OF LIFE

Conservation must become a way of life for everyone in California. Much has changed in the past half century, and our technology, values and awareness of how we use water have helped to integrate conservation into our daily lives. There is more that can be done and all Californians must embrace this effort. In 2009, the state adopted the Water Conservation Act through the passage of Senate Bill X7 7 requiring that we achieve a 20 percent reduction in urban per capita water use by December 31, 2020, promoting expanded development of sustainable water supplies at the regional level, and requiring agricultural water management plans and efficient water management practices for agricultural water suppliers. Conservation and efficiency are also keys to reducing the energy needed to pump, transport, treat and deliver water – an important action included in the state's Climate Change Scoping Plan for reducing greenhouse gas emissions. We must continue to build on our existing efforts to conserve water and promote the innovation of new systems for increased water conservation.

- **Expand Agricultural and Urban Water Conservation and Efficiency to Exceed SBX7 7 Targets**
  The administration will expand existing programs to provide technical assistance, shared data and information, and incentives to urban and agricultural local and regional water agencies, as well as local governmental agencies, to promote agricultural and urban water conservation in excess of the amounts envisioned by SBX7 7. We will work collaboratively with stakeholders to identify and remove impediments to achieving statewide conservation targets, recycling and stormwater goals; to evaluate and update targets for additional water use efficiency, including consideration of expanding the 20 percent by 2020 targets by holding total urban water consumption at 2000 levels until 2030, achieving even greater per capita reductions in water use. The administration will also work with local and regional entities to develop performance measures to evaluate agricultural water management.

- **Provide Funding for Conservation and Efficiency**
  The administration will work with the Legislature to expand funding for urban and agricultural water use efficiency research, and the development and implementation of efficiency standards through existing and new programs that save water and the energy associated with water use. Conservation programs must include numeric targets and be designed to achieve the state-developed targets and performance measures.

- **Increase Water Sector Energy Efficiency and Greenhouse Gas Reduction Capacity**
  The administration will continue supporting the collection of regional data and development of efficiency standards that save water and energy associated with water use and will provide guidance on conservation rates and sustainable financing that achieve water and energy savings. The administration will also continue to collaborate with water and wastewater agencies and energy utilities to educate consumers on the water-energy nexus. The administration will work with the Legislature to eliminate barriers to co-funding projects with water and energy benefits and expand and prioritize funding and technical support for water and wastewater agencies that achieve energy efficiency co-benefits and greenhouse gas reductions.

- **Promote Local Urban Conservation Ordinances and Programs**
  Local agencies are increasingly conserving water by prohibiting certain types of wasteful water use. Examples include: prohibiting watering hard surfaces such as sidewalks, walkways, driveways or parking areas; prohibiting outdoor watering during periods of rain; and not serving water to customers in restaurants unless specifically requested. Local agencies are also pioneering incentive programs, for example, converting lawns to drought tolerant landscapes—and programs to capture rainwater.

2. INCREASE REGIONAL SELF-RELIANCE AND INTEGRATED WATER MANAGEMENT ACROSS ALL LEVELS OF GOVERNMENT

While California has vast infrastructure to store and deliver water miles from its origin, the majority of infrastructure management and investment resides at the local and regional levels. Sometimes that management is done by agencies responsible for multiple functions such as flood management, water supply and water quality. Other times, individual agencies handle those functions separately. Over the past decade, the state has provided technical and financial assistance to regions to incentivize inter-agency/stakeholder cooperation in planning and implementing multi-objective actions that provide both regional and statewide benefits to water resources management and protection. Called "integrated water management," this approach balances the objectives of improving public safety, fostering environmental stewardship, and supporting economic stability. Developing local supplies can also save energy by reducing the distance that water must be transported. State grants are provided to both incentivize regional integration and leverage local financial investment.

Ensuring water security at the local level includes efforts to conserve and use water more efficiently, to protect or create habitat for local species, to recycle water for reuse, to capture and treat stormwater for reuse, and to remove salts and contaminants from brackish or contaminated water or from seawater. But, mostly it requires integrating disparate or individual government efforts into one combined regional commitment where the sum becomes greater than any single piece.

- **Support and Expand Funding for Integrated Water Management Planning and Projects**
  The administration will work with the Legislature to enhance the Integrated Water Management Planning program. Providing funding for regionally-driven, multi-benefit projects that prioritize protection of public health is critical. The administration will target funding to local regional projects that increase regional self-reliance and result in integrated, multi-benefit solutions for ensuring sustainable water resources.

- **Update Land Use Planning Guidelines**
  The Governor's Office of Planning and Research (OPR) will engage local land use authorities, California Native American tribes, and water agencies to amend the general plan guidelines to promote greater consistency between local land use plans and decisions and integrated regional water management plans and decisions. OPR will also work with the Legislature to determine whether water should be a mandatory feature of the general plan guidelines.

- **Legislation for Local and Regional Self Reliance**
  The administration will work with the Legislature to encourage local governments to adopt or amend local ordinances that enhance local and regional water supply reliability and conservation, such as ordinances that establish minimum requirements for infiltration or injection of water into the groundwater table, detection and prevention of utility system leaks, landscaping measures, and indoor/outdoor water use efficiency standards.

- **Provide Assistance to Disadvantaged Communities**
  The administration will provide technical assistance, tools, and allocate dedicated funds for grant administration, project development, and stakeholder collaboration to under-represented and economically-disadvantaged communities to promote greater participation and success in regional grant programs.

- **Demonstrate State Leadership**
  All state agencies should take a leadership role in designing new and retrofitted state owned and leased facilities to increase water efficiency, use recycled water, and incorporate stormwater runoff capture and low-impact development strategies.

- **Encourage State Focus on Projects with Multiple Benefits**
  The administration will direct agencies and departments to evaluate existing programs and propose modifications to incentivize and co-fund multi-benefit projects that promote integrated water management, such as stormwater permits that emphasize stormwater capture and infiltration, which provide both flood protection and groundwater recharge benefits, and agricultural groundwater recharge projects that emphasize water quality and conjunctive use. The commitment to emphasize multiple benefit projects will be applied to most of the actions in this plan.

- **Increase the Use of Recycled Water**
  California needs more high quality water, and recycling is one way of getting there. The state will adopt uniform water recycling criteria for indirect potable reuse of recycled water for groundwater recharge. Technical and financial assistance will be provided to projects that meet these criteria. The administration will also develop criteria for direct potable reuse and will seek to consolidate the state's recycling programs in the State Water Resources Control Board to promote program efficiencies.

- **Streamline Permitting for Local Water Reuse or Enhancement Projects**
  The administration will review and propose measures to streamline permitting for local projects that make better use of local water supplies such as recycling, stormwater capture, and desalination of brackish and seawater as well as projects that provide multiple benefits, such as enhancing local water supplies while improving wildlife habitat.

3. ACHIEVE THE CO-EQUAL GOALS FOR THE DELTA

The Delta is California's major collection point for water, serving two-thirds of our state's population and providing irrigation water for millions of acres of farmland. The region supports farming, wetland and riparian habitats, as well as numerous fish and wildlife species. In recent years, important fish populations have declined dramatically, leading to historic restrictions on water supply deliveries. Moreover, the current system relies on water flowing through a network of fragile levees from the northern part of the Delta to the pumps in the south, where two out of three fish trapped near the pumps die. These levees were not designed to resist a significant seismic event, the probability of which is greater than 60 percent over the next 50 years. They are also vulnerable to major floods and rising sea levels, all of which puts unacceptable risk on the people who live in the Delta as well as the water supply for 25 million people and 3 million acres of farmland. Plans are underway to address these problems. The issues are contentious and have been for decades. But, the status quo in the Delta is unacceptable and it would be irresponsible to wait for further degradation or a natural disaster before taking action.

The Delta Stewardship Council was created in legislation to achieve the state-mandated co-equal goals of providing a more reliable water supply for California and to protect, restore and enhance the Delta ecosystem. Those two goals are to be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource and agricultural values of the Delta as an evolving place. The council recently adopted its Delta Plan and will establish a high-level interagency coordinating body to commence implementation of a suite of actions designed to achieve the co-equal goals. The Implementation Committee can play a strong role in moving forward on the actions included in this plan, which include and build on many of the priorities included in the council's Delta Plan.

- **Begin Implementation of the Delta Plan**
  The administration directs all of its relevant agencies to fully participate in the Implementation Committee established by the Delta Stewardship Council and to work with the Delta Science Program, the Interagency Ecological Program, and others to implement the Delta Science Plan to enhance water and natural resource policy and management decisions.

- **Complete Comprehensive Plans to Recover Populations of Threatened and Endangered Species in the Delta and Improve Water Supply Reliability for Users of Delta Water**
  State and federal agencies will complete planning for a comprehensive conservation strategy aimed at protecting dozens of species of fish and wildlife in the Delta, while permitting the reliable operation of California's two biggest water delivery projects. The Bay Delta Conservation Plan (BDCP) will help secure California's water supply by building new water delivery infrastructure and operating the system to improve the ecological health of the Delta. It will also restore or protect approximately 145,000 acres of habitat to address the Delta's environmental challenges. The BDCP is made up of specific actions, called conservation measures, to improve the Delta ecosystem. It includes 22 conservation measures aimed at improving water operations, protecting water supplies and water quality, and restoring the Delta ecosystem within a stable regulatory framework. The project will be guided by 214 specific biological goals and objectives, improved science, and an adaptive management approach for operating the water conveyance facilities and implementing other conservation measures including habitat restoration and programs to address other stressors. As the Delta ecosystem improves in response to the implementation of the conservation measures, water operations would become more reliable, offering secure water supplies for 25 million Californians, an agricultural industry that feeds millions, and a thriving economy.

State and federal agencies will complete the state and federal environmental review documents; seek approval of the BDCP by the state and federal fishery agencies; secure all permits required to implement the BDCP; finalize a financing plan; complete the design of BDCP facilities; and begin implementation of all conservation measures and mitigation measures, including construction of water conveyance improvements. Once the BDCP is permitted, it will become part of the Delta Plan.

- **Restore Delta Aquatic and Intertidal Habitat**
  In coordination with restoration proposed by the BDCP, a specific set of projects or acreage for restoration will be identified in the six priority areas listed in the Delta Plan: (1) Yolo Bypass; (2) Cache Slough Complex; (3) the confluence of the Cosumnes and Mokelumne rivers; (4) the lower San Joaquin River floodplain; (5) Suisun Marsh; and, (6) western Delta/eastern Contra Costa County. The Department of Water Resources, in consultation and coordination with the Department of Fish and Wildlife, the Delta Science Program, and the Delta Plan Implementation Committee will initiate projects to restore 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh. These agencies will also coordinate with federal agency partners to ensure consistency with federal restoration efforts or requirements.

- **Implement Near-Term Delta Improvement Projects**
  In coordination with restoration proposed in BDCP, the Department of Water Resources will initiate a project to remove fish passage barriers within the Yolo Bypass and modify the Fremont Weir to increase the amount and quality of fish rearing habitat by improving access to seasonal floodplain habitat.

- **Maintain Important Infrastructure**
  The Department of Water Resources will continue implementation of the Delta Levees Subventions, Delta Special Projects, and Floodway Corridor Programs to provide financial assistance to local agencies for repair and improvement of levees and other multipurpose projects in the Delta.

- **Bay Delta Water Quality Control Plan**
  The State Water Resources Control Board will complete its update of the Water Quality Control Plan for the Delta and its upstream watersheds. The plan establishes both regulatory requirements and recommended actions. The State Water Resources Control Board's action will balance competing uses of water including, municipal and agricultural supply, hydropower, fishery protection, recreation, and other uses.

4. PROTECT AND RESTORE IMPORTANT ECOSYSTEMS

Streams and rivers once ran freely from high in the mountains to downstream reaches, meandering naturally through lowland and floodplain habitats, connecting with coastal estuaries and the Pacific Ocean. The variability of natural water flows in this complex system created vibrant and resilient habitat for many species and functioned to store water, recharge groundwater, naturally purify water, and moderate flooding. Over 80 percent of the Central Valley's historical floodplain, riparian and seasonal wetland habitats have been lost in the last 150 years. This loss affects the physical and ecological processes of the Central Valley and beyond, contributes to the decline of salmon and steelhead, restricts habitat for waterfowl and other species, and impacts water supply, flood protection, and sediment control. In watersheds around the state, fish and wildlife no longer have access to habitat or enough cold, clean water at key times of the year. In response to these losses and ecological challenges, as well as in anticipation of the effects of climate change on the timing, volume and temperature of water flows, activities to protect and restore the resiliency of our ecosystems will help support fish and wildlife populations, improve water quality, and restore natural system functions. This effort will increase collaboration and transparency and ensure that management decisions are supported by the best available science.

- **Restore Key Mountain Meadow Habitat**
  The Department of Fish and Wildlife, in coordination with other state resource agencies, will restore 10,000 acres of mountain meadow habitat in strategic locations in the Sierra Nevada and Cascade mountain ranges, which can increase groundwater storage and provide habitat for more than 100 native species, many of which are at risk as threatened or endangered. The department will also coordinate with federal agencies, local governments, conservation organizations, tribes, and others as necessary on this action to maximize efforts and avoid duplication.

- **Manage Headwaters for Multiple Benefits**
  Watersheds in the Cascades, Sierra Nevada and other forested areas of the state are the places of origin for more than two-thirds of the state's developed water supply. Water originating in the Cascades and Sierra Nevada supplies all or part of the need for 23 million Californians and millions of acres of agricultural land. Up to one-half of the fresh water flowing into the Delta begins as snow and rain in these watersheds.

Many of these crucial watersheds are in poor health due to a number of factors. A changing climate of warmer temperatures will exacerbate the diseases and pests that create additional fire risk and, with more precipitation falling as rain instead of snow, create significant operational challenges for our reservoirs. Large, intense fires such as the recent Rim Fire will produce tons of sediment, much of which will end up in reservoirs, significantly reducing storage capacity and impacting water quality.

In order to reduce the significant risks posed to the water resources flowing from the Cascade, Sierra and other watersheds in the state, there is a critical need to address the following:

- Restore forest health through ecologically sound forest management. Overgrown forests not only pose a risk of catastrophic fire, but can significantly reduce water yield.

- Protect and restore degraded stream and meadow ecosystems to assist in natural water management and improved habitat. Meadows provide a natural storage opportunity, critically important with a changing climate, while properly functioning stream systems reduce downstream sedimentation and enhance critical aquatic habitat.

- Support and expand funding for protecting strategically important lands within watersheds to ensure that conversion of these lands does not have a negative impact on our water resources. By working with willing landowners, protection of key lands from conversion will result in a healthier watershed by reducing polluted runoff and maintaining a properly functioning ecosystem.

- **Bring Back Salmon to the San Joaquin River**
  The Department of Fish and Wildlife and the Department of Water Resources will lead the state's effort to achieve the goals of restoring flows to the San Joaquin River from Friant Dam to the confluence of the Merced River, and bring back a naturally-reproducing, self-sustaining Chinook salmon fishery while reducing or avoiding adverse water supply impacts. Chinook will be reintroduced pursuant to the San Joaquin River Restoration Program, and the Department of Fish and Wildlife will complete construction of the conservation hatchery and research facility. The Department of Water Resources will perform activities that support the implementation of channel and structural improvements that result in restoring fish and flows. The administration will work with the Legislature and others to secure further funding as necessary to achieve these activities and the restoration goal.

- **Protect Key Habitat of the Salton Sea Through Local Partnership**
  The Natural Resources Agency, in partnership with the Salton Sea Authority, will coordinate state, local and federal restoration efforts and work with local stakeholders to develop a shared vision for the future of the Salton Sea. The Salton Sea is one of the most important migratory bird flyways in North America and is immediately threatened with reduced inflows and increasing salinity. The Department of Fish and Wildlife and the Department of Water Resources will begin immediately to implement the first phase of this effort with the construction of 600 acres of near shore aquatic habitat to provide feeding, nesting and breeding habitat for birds. This project is permitted to increase to 3,600 acres and could be scaled even greater with additional resources. Concurrently, the Natural Resources Agency and the Salton Sea Authority are developing a roadmap for the Salton Sea that will evaluate additional restoration projects and identify economic development opportunities through renewable energy development.

- **Restore Coastal Watersheds**
  The Department of Fish and Wildlife in coordination with other state resource agencies and other stakeholders, as appropriate, will develop at least 10 off-channel storage projects, modernize at least 50 stream crossings, and also implement at least 10 large-scale habitat projects along the California coast in strategic coastal estuaries to restore ecological health and natural system connectivity, which will benefit local water systems and help defend against sea level rise.

- **Continue Restoration Efforts in the Lake Tahoe Basin**
  California, in partnership with the state of Nevada and the federal government, will continue its efforts to protect the beautiful and unique waters of Lake Tahoe. The Natural Resources Agency will maintain its role in leading the coordination of the state departments, the boards, and the conservancy involved in the bi-state efforts underway to restore, preserve and enhance the Lake Tahoe region. California's restoration efforts at Lake Tahoe include, among other things, support of the Tahoe Regional Planning Agency's implementation of its Regional Plan Update, putting into place the science provisions contained in the recently enacted SB 630, and support for projects contained in the region's Environmental Improvement Program.

- **Continue Restoration Efforts in the Klamath Basin**
  The Department of Fish and Wildlife and the Natural Resources Agency will continue to work with diverse stakeholders to implement the Klamath Basin restoration and settlement agreements. Those agreements include measures to improve water quality in the Klamath River, restore anadromous fish runs, including Chinook and Coho salmon, and improve water reliability for agricultural and other uses by providing a drought planning mechanism for low water years. The administration will work with Congress to secure the necessary federal authorizations for the agreements and secure the necessary funding for removal of four hydroelectric dams on the Klamath River and funding for the necessary basin restoration.

- **Water for Wetlands and Waterfowl**
  The Department of Fish and Wildlife in coordination with other state resource agencies will develop and implement a water acquisition, management, and water use efficiency strategy in coordination with the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, Central Valley Project Improvement Act refuge water program, and Central Valley Joint Venture to secure reliable and affordable water for managed wetlands statewide. The administration will work with the Legislature, and others, to secure funding to acquire water and to replace or repair the most in need conveyances for delivering water for wetlands.

- **Eliminate Barriers to Fish Migration**
  This action has three parts. First, in coordination with the Central Valley Project Improvement Act Anadromous Fish Screen Program, the Department of Fish and Wildlife will create and publish a Priority Unscreened Diversion List in the Central Valley area. Second, the administration will work with the Legislature and others to secure funding to install or repair the top 10 unscreened diversions on the priority list described above. Third, in smaller watersheds around the state, the Department of Fish and Wildlife will complete a comprehensive analysis, working with other state and federal agencies, to optimize barrier removal projects and river and stream priorities, and then complete culvert and bridge improvement and small dam removal projects to provide anadromous fish species access to historic spawning and rearing habitat.

- **Assess Fish Passage at Large Dams**
  The Department of Fish and Wildlife, in coordination with state and federal resource agencies, will develop an evaluation and feasibility process for addressing fish passage at California's rim dams and develop rim dam solution plans for the most feasible locations. Rim dams are the large dams at the base of most major river systems in California. They are too integral to California's water infrastructure to consider removing, but, where feasible, passage around the rim dams may be necessary to recover salmon and steelhead, because 95 percent of the historical habitat for these fish is above the dams. This action will require coordination with local water agencies and dam owners and operators, as well as other stakeholders.

- **Enhance Water Flows in Stream Systems Statewide**
  The State Water Resources Control Board and the Department of Fish and Wildlife will implement a suite of individual and coordinated administrative efforts to enhance flows statewide in at least five stream systems that support critical habitat for anadromous fish. These actions include developing defensible, cost-effective, and time-sensitive approaches to establish instream flows using sound science and a transparent public process. When developing and implementing this action, the State Water Resources Control Board and the Department of Fish and Wildlife will consider their public trust responsibility and existing statutory authorities such as maintaining fish in good condition.

- **Achieve Ecological Goals through Integrated Regulatory and Voluntary Efforts**
  The San Francisco Bay and Sacramento-San Joaquin River Delta are some of the most studied ecosystems in the nation. Similarly, there are many scientific and management plans about the decline of salmon and steelhead in California. A fundamental ecological principle is that aquatic species and estuarine ecosystems need enough cold, clean water at the right times of year to ensure species abundance and health and ecological function. Integration across and between all voluntary and regulatory efforts may be necessary to truly achieve basic ecological outcomes.

As a goal, the state must continue to consider how to provide water flows necessary to meet current state policy, such as significantly increasing salmon, steelhead and trout populations while also supporting viable, self-sustaining populations of a broad range of other native aquatic species, and ensure sustainable river and estuary habitat conditions for a healthy, functional Bay Delta ecosystem. The administration, with the involvement of stakeholders, will build on the work in tributaries to the Sacramento and San Joaquin rivers, analyze the many voluntary and regulatory proceedings underway related to flow criteria, and make recommendations on how to achieve the salmon and steelhead and ecological flow needs for the state's natural resources through an integrated, multi-pronged approach.

5. MANAGE AND PREPARE FOR DRY PERIODS

Water supply reliability is critical to maintaining California's economy. Temporary shortages caused today by extended, severe dry periods will become more frequent with climate change. Effective management of water resources through all hydrologic conditions will reduce impacts of shortages and lessen costs of state response actions. Many actions will help to secure more reliable water supplies and consequently improve drought preparedness. The actions identified below are specifically designed to address drought conditions and make California's water system more resilient.

- **Revise Operations to Respond to Extreme Conditions**
  State natural resources and water quality agencies, in collaboration with their federal counterparts, will implement a series of administrative solutions through a transparent process to make water delivery decisions and propose options to address water quality and supply objectives in extreme conditions. Through these state agencies, the administration will exercise the maximum administrative discretion and flexibility possible to address the current dry conditions now and into 2014. Especially in drought conditions, adaptive management can have substantial fishery, water quality, and water supply benefits. The identification of such opportunities requires continued improved water forecasting and prompt inter and intra agency coordination and communication. It also requires an effective coordination mechanism involving the Department of Water Resources, the U.S. Bureau of Reclamation, the State Water Project and the Central Valley Project contractors, the state and federal fishery agencies, and the State Water Resources Control Board, at a minimum.

- **Streamline Water Transfers**
  State agencies, in collaboration with their federal counterparts, will take all feasible steps to streamline water transfer processes to address both extreme situations and normal system operations. These include refining the schedule for the water transfer process, while considering cumulative, ground and surface water and third party impacts; and ensuring that transfers are based on measured water use. The administration will also improve outreach in support of local water transfer programs.

6. EXPAND WATER STORAGE CAPACITY AND IMPROVE GROUNDWATER MANAGEMENT

On average, the state receives about 200 million acre-feet of water per year in the form of rain and snow. In reality, the average rarely occurs, as California has the most variable weather conditions in the nation and climate change may increase the variability. Storage, whether surface storage or groundwater storage, can hold water when it flows heavily for use at times when it does not and create greater flexibility in the system. Above ground (surface storage) can be in the form of large on-stream dams and reservoirs, or smaller on stream and off stream reservoirs. Groundwater storage consists of replenishing groundwater basins either directly through injection, or by allowing water to percolate into the ground naturally or from constructed spreading basins and some forms of stormwater capture. Surface storage can be operated in conjunction with groundwater storage to increase opportunities for groundwater recharge during high flow periods and thereby increase comprehensive water management benefits. Constructing surface storage can be challenging for environmental or financial reasons. Developing groundwater storage can be challenging because many basins are contaminated and this method of storage also requires an ability to measure and withdraw water.

The bottom line is that we need to expand our state's storage capacity, whether surface or groundwater, whether big or small. Today, we need more storage to deal with the effects of drought and climate change on water supplies for both human and ecosystem needs. Climate change will bring more frequent drought conditions and could reduce by half our largest natural storage system—the Sierra snowpack—as more precipitation falls as rain rather than snow, and as snow melts earlier and more rapidly. Moreover, we must better manage our groundwater basins to reverse alarming declines in groundwater levels. Continued declines in groundwater levels could lead to irreversible land subsidence, poor water quality, reduced surface flows, ecosystem impacts, and the permanent loss of capacity to store water as groundwater.

Demand for water goes well beyond water supply and flood management, the traditional purposes for which California's major reservoirs were built. Today, water storage is also needed to help provide widespread public and environmental benefits, such as seasonal fish flows, improved water quality, water cool enough to sustain salmon, and increased flexibility to meet multiple demands, especially in increasingly dry years. The financing of additional water storage in California must reflect not just specific local benefits, but also these broader public benefits.

- **Provide Essential Data to Enable Sustainable Groundwater Management**
  The administration will expand and fund the California Statewide Groundwater Elevation Monitoring Program, which provides essential data to characterize the state's groundwater basins, including identifying basins in decline. In coordination with federal, tribal, local and regional agencies, state agencies will conduct groundwater basin assessments and develop assessment reports.

- **Support Funding Partnerships for Storage Projects**
  The administration will work with the Legislature to make funding available to share in the cost of storage projects if funding partners step forward. The state will facilitate among willing local partners and stakeholders the development of financeable, multi-benefit storage projects, including working with local

partners to complete feasibility studies. For example, the Sites Project Joint Powers Agreement, formed by a group of local government entities in the Sacramento Valley, is a potential emerging partnership that can help federal and state government determine the viability of a proposed off stream storage project – Sites Reservoir.

- **Update Bulletin 118, California's Groundwater Plan**
  The Department of Water Resources, in consultation with the U.S. Bureau of Reclamation, U.S. Geological Survey, the State Water Resources Control Board, and other agencies and stakeholders will update Bulletin 118 using field data, California Statewide Groundwater Elevation Monitoring, groundwater agency reports, satellite imagery, and other best available science, so that this information can be included in the next California Water Plan Update and be available for inclusion in future water management and land use plans. The Bulletin 118 update should include a systematic evaluation of major groundwater basins to determine sustainable yield and overdraft status; a projection of California's groundwater resources in 20 years if current groundwater management trends remain unchanged; anticipated impacts of climate change on surface water and groundwater resources; and recommendations for state, federal and local actions to improve groundwater management. In addition, the Bulletin 118 update should identify groundwater basins that are in a critical condition of overdraft.

- **Improve Sustainable Groundwater Management**
  Groundwater is a critical buffer to the impacts of prolonged dry periods and climate change on our water system. The administration will work with the Legislature to ensure that local and regional agencies have the incentives, tools, authority and guidance to develop and enforce local and regional management plans that protect groundwater elevations, quality, and surface water-groundwater interactions. The administration will take steps, including sponsoring legislation, if necessary, to define local and regional responsibilities and to give local and regional agencies the authority to manage groundwater sustainably and ensure no groundwater basin is in danger of being permanently damaged by over drafting. When a basin is at risk of permanent damage, and local and regional entities have not made sufficient progress to correct the problem, the state should protect the basin and its users until an adequate local program is in place.

- **Support Distributed Groundwater Storage**
  The administration will support a comprehensive approach to local and regional groundwater management by funding distributed groundwater storage projects that are identified in groundwater management plans and removing barriers to implementation.

- **Increase Statewide Groundwater Recharge**
  The administration will work with the Legislature to discourage actions that cause groundwater basin overdraft and provide incentives that increase recharge. State agencies will work with tribes and federal, regional and local agencies on other actions related to promoting groundwater recharge and increasing storage, including improving interagency coordination, aligning land use planning with groundwater recharge, and identifying additional data and studies needed to evaluate opportunities, such as capturing and recharging stormwater flows and other water not used by other users or the environment.

- **Accelerate Clean-up of Contaminated Groundwater and Prevent Future Contamination**
  Throughout the state, groundwater basins are contaminated by historic manufacturing, farming practices and other current uses. The State Water Resources Control Board and the Department of Toxic Substances Control will develop recommendations and take action to prevent the spread of

contamination, accelerate cleanup, and protect drinking water in urban areas. The State Water Resources Control Board will continue to implement appropriate control measures to address these sources through its water quality permitting authority.

7. PROVIDE SAFE WATER FOR ALL COMMUNITIES

All Californians have a right to safe, clean, affordable and accessible water adequate for human consumption, cooking, and sanitary purposes. Disadvantaged communities, in particular, often struggle to provide an adequate supply of safe, affordable drinking water. The reasons for this are numerous: changes in drinking water quality standards, pollution, aging infrastructure, lack of funding for basic infrastructure, lack of funding for ongoing operation and maintenance, and unreliable supplies resulting in service interruptions are among the most common. Programs designed to protect the quality of our waters for drinking and other uses are housed in multiple agencies, reducing their effectiveness and ability to meet communities' needs.

- **Consolidate Water Quality Programs**
  The administration is pursuing consolidation of the drinking water and surface and groundwater quality programs into a single agency to achieve broader program efficiencies and synergies that will best position the state to respond to existing and future challenges. This initiative will also better restore and protect water quality and public health for disadvantaged communities.

- **Provide Funding Assistance for Vulnerable Communities**
  The administration will work with the Legislature to establish a stable, long-term funding source for provision of safe drinking water and secure wastewater systems for disadvantaged communities. The funding will be made available through a framework of statutory authorities for the state, tribes, regional organizations, and county agencies that will assess alternatives for providing safe drinking water and wastewater, including regional consolidation, and to develop, design, implement, operate and manage these systems for small disadvantaged communities impacted by contaminated drinking water and lack of sanitary wastewater infrastructure.

- **Manage the Supply Status of Community Water Systems**
  The state will identify drought-vulnerable public water systems and monitor the status of these systems to help prevent or mitigate any anticipated shortfalls in supply and to secure alternative sources of water for the communities when needed. The state will also work with local governments and agencies to identify drought-vulnerable areas served by domestic wells and collaborate to prevent or mitigate any anticipated shortfalls.

8. INCREASE FLOOD PROTECTION

California's exposure to flood risk presents an unacceptable threat to public safety, infrastructure, and our economy. More than 7 million people and $580 billion in assets are exposed to flood hazards in the state and the lack of sufficient and stable funding for flood management exacerbates the state's risk.

When California floods, public safety and health is endangered, critical infrastructure is damaged, vital services become isolated or interrupted, vast agricultural areas are rendered unproductive, and water supplies are threatened or impacted. The effects of climate change on the state's water runoff patterns will magnify these challenges. Actions by state, local, tribal and regional governments, however, can reduce flood risks and improve

the state's preparedness and resiliency when flooding inevitably occurs. Flood projects done in an integrated, regionally-driven way can also achieve multiple benefits. It is possible through collaborative planning efforts to integrate our flood and water management systems, and implement flood projects that protect public safety, increase water supply reliability, conserve farmlands, and restore ecosystems.

- **Streamline and Consolidate Permitting**
  The administration will convene a task force of federal, state and local permitting and flood management agencies, to develop a programmatic regulatory permitting process to replace current site-by-site mitigation requirements and expedite permitting of critical maintenance activities and flood system improvement projects. The effort to streamline and consolidate will also incorporate regional advanced mitigation as a means to expedite planning.

- **Create a Delta Levee Assessment District**
  The administration, in consultation with the Delta Protection Commission and the Department of Water Resources, will sponsor legislation establishing a Sacramento-San Joaquin River Delta levee assessment district with authority to collect fees needed to repair and maintain more than 1,000 miles of Delta levees, many of them privately constructed before modern engineering standards were in place.

- **Improve Access to Emergency Funds**
  The administration will sponsor legislation revising the California Disaster Assistance Act to enhance the Governor's Office of Emergency Services' ability to advance funds for flood response efforts in close coordination with the Department of Water Resources.

- **Better Coordinate Flood Response Operations**
  The Governor's Office of Emergency Services, working in coordination with the Department of Water Resources, the U.S. Army Corp of Engineers, and others, will develop and implement a common interagency protocol that all jurisdictions and agencies at all levels of government operating in the Delta in an emergency will use to establish joint field incident commands for flood operations and other emergency response functions.

- **Prioritize Funding to Reduce Flood Risk and Improve Flood Response**
  An estimated $50 billion is needed to reduce flood risk statewide. The administration will focus on the highest risk areas and develop proposals to fund projects through a combination of financing options.

- **Identify State Funding Priorities for Delta Levees**
  The Delta Stewardship Council, in consultation with the Department of Water Resources, the Central Valley Flood Protection Board, the Delta Protection Commission, local agencies, and the California Water Commission, should develop funding priorities for state investments in Delta levees. These priorities will be consistent with the provisions of the Delta Reform Act in promoting effective, prioritized strategic state investments in levee operations, maintenance, and improvements in the Delta for both levees that are a part of the State Plan of Flood Control and non-project levees.

- **Encourage Flood Projects That Plan for Climate Change and Achieve Multiple Benefits**
  State agencies engaged in planning and implementing flood projects, such as those outlined in the Central Valley Flood Protection Plan, will factor in the effects of climate change as well as pursue projects that provide the greatest number of benefits in addition to flood and public safety. Projects should be developed in a manner that anticipates the extremes that are predicted to worsen due to climate change, and pursue multiple benefits as a climate adaptation strategy like increasing water supply reliability,

giving rivers more room to move through widening floodways, conserving farmlands, and restoring ecosystems.

9. INCREASE OPERATIONAL AND REGULATORY EFFICIENCY

Efficiently operating the State Water Project and Central Valley Project, while complying with the requirements of state and federal endangered species acts and operating consistent with the conditions of water rights, contracts and other entitlements, is a delicate balancing act. Current coordination efforts, while longstanding and intended to cover a broad range of conditions, do not reflect the entire Delta watershed, nor do they effectively integrate all of the activities that other agencies and organizations are undertaking to improve the ecosystem.

- **Prepare for 2014 and Beyond Through Better Technology and Improved Procedures**
  The administration will work with federal and regional counterparts to improve coordination of operations of all major water supply (storage facilities and direct diversions), flood control, hatchery facilities, and habitat restoration projects to improve water supply and fishery conditions. The goals are to improve water project near-term operational flexibility for water year 2014 and build upon those actions in subsequent years. Better technology can result in improved coordination and more accurate data for decision making. Examples of better technology and improved coordination include but are not limited to the following:

  - Improve data availability, communication procedures, and analytical methods used to monitor and communicate risks to listed fish species and to water supplies when making regulatory decisions associated with implementation of incidental take provisions in the existing biological opinions.

  - Develop a pilot project to test if a new index for Old River and Middle River reverse flows enables compliance with biological opinion requirements.

  - Develop and employ new turbidity models to improve real-time turbidity management in the south Delta.

  - Analyze through the South Delta Science Collaborative associated operational approaches for minimizing loss of salmon in the area of the Old River barrier and effects of the operations on water supply.

  - Develop a Delta smelt life cycle model to help manage operations to avoid entrainment of smelt at the water project's intakes.

  - Implement a 3.5-year study to enhance and modernize Delta smelt monitoring (fish abundance and geographic distribution in the Delta), to improve the ability to protect fish populations while minimizing the impacts of fish protective measures on water project operations.

  - Work with federal agencies to improve coordination of hatchery fish releases with hydrologic conditions and water project operations to improve fish survival.

  - Improve state and federal interagency coordination and water contractor coordination on real-time forecasting and management associated with meeting water quality control objectives, to optimize project operations and avoid redirected fishery impacts.

- Fund and revive the National Hydrological Dataset for California to improve high-quality framework geospatial data and the precision and accuracy of mapping and scientific studies.

- **Improve and Clarify Coordination of State Bay Delta Actions**
  The problems affecting the Delta need to be addressed on multiple fronts, including habitat loss, export conveyance, water projects operations, pollution control, and flows. The principal state entities charged with addressing these issues are the Delta Stewardship Council, Department of Water Resources, Department of Fish and Wildlife, and the State Water Resources Control Board. Several federal agencies exercise regulatory authority related to these issues. There are also multiple water districts, private parties, nongovernmental organizations and tribal communities with a profound stake in these issues.

  A coordinated approach to managing the Delta is essential to serve the needs of California's residents. State agencies will commit to using collaborative processes to achieve water supply, water quality and ecosystem goals. This approach embraces enhanced sharing of data, consistent use of peer-reviewed science, coordinated review under the California Environmental Quality Act, improved integration of related processes, and encouragement of negotiated resolutions.

  - The Delta Stewardship Council, Department of Water Resources, Department of Fish and Wildlife, and the State Water Resources Control Board will ensure all relevant information is shared and will assist each other, as appropriate, to complete respective efforts to improve Delta conditions.

  - State entities will encourage negotiated agreements among interested parties to implement flow and non-flow actions to meet regulatory standards and support all beneficial uses of water. State staff will participate in these processes to the maximum extent possible when requested.

  - The Delta Stewardship Council's Implementation Committee, which includes leaders from all the affected state entities, will meet regularly to review progress in coordination.

  - The administration will direct relevant agencies and departments to work with the Delta Science Program, the Interagency Ecological Program, and others conducting science in the Delta to implement the Delta Science Plan, committing resources and funding for shared science to achieve integrated, collaborative and transparent science to enhance water and natural resource policy and management decisions.

10. IDENTIFY SUSTAINABLE AND INTEGRATED FINANCING OPPORTUNITIES

California has a long history of making sound financial investments in water resources. However, our current investments are not keeping pace with the need. Our infrastructure is aging, levees are in need of repair, communities are without safe water, and our environment, farms and economy are suffering from unreliable and degraded water supplies. The effects of climate change will only accelerate the challenges facing our water resources and infrastructure. This plan includes actions that will require multiple funding sources. We have access to a variety of funding sources including federal grants and loans, general obligation bonds, revenue bonds, rate payer dollars, local initiatives, user fees, beneficiary fees, local and statewide taxes, private investment, public-private partnerships, and more. A better understanding of the variety and types of funds and financing available for water investment will help us to make the best, most efficient and sustainable uses of the funding available.

- **Remove Barriers to Local and Regional Funding for Water Projects**
  The administration will work to clarify the 1996 Right to Vote on Taxes Act's (Proposition 218) applicability to water related fees and taxes, including sponsoring legislation if necessary.

- **Develop Water Financing Strategy**
  The administration will develop a water financing strategy that leverages various sources of water-related project funding and proposes options for eliminating funding barriers, including barriers to co-funding multi-benefit projects. The strategy will identify all potential funding sources for water-related projects including cap and trade auction revenue under AB 32, energy efficiency funds, user and beneficiary fees, polluter fees, local measures, and other sources and will establish principles to guide the use of these funding sources. The strategy will consider measures for energy efficiency and renewable energy to achieve greenhouse gas reductions that would be a co-benefit of water infrastructure investments.

- **Analyze User and Polluter Fees**
  The administration will direct agencies to identify areas where user and/or polluter fees may be appropriate. The agencies will assess the following: areas where users may not be fully funding the costs or impacts associated with their use, instances where polluters are not able to diminish their pollution and have not adequately accounted for the impacts of that pollution, and opportunities to use fees to incentivize positive behavior. The agencies will provide recommendations on fees, who would pay them, how they would be collected, and how they would be used.

Conclusion

All Californians have a stake in our water future. These actions set us on a path toward reliability, restoration, and resilience in California water. We must adapt to this "new normal" and recapture California's resource management leadership and our economic and environmental resilience and reliability. There are no silver bullets or single projects that will "fix the problem." We must have a portfolio of actions to comprehensively address the challenges this state faces. Some actions must be taken immediately to address current risks such as the looming drought and inadequate safe drinking water. Additionally, over the next five years, we must address fundamental changes in our approach to water resource management and be prepared for the changes the future holds.

Flows and Fishes in the Sacramento-San Joaquin Delta

Research Needs in Support of Adaptive Management

A Review by the
Delta Independent Science Board

August 2015

The Delta Independent Science Board (Delta ISB) is a standing board of nationally and internationally prominent scientists with appropriate expertise to evaluate the broad range of scientific programs that support adaptive management of the Sacramento-San Joaquin Delta.

Created by the Delta Reform Act of 2009 and appointed by the Delta Stewardship Council, the Delta ISB provides oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews.

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The Delta Independent Science Board thanks the scientists from federal, state, academic, and private institutions (Appendix A) who provided their time and candid input to the initial process. We are impressed by the dedication, enthusiasm, openness, and knowledge of the interviewees and appreciate the scientific and institutional challenges they face. The Delta ISB also thanks those who provided valuable public comment on earlier drafts of this report. The Delta ISB also thanks Jennifer Bigman, a California State Sea Grant Fellow with the Delta Science Program for her assistance in the literature review and preparation of this report. This work was supported by the Delta Stewardship Council as part of its support to the Delta ISB.

Summary

Record-low counts of Delta smelt at a time of persistent drought underscore the importance and challenges of managing freshwater flows for the benefit of fishes in the Sacramento-San Joaquin Delta while also meeting human demands for water. Understanding the effects of water flows on fishes is central to understanding how the Delta ecosystem functions and is key to achieving the state's coequal goals of "providing a more reliable water supply for California and protecting, restoring and enhancing the Delta ecosystem ... in a manner that protects and enhances ... the values of Delta as an evolving place". The economic, ecological, and social costs of scientific uncertainty in water management controversies are significant - and to some degree unavoidable.

Scientific findings that relate fishes and flows increasingly guide decisions on how to manage flows for the well-being of threatened or endangered species in the Delta. Many studies – and management decisions – rely on correlations between water flows and fish populations. But the decisions warrant fuller understanding of precisely how the flows affect the fishes. Knowledge of these underlying mechanisms is likely to facilitate adaptive management by clarifying uncertainty and risk, by creating specific expectations for outcomes and by strengthening testable hypotheses. This report therefore recommends, first and foremost (there are other recommendations as well), redoubling effects to identify causes and effects concerning fishes and flows in the Delta.

The scientific challenges to providing a Delta flow regime that benefits desirable fishes (or at least minimizes harm) while providing water supply reliability are well recognized:

- The modern Delta estuary and its tributaries differ starkly from the conditions under which the Delta's native fish evolved. Non-native fishes now predominate, and the habitat and flow needs of the native species are difficult to define in the transformed place and in a novel ecosystem.

- Flows in the Delta, which vary greatly with location and season, affect fishes directly and indirectly. The indirect effects work through other environmental factors and differ among species and life stages within a species. Other drivers of fish production in the ecosystem confound the effects of flow.

- Many agencies are involved in Delta fish and flow decisions and in scientific efforts to support management of water supply and fishes.

The Delta Independent Science Board (Delta ISB), established under the Delta Reform Act of 2009, has a legislative mandate to review Delta science programs in support of adaptive management. The Board is structuring the review by themes. The theme in this review is research on how freshwater flows affect Delta fish populations. The report offers several recommendations on scientific strategies to benefit adaptive management, and to enhance collaboration and communication among institutions, scientists, and managers:

1) **Focus on cause and effect - the mechanisms that enable flows to affect fishes.** Deeper causal understanding is important for identifying and reducing risks to water supply and fish populations. It can yield specific hypotheses for use in adaptive management (e.g., MAST 2015, Monismith et al. 2014). Flows and other drivers need to be examined for their direct and indirect effects on fish

growth, reproduction, mortality, and migration or transport. The overarching questions include: What are the essential requirements of a fish species for individual and population growth and sustainability, and how do flows change those requirements?

2) **Expand integrative science approaches.** Examine these mechanisms through comprehensive, integrative studies that focus on drivers and responses, and which are relevant to management questions. In the words of a 2012 National Research Council report, "only a synthetic, analytical approach to understanding the effects of suites of environmental factors (stressors) on the ecosystem and its components is likely to provide important insights that can lead to enhancement of the Delta and its species." Strategies that strengthen interagency and interdisciplinary work can speed and solidify scientific discoveries and their application.

3) **Link quantitative fish models with three-dimensional models of water flows.** Such a linkage will provide a comprehensive, heuristic modeling framework for identifying information gaps, key drivers and appropriate time and space scales for integrating interagency and interdisciplinary science activities and priorities, and for improving and underpinning decision support. A specific collaborative effort will be needed to develop a 3-D, open-source, hydrodynamic model that can be more widely adopted and integrated with generic and species-specific models of fish growth, movement, mortality, and reproduction and with food-web models. The modeling framework should extend across agencies and programs. A well-led standing working group of both hydrodynamic and fish modelers as well as lower food-web modelers should carry this effort forward and provide linkages to other ongoing modeling efforts. Fish endpoints should drive model development. Significant progress can be accomplished in the short term.

4) **Examine causal mechanisms on appropriate time and space scales.** A focus on mechanisms will require a close consideration of time, space and parameter scales relevant to biological processes. Dealing with fish and flow scales that simply overlap is not sufficient, as there are other relevant drivers and intermediaries operating at different scales. Models for water management developed with time and space (depth, width, and time variation) scales appropriate for water management questions may not be useful to answer fish and ecosystem questions. For instance, flow variability in time and space has important biological consequences that are often not captured in mean monthly flow values or annual fish population estimates.

5) **Monitor vital rates (e.g., individual growth rates) of fishes.** Monitoring is done to estimate ecosystem conditions or to assess the consequences of specific management actions. A focused program is needed to monitor expected first-order responses by which flows affect fishes, linked to multiscale modeling efforts. Rate responses, such as individual fish growth rates, more aptly reflect response to changing conditions and give more certain and causal insights than annual indices of fish population size. A monitoring program that is organic with model expectations can improve the contribution of science to adaptive management.

6) **Broaden species focus.** The comprehensive research on threatened or endangered species needs to expand to other native species, as well as non-native species that now dominate fish populations in the Delta. Little is known about the impact of flows on many of these other

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species, and they likely have important food-web relationships to threatened or endangered species.

7) **Enhance national and international connections.** Provide state-agency scientists with convenient access to scientific journals and with opportunities for travel to conferences, workshops, and relevant field sites. The problems faced in the Delta are not unique. To accelerate and improve scientific insights and reduce their costs, agency scientists need access to the wealth of knowledge and thinking from other representative ecosystems.

8) **Promote timely synthesis of research and monitoring.** Synthesis of results is needed for managing the Delta, managing the science, and stakeholder engagement. Agencies must recognize the importance and need for routine and timely scientific synthesis for both directing scientific efforts and summarizing scientific outcomes and uncertainties for managers. This requires additional dedicated staff time and resources.

9) **Improve coordination among disciplines and institutions.** Improve understanding among ecologists, hydrologists, hydrodynamicists and across the various institutions where they work. Interdisciplinary, interagency understanding can be facilitated through implementing the Delta Science Plan, which has been designed to encourage sustained commitment and increased coordination for addressing contentious issues and complex problems.

Overall, modeling capabilities and ecosystem understanding in the Delta have grown to a level that could support development of predictive and causally based approach recommended in this report, given sufficient targeted and purposeful effort. These recommendations are broader than just a suggestion to construct another model. The mechanistic modeling approach should serve as a framework to integrate interactions of scientists and agencies working on water flows with those working on fishes and lower food webs. The goals would be to develop decision-support tools and data, guide monitoring and data collection, conduct specific scientific studies to fill major information gaps, identify important time and space scales, and identify the uncertainties with which policymakers need to work. Adaptive management can be improved through an iterative evaluation process that tests management scenarios and uses modeling to explore the range of possible outcomes.

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Introduction and Management Needs

California's persistent drought has brought renewed focus to the practical and scientific problems of managing flows to benefit desirable fishes in the Sacramento-San Joaquin Delta (Delta) while also meeting human demands for water. When one-acre-foot of water is worth $1000 or more, even small amounts of water imply millions of dollars in water supply. At the same time, counts of the endangered Delta smelt in the Delta have reached an all-time low, triggering headlines and discussions that signal the near extinction of this critical indicator species. The economic, ecological, and social costs of scientific uncertainty on the relationships of fishes and flows in water management controversies are significant.

Understanding the dependencies of fishes on water flows is central to understanding the Delta ecosystem and is key to achieving the state's coequal goals of "providing a more reliable water supply for California and protecting, restoring and enhancing the Delta ecosystem ... in a manner that protects and enhances ... the values of the Delta as an evolving place" (Water Code Section 85054). 'Water flows' are key to management decisions on water supply, and 'fishes' are the key indicator of the Delta ecosystem's health and services and a major driver of ecosystem policies. Relationships between fishes and flows drive state and federal policy and related regulatory and management decisions, and consequently have been central to legal arguments and decisions.

Since water flows are a defining process of the Delta, as in river ecosystems worldwide (e.g., Webb et al. 2015), scientific interest in this topic is keen. Water flow has been dubbed the 'master' ecological variable in the Delta (e.g., Mount et al. 2012), not

The economic, ecological, and social costs of scientific uncertainty on the relationships of fishes and flows in water management controversies are significant

because of the precise way in which flows affect fishes, but because of flows' pervasive influences on so many other variables in the Delta ecosystem. Water managers have considerable influence on flows in the Delta through reservoir releases, upstream and in-Delta diversions, levees, and flow barriers. People have come far in "mastering" water flows, within the limits of climate and society-determined water abundance, scarcity, and demand. Using this mastery to reach the coequal goals of water reliability and protecting the Delta's ecosystems requires improved knowledge of the relationships among water flows and fishes.

A large body of scientific research explores how water flows in the Delta and elsewhere affect fishes. The state of science of these processes in the Delta have been examined extensively in the scientific literature and through targeted reviews including two reports by the National Research Council linking water management and threatened and endangered fishes (NRC 2010; 2012) and the assessments of "Delta Outflows and Related Stressors" (Reed et al. 2014) and "Interior Delta Flows and Related Stressors" (Monismith et al. 2014). Other reports have focused on specific fish species (e.g., Sommer et al. 2007, Miller et al. 2012, Armstrong and Nislow 2012, Sommer et al. 2013, Cavallo et al. 2015, MAST 2015), groups of fish species (Baxter et al. 2010, SWRCB 2012), specific issues such as entrainment (Grimaldo et al. 2009, Anderson et al. 2015, Perry et al. 2015) or assessments of new water transport systems (BDCP 2013). These reviews highlight the complexity of the problem and the challenges of defining the

relative role of flows and other environmental drivers in a dynamic ecosystem such as the Delta.

Scientific findings that relate fishes and flows increasingly guide decisions on how to manage flows for the well-being of threatened or endangered species in the Delta. Many findings rely on correlations between flows and fish populations (e.g., MacNally et al. 2010, Thompson et al. 2010, SWRCB 2012, Latour 2015, Reed et al. 2014 and Monismith et al. 2014 and references cited therein). In a continuously changing system like the Delta, studies are needed that yield a deeper causal understanding of how flows affect fishes. It is important to look beyond correlations obtained using controlled studies or a limited number of variables to establish underlying mechanisms that can aid adaptive management, help identify uncertainty and risks, and create specific expectations for outcomes. This report recommends a scientific strategy intended to yield testable predictions and delineate mechanisms on how flow management decisions affect the magnitude or sometimes even the direction of changes in fish populations.

Improved understanding of the causal relationships between flows and fishes is critical for effective adaptive management, identifying uncertainty and risks and for creating specific outcome expectations

The Delta ISB established under the Delta Reform Act of 2009, is instructed to regularly review Delta scientific programs in support of adaptive management. The Board is carrying out this responsibility with reviews of overarching research themes. The theme in this review concerns how freshwater flows affect Delta fish populations. The report develops several recommendations on scientific strategies to benefit adaptive management, and to enhance collaboration and communication among institutions, scientists, and managers. The review process is described in Appendix A.

Scientific Challenges

The scientific challenges to determining a flow regime that benefits desirable fishes or minimizes the harm to them and, at the same time, provides water supply reliability are well recognized:

- The Delta ecosystem has experienced considerable changes and is still evolving. The modern estuary and its tributaries differ starkly from the conditions under which the Delta's native fish evolved. Non-native fishes now predominate, and the habitat and flow needs of the native species are difficult to define in the transformed place and in a novel ecosystem.

- Flows in the Delta, which vary greatly with location and season, affect fishes directly and indirectly. The indirect effects work through other environmental factors, and these differ among species and life stages within a species. Other drivers of fish production in the ecosystem confound the effects of flows.

- Many agencies are involved in Delta fish and flow decisions and in scientific efforts to support management of water supply and fishes.

These issues are briefly reviewed below.

Delta as an Evolving Place

The Delta ecosystem has experienced considerable changes and is still evolving. The current Delta and its tributaries bear little resemblance to the pre-development Delta in terms of its water flow regime, habitat structure, and fish communities (e.g., Nichols et al. 1986, Bennett and Moyle 1996, Moyle and Light 1996, Moyle 2002, Lund et al. 2010, Whipple et al. 2012) and differ starkly from the conditions under which the Delta's native fish evolved. Non-native fishes now predominate, and the habitat and flow needs of the native species are difficult to define in the transformed place and in a novel ecosystem.

The Delta ecosystem has experienced considerable changes and is still evolving. The current Delta bears little resemblance to the pre-development Delta in terms of its water flow regime, habitat structure, and fish communities

Land development has greatly altered the Delta's geometry and its hydrologic system of water flow channels, flow volumes, and flow dynamics. Marshes were diked and drained for farming, dams were built upstream to store water, waterways were leveed for flood control, and large pumping diversions were constructed that moved water in unnatural ways. Collectively, these changes have transformed flow pathways and dynamics, altered sediment and organic matter supply (Canuel et al. 2009), and destroyed or limited the access to certain fish habitats.

Historical flow conditions in the Delta had more marsh area, more dynamic flow and salinity regimes, higher turbidity, and more seasonally and tidally inundated wetlands (Moyle 2002, Baxter et al. 2010, Whipple et al. 2012). Over 98 percent of marshes have been lost, and the inundation frequency has decreased (Whipple et al. 2012). Historically, the flow regime in the Delta was extremely variable and influenced by the seasons, rainfall, and snowmelt (Moyle 2002, Whipple et al. 2012). Channels of the historical Delta were dominated by the tides, and its large capacity for

flood attenuation was due to the wide tidal channels, low banks, and broad wetland plain (Whipple et al. 2012).

Currently, water flows in the Delta are driven primarily by the tides, with additional significant contributions of freshwater inflows (affected by major upstream releases and diversions), local Delta inflows downstream, pumped diversions and return flows within the Delta, groundwater pumping, evaporation, precipitation, drainage and consumptive uses including those for local agriculture. Tidal flows dominate the western Delta, where rapid channel flows of hundreds of thousands of cubic feet per second are overwhelmingly driven by tides. Farther upstream, tidal effects diminish, but have some importance as far upstream as Sacramento (on the Sacramento River) and upstream of Stockton (on the San Joaquin River). The California State Water Project (SWP) and federal Central Valley Project (CVP) pump water from the southern Delta, drawing on large amounts of fresher and higher quality Sacramento River water through the Delta Cross Channel and Georgiana Slough, down to the lowest parts of the Mokelumne River, and then up Old and Middle rivers (which reverses these river flows at times), and into the south Delta pumping plants (Jackson and Paterson 1977, Monsen et al. 2007, Lund et al. 2010). To facilitate water exports from the Delta and maintain water quality for in-Delta diverters, most of the Delta is maintained as a freshwater system, controlled by many structures

The species in the Delta fish community have changed markedly in the past century in response to ecosystem changes and deliberate introductions. Non-native species now predominate in most regions of the Delta

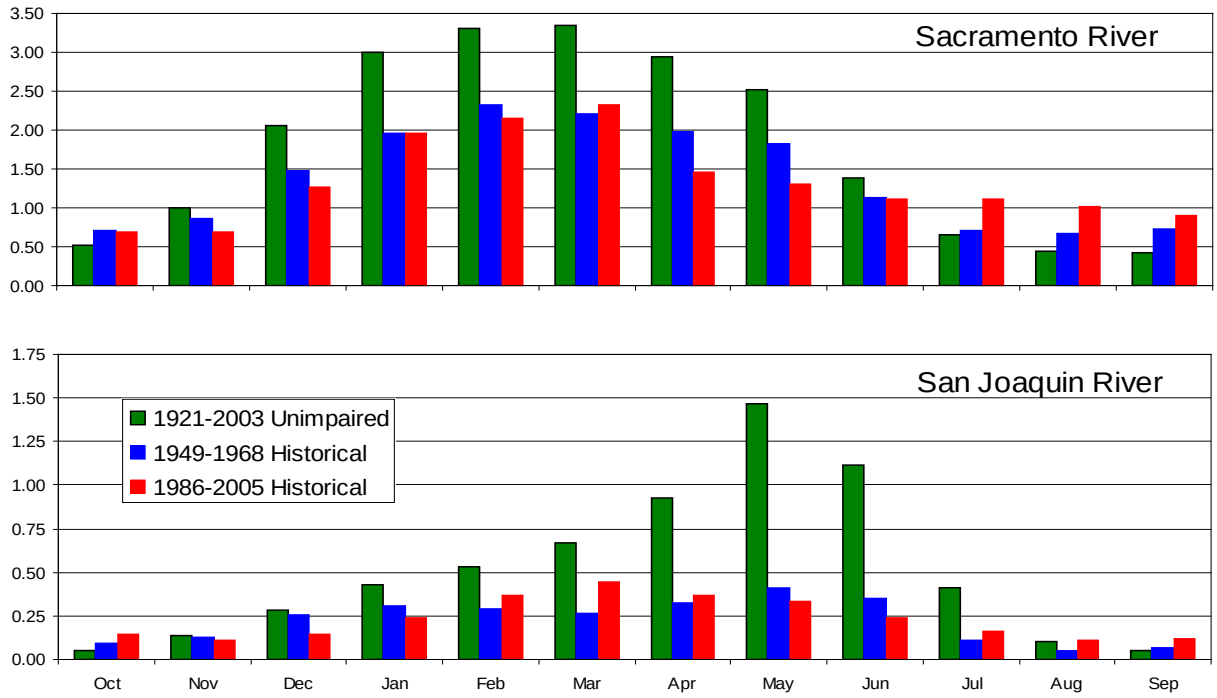


Figure 1. *Changes in Delta flow patterns. The y-axis is the average flow in million acre feet per month (Fleenor et al. 2010). (Note: Unimpaired flow does not account for upstream natural evapotranspiration under pre-development conditions.)*

(i.e., dams, gates, levees, etc.) and water operations (Jackson and Paterson 1977, Moyle 2002, Lund et al. 2010).

The Delta is now a simplified system of leveed islands, perennial freshwater-maintained channels with reduced outflow, less variability in salinity (in western areas), and altered channel morphology. Overall changes to annual total freshwater inflows and their seasonal patterns are illustrated in Figure 1. Upstream diversions for irrigation and cities have reduced inflows (somewhat counteracted by reductions in evapotranspiration from lost seasonal wetlands upstream). The regulation of streams by reservoirs and the highly seasonal patterns of upstream water diversions have made major changes to the seasonality of inflows, including increased inflows during the summer and reduced peak flows in winter and spring.

Other major changes have also affected the Delta ecosystem. These include large influxes of sediment from hydraulic and placer mining, changes in land-use patterns, increases in nutrient loading and pollutants (e.g., Dugdale et al. 2013, Glibert et al. 2014), commercial and recreational fisheries, and many introduced and invasive species of flora and fauna. The broader San Francisco Bay Estuary is one of the most modified and invaded ecosystems in the world (Cohen and Carlton 1998, Moyle and Bennett 2008, Greene et al. 2011). Changes in the lower food web of the Delta are well documented (e.g., Kimmerer 2006, Kimmerer et al. 1994, 2005, 2012).

Not surprisingly, the species composition of the fish community and abundances of individual species have changed markedly over the past century in response to changes in the ecosystem described above, as well as deliberate introductions (e.g., Striped bass, American shad). Currently over 30 fish species are common in the Delta (Moyle and Bennett 2008). This composition has shifted from dominant numbers of native fishes to today's dominance of non-native species with low numbers of natives (Moyle et al. 1986, Brown 2000, Marchetti and Moyle 2001, Moyle 2002, Feyrer and Healey 2003, Brown and Michniuk 2007). For example, Feyrer and Healey (2003) sampled fishes in the southern Delta from 1992-1999 and found that native species were 8 out of 33 fish taxa and less than 0.5 percent of the total number of fishes sampled. Feyrer (2004) sampled fish larvae in the southern Delta from 1990-1995 and found that 98 percent of the fishes caught were non-native species. Countless studies draw the same conclusions: native species in the Delta have declined substantially and nonnative species are now dominant in most of the Delta, particularly in the southern Delta. Several native species have been listed as endangered or threatened (Feyrer et al. 2007).

Interannual extremes of climate, such as the current drought, also affect flows and regulatory restrictions on flows. Substantial future changes in Delta flow volumes, pathways, and dynamics are expected. Engineering changes and enhanced adaptive management actions are being considered that include water flow management (e.g., operation of channel gates, pumping, reservoir releases, water diversions), wetland habitat restoration, and planned permanent and seasonal flooding. The Delta also will be subjected to interannual variations in water supply through changes in the patterns of precipitation and evaporation, sea level rise caused by climate change, continued growth of the human population and increased urbanization, changes in land-use, and extreme events such as droughts, floods, or levee failures. New species invasions are likely. The need to understand and predict how these evolving changes will affect fishes will become even more important.

Habitat requirements differ across species and life stages within a species. Flows favorable to one species may be unfavorable to another

Responses to Environmental Conditions Differ Among Species

Different species and different life stages within a species differ in their habitat requirements and their resilience/vulnerability to habitat changes and environmental drivers. Therefore, the response of 'fishes' to 'flows' will be species-, life-stage-, and location-specific. The status of selected, native Delta fish populations has been used to indicate the health of the Delta's ecosystem. The endangered Delta smelt and Chinook salmon have been studied extensively (e.g., Limm and Marchetti 2009, Sommer and Mejia 2013, Alexander et al. 2014, Zueg and Cavallo 2014, Cavallo et al. 2015, Perry et al. 2015, MAST 2015) and illustrate the wide breadth of responses to flows. The effects of flows on fishes are often discussed in relation to annual indices of (relative) population abundance. In an ecosystem, fish abundance (total population at a point in time) is determined by a combination of reproductive success, individual growth rates at different life stages, and mortality rates. The rates of these processes are driven by physical, chemical, and biological habitat conditions, and the mechanistic relationships thereof are complex.

Multiple Drivers Affect Fishes

Flow is but one factor affecting fishes and its effects are confounded by other drivers of fish production in the ecosystem. Five major drivers are considered as agents of change in any given ecosystem. These are habitat alteration and loss, resource use and exploitation, invasive species, pollution, and climate. All of these drivers have played a role in the Delta and affected fishes. Separating the influence of flow from myriad other factors in the Delta is confounded by the action of many drivers over long time periods, ecosystem complexity and nonlinear responses to drivers, a narrow focus of research on a few species and relatively little on other ecologically important species or processes (e.g., predation, food webs, behavior in migration corridors), and lack of comprehensive, integrated data sets.

Specific reasons for the declines in abundances of native species in the Delta remain unclear but are likely caused by multiple drivers (or stressors) and the interactions thereof (Bennett and Moyle 1996, Moyle 2002, Kimmerer 2002a, 2002b, Feyrer and Healey 2003, Brown and Michniuk 2007, Feyrer et al. 2007, Moyle and Bennett 2008, Hanak et al. 2013). The NRC 2010 report concluded that "Nobody disagrees that engineering changes, the introduction of many exotic species, the addition of contaminants to the system and the general effects of an increasing human population have contributed to the fishes decline", but the relative contributions of these drivers and the significance of their interactions are inadequately known. The role of multiple stressors in the Delta has been discussed in previous reviews by Mount et al. 2012, NRC 2010 and 2012, Hanak et al. 2013, Reed et al. 2014, and Monismith et al. 2014.

It is almost impossible to assess how flows affected fishes historically in the Delta because the ecosystem has undergone and is still experiencing dramatic alterations in habitat, species composition and interactions, channel morphology, and water quality. These factors also interact in complex ways.

Fish abundance is driven by many factors that may or may not be influenced by water flows. The relative contributions of these drivers and the significance of their interactions are inadequately known

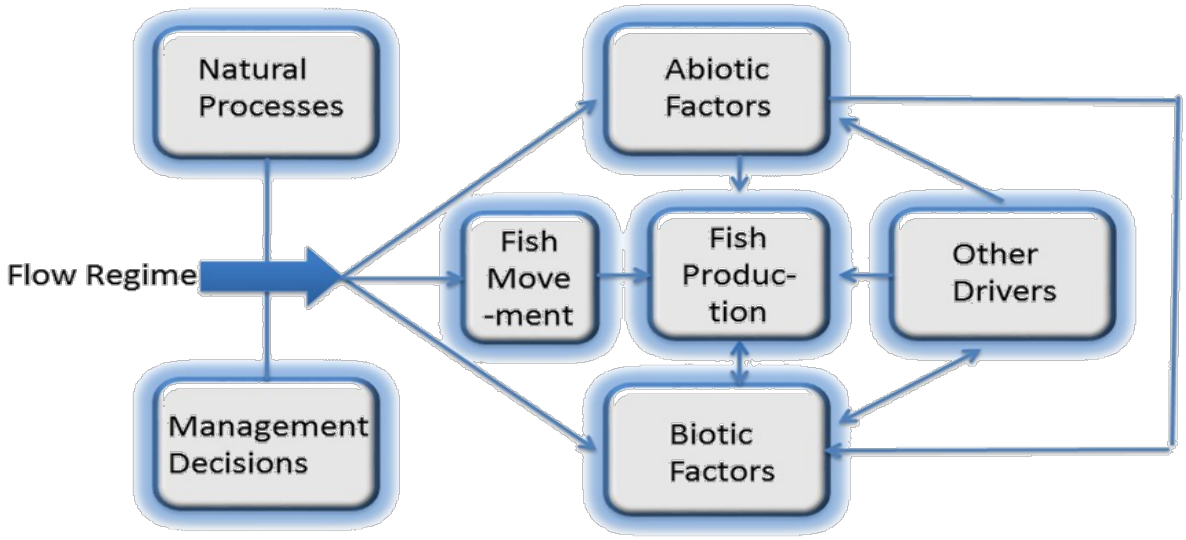


Figure 2. *Simplified diagram of how flows affect fish populations directly and indirectly, interacting with other drivers.*

Statistical correlations support specific hypotheses. For example, studies support the hypothesis that changes in historical flows (e.g., wet years and dry years,) affected certain fish population abundances and that the location of the salinity gradient (X2) is correlated with abundances of certain species (e.g., Kimmerer 2002b, Feyrer and Healey 2003, MacNally et al. 2010, Reed et al. 2014, Monismith et al. 2014 and references cited therein).

Direct and Indirect Effects of Flows

Flows may affect fishes through multiple direct and indirect (i.e., proximate and ultimate) processes. Direct effects largely include physical transport and alteration of migratory pathways. The indirect effects work through other biotic and abiotic factors in the ecosystem that, in turn, affect fish growth, reproduction, mortality, and ultimately fish population size. A conceptual diagram of the potential factors affecting fish production illustrates the scientific challenges and helps identify gaps in our understanding (e.g., Figure 2and Appendix B).

Water flows generally define and shape a delta and the term 'flow' is used in different ways, often without explicit definition. "Flow" commonly is used by water managers to be an amount or volume of freshwater. To assess how freshwater 'flow' affects fishes, explicit definitions of the components of flow is required that better reflect the potential processes affecting fishes (as also suggested by Monismith et al. 2014).

In simple terms, flow (Q) is a rate that defines the total volume of water moving through a given cross-section of the river per unit time (ft^3 or m^3 / s). Q is the product of cross-sectional averaged water velocity and the channel's cross sectional area. Fishes cannot detect flow per se because they do not know the width and depth of the channel. Thus the relevant parameters of a 'flow' for fishes are the local water velocity, duration, direction, timing, rate of change, and intensity of turbulence. Flows can have high or low velocity in different

locations depending on channel morphology, be irregular in time (e.g., seasonality of precipitation), intermittent (e.g., floods), change regularly (e.g., tides), and have a particular direction. Water flows in the Delta are complex, and are the combined result of tidal movements, freshwater inflows, return flows, diversions, precipitation, evaporation, drainage, and water exports.

Fishes experience the combined flows of freshwater in the context of a tidal environment (Figure 2). At any point in the Delta, the bulk flow regime (volume, average velocity, unsteadiness, flow direction) is determined by a combination of natural processes and management decisions (historic or operational). Current conditions of land-use and cover, channel morphology, dams, and levees set the morphologic framework. Precipitation, evaporation, basin runoff, snowmelt, and tides are natural processes that affect the flow (hydrologic) regime which can be modified through management decisions on storage and release of water from reservoirs, exports, consumptive uses, barriers, channel cuts, levees, and diversions. The current California drought is an extreme example of how natural processes can drive flow dynamics and fundamentally alter water management scenarios.

Understanding the coupling of water motion to fish movements is a key aspect of fishes and flows research

Coupling water motion and fish movements is a key aspect of fishes and flows research. Overall flow dynamics directly affect fish movement by defining viable routes (e.g., channeling) and pathways, restricting movements (e.g., dams), providing upstream homing (e.g., olfactory) cues to direct fish migrations to spawning grounds, providing currents through which fishes must swim, and through passive transport downstream. Fishes that evolved in an ecosystem with characteristic flow dynamics may use those flow dynamics as part of their life history strategy, and thus, changes in flows may trigger migrations, or seasonal flooding may cue spawning activity. Water velocity, which is directly perceived by fishes, affects migration rates because fishes can drift with currents or must swim against/across currents to reach reproductive or nursery areas (Mesick 2001, Nislow et al. 2004, Nobriga et al. 2006, del Rosario et al. 2013). High river flows can increase energy expenditures to maintain position or to swim upstream (Rand et al. 2006, Martins et al. 2012). Artificial changes in these flows could disrupt normal migratory cues and behavior or cause larval or juvenile fishes to drift to unsuitable habitats or to entrainment locations (e.g., Bennett and Moyle 1996). For example, pumping for water exports alters Delta-wide hydrodynamics and may draw fishes towards export facilities and away from more productive or safe habitat areas (Jackson and Paterson 1977, Herbold and Moyle 1989, Monsen et al. 2007, Kimmerer 2008, Kimmerer and Nobriga 2008). Pump entrainment has been implicated in the decline of certain fishes in the Bay-Delta system, especially the Delta smelt (Kimmerer 2008, Baxter et al. 2010, Anderson et al. 2015).

Perhaps the greatest impact of flows on fishes is through water flows' influences on other environmental factors. In river ecosystems and the Delta, flows have pervasive effects on physical, biological, and chemical aspects of the environment that drive biological processes and fish vital rates (e.g., physiology and behavior) (Bunn and Arthington 2002, Baxter et al. 2010). Flow rates can directly affect water temperature, salinity, depth, oxygen concentration, food supply, chemical concentrations, turbidity, and sediment load, among other factors (e.g., Jassby et al. 2002, Wagner et al. 2011, Arismendi et al. 2012, Walters and Post 2011, Anderson et al. 2015). These

directly affect the fish vital rates and other biological factors that affect fish production. For example, temperature affects fish growth rates and mortality directly, but also indirectly, because temperature affects predation rates and thus predation-induced mortality. As another example, flows can affect residence time (e.g., Kimmerer et al. 2014, Glibert et al. 2014), which can affect phytoplankton production, zooplankton movement, or even phytoplankton clearance by sedentary invasive bivalves. In addition, these flow-related factors "co-vary" with one another, and their effects on fish growth, mortality, and reproduction are not static. Rather, they change under different circumstances and ecosystem conditions. Understanding the quantitative relationships of these drivers to fish growth rates, reproductive success, and survival, and understanding how a flow regime affects these drivers is important to making informed management decisions and predicting the consequences of these decisions.

Water flows have pervasive effects on the physical, biological, and chemical aspects of the environment that drive biological processes and fish vital rates

Mathematical models of hydrodynamics have been developed to simulate Delta flow regimes so the flow implications of management decisions are reasonably well understood on a broad scale. Yet, understanding flow regimes is insufficient, as local nuances of flow may determine the local response of fishes and collectively, the overall behavior of fishes. Science should be able to assess how particular changes in flows affect a change in environmental conditions and how those changes might affect fish vital rates. Since flows can affect multiple habitat features, the final result will depend on cumulative impacts.

Drivers other than flow also can affect fishes directly or through changes in the biological, chemical, or physical habitat. Fundamental drivers in all ecosystems are habitat alterations, pollution, climate, resource use (e.g., fishing) and invasive species. For example, temperature also is driven by overlying weather conditions, food levels can be affected by invasive species such as filtering by bivalves, predation risk is a function of predator densities and availability of alternative prey, and fishing causes additional fish mortality. Anadromous species spend only part of their life in the Delta, so their abundance also is influenced by ocean conditions. The strength of these effects on fish production differs among species and with prevailing conditions, and they should not be ignored in population assessments.

Challenges in the Organization of Management and Science

Many agencies are involved in Delta fish and flow decisions and in scientific efforts to support management of water supply and fishes. A key scientific challenge is that decision-making on water flows and fisheries management are made by different agencies, and agency science and monitoring align with agency priorities and mandates. Most science and models developed for water management may not be appropriate in time (e.g., water releases, timing of diversions), space (e.g., local entrainment, diversions), or parameter (e.g., temperature) level for models needed to understand fish production driven by growth, reproduction, survival, and transport/ movement.

The central management challenge is encompassed in the state's coequal goals for the Delta. How do decisions on water reliability affect fishes? Legal requirements also focus on threatened or endangered species where much of the science has been done. Key management challenges include: 1) fish abundances are affected by various interrelated factors that are insufficiently quantified, and 2) many separate agencies and programs have responsibilities for different aspects of the issue (Table 1).

Agencies that manage fish populations in the Delta include the California Department of Fish and Wildlife (CDFW), the federal National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), and the U.S. Environmental Protection Agency (USEPA). Their strongest authorities lie in federal and state Endangered Species acts. The State Water Resources Control Board (SWRCB) has discretionary authority under state and federally delegated clean water legislation, as well as state constitutional and water rights authorities, to balance reasonable use of water resources. Flow management and model development are largely designed to improve water reliability for cities and agriculture. However, flow management in the Delta serves several, sometimes competing, purposes that are often overseen by different agencies. For example, high flows, which provide the greatest access to floodplain habitat, are limited for flood control by the Division of Flood Management of California Department of Water Resources (CDWR), the U.S. Army Corps of Engineers (USACE), and numerous local levee districts. Fish habitat in Suisun Marsh, Yolo Bypass, the northeastern Delta, and the lower San Joaquin River is restricted by flood management in these regions.

Flows in the interior Delta are affected by reservoir releases into the Delta, from both the Sacramento and San Joaquin rivers, the operation of gates and pumps by the federal CVP (operated by the U.S. Bureau of Reclamation [Reclamation]) and California's SWP (operated within CDWR), and decisions of the SWRCB, which has water rights and water quality regulation authority. Local water diversions also have some effect on flows and water quality within the Delta. The myriad agencies with differing mandates and missions make the challenges for maintaining flows that support a variety of native fish populations difficult.

Table 1. Governmental agencies involvement in Delta fish and flows

Level of government	Primary fish management responsibility	Primary flow management responsibility
Federal	NMFS, USFWS, USEPA	Reclamation, USACE
State	CDFW, SWRCB, Council	CDWR, SWRCB, Council
Local		Local water diverters, individuals, counties

Over several decades, the Delta scientific community has made substantial strides in understanding this complex ecosystem. As with most large ecosystems, the scientific effort is scattered among mission-oriented state and federal agencies, academic institutions, private consultants, and NGOs. Science communication is fostered through scientific conferences (e.g., the Bay-Delta Science Conference), meetings, workshops, newsletters, websites and peer-reviewed publications (e.g., *San Francisco Estuary and Watershed Science*). The Delta Science Program has helped increase the rigor by contributing a number of scientific reviews, providing a forum for reasoned scientific debate, providing educational and training opportunities and leading the development of a unified science plan for the Delta. Examples of successful interdisciplinary collaboration and synthesis of research in the Delta have been the result of excellent leadership and willing participants.

All relevant state and federal agencies have some scientific activities and responsibilities in the Delta, although not all are relevant to fishes and flow. Some of the largest local water agencies and university scientists also have their own science programs or participate in the joint science program of the State and Federal Contractors Water Agency. There have been several successful models of interagency science collaboration in the Delta. For instance, the Interagency Ecological Program (IEP) is a longstanding effort of federal and state agencies to have a combined biological monitoring and research program for the Delta. The Collaborative Adaptive Management Team and the Collaborative Science and Adaptive Management Program is a collaboration among state and federal agencies, public water agencies, water contractors and NGOs to develop science and adaptive management programs to implement biological opinions on smelt and salmon (Anderson et al. 2014). The California Water and Environmental Modeling Forum (CWEMF) promotes exchange of information and discussion on California water modeling issues. The Management Analysis and Synthesis Team completed a comprehensive conceptual model of the Delta smelt (MAST 2015), and there have been some successful attempts to connect hydrologic and fish models (e.g., Rose et al. 2013a, 2013b). However, implementation of a comprehensive, focused, and strategic framework for scientific research linking water flow to the complex processes influencing fishes is required for managing both the Delta ecosystem and Delta science.

Many state and federal agencies are involved in decisions related to water flows and to fishes. However, a comprehensive, focused, and strategic framework for research linking water issues to a complex of fishes has not been implemented

Recommendations on Strategic Science Needs

Improving scientific understanding of fishes and flows, and bringing this knowledge into useful decision-support for adaptive management has clear urgency. Workshop reports by Reed et al. (2014) and Monismith et al. (2014) clearly lay out a series of management-critical questions related to water management and effects on fishes. The reports also identify scientific gaps in our information on these topics. Among these, the Delta ISB concurs that management decisions could be improved with better forecasts of outcomes, greater understanding of the conditional impacts of other drivers on fishes, and quantitative assessments of the combined effects of flows on other parts of the physical and biological ecosystems as they relate to fishes. The Delta ISB recommends the following scientific strategy to address the near- and long-term scientific challenges related to management of flows relative to fishes and for its ability to yield testable predictions on how flow management decisions will affect the magnitude of changes in fish populations.

1. *Focus on cause & effect – mechanisms that enable flows to affect fishes*

Deeper understanding of the causal mechanisms by which water flows affect fishes is critical for effective adaptive management, identifying and reducing uncertainty and risks, and for creating specific outcome expectations for management actions. It can also yield specific hypotheses for use in adaptive management (e.g., MAST 2015, Monismith et al. 2014).

Improving scientific understanding of fishes and flows, and bringing this knowledge into useful decision-support for adaptive management has clear urgency

For effective adaptive management, improved quantitative understanding of causal mechanisms is required

Flows and other drivers on fishes need to be examined for their direct and indirect effects on essential fish production processes and vital rates (i.e., growth rates, reproduction success, mortality rates, and migrations/transport). Increased focus on measurable rate processes (e.g., individual fish growth rates) can complement annual population levels that integrate all factors affecting fishes. The overarching questions include: What are the essential requirements of a desirable fish species for individual and population growth and sustainability and how do flows change those requirements?

A mechanistic understanding of the responses to environmental drivers/conditions will improve quantitative predictions. Strategic scientific efforts should focus on:

- *Understanding how the time and space dynamics of water flows affect fish movement through passive transport, active swimming (with or against flow direction), and as triggers that cue migrations or spawning activities.* Fish movement cues, swimming ability, and behavior are critical to understanding how flows assist or disrupt life history strategies. For example, better understanding of hydrodynamics (flow fields) and fish behavior at channel junctions could help keep migrating salmon from the interior Delta, and perhaps reduce mortality.

- *Understanding how flow velocities, depths, and dynamics affect key physical, chemical, and biological factors important to fishes as well for developing fish-flow models.*
- *Quantifying how fish vital rates (growth rate, reproductive success, and mortality rate) are affected by the interaction of biotic and abiotic conditions in the environment and how these interactions translate into population abundances.*

Effects of flows and other drivers on fishes need to be examined for their direct and indirect effects on essential fish production processes and vital rates (i.e., growth rates, reproductive success, mortality rates, and migrations/ transport)

2. Expand integrative science approaches

Addressing specific science priorities requires the development of an integrative, and well-planned scientific approach grounded on management questions and focused on processes, drivers, and predictions. In the words of a 2012 National Research Council report, "only a synthetic, analytical approach to understanding the effects of suites of environmental factors (stressors) on the ecosystem and its components is likely to provide important insights that can lead to enhancement of the Delta and its species." Adaptive science that is flexible and responsive to knowledge-gap identification can provide an effective means to improve management. Research strategies that strengthen interagency and cross-disciplinary work can speed and solidify scientific discoveries and their application. An integrative approach is essential for developing flow management tools that also ensure the health of fish populations.

3. Link quantitative fish models with 3-D models of water flows

The direct linkage of quantitative fish models with 3-D models of water flows is needed to provide a comprehensive, heuristic modeling framework for identifying information gaps, key drivers, and appropriate time and space scales for integrating interagency and interdisciplinary science activities and priorities and underpinning decision support. A targeted collaborative effort will be needed to develop a 3-D open-source hydrodynamic model that can be widely adopted and integrated with generic and species-specific models of fish growth, movement, mortality, and reproduction and with food-web models. The modeling approach should be fish-centric with fish endpoints driving model development. To be relevant for modeling effects on fishes, hydrodynamic models will need to be more related to the habitat (biological, chemical, physical) requirements for fish species and the proximal causes that affect fish reproduction, mortality, and individual growth rates. This framework can be refined as the model development proceeds. The inputs/outputs should be developed jointly by hydrodynamic and fish modelers as well as lower trophic level modelers. Such a modeling framework should catalyze interagency and interdisciplinary science collaboration and directions, help define major gaps in information and monitoring needs, and be targeted towards decision support. Such a model needs a dedicated home that can provide continuous maintenance, upgrades, access, transparency, and support for the users.

A comprehensive, integrative, and well-planned scientific approach focused on processes, drivers, and predictions is needed to aid near-term and long-term adaptive management and to predict how future changes might affect fishes

This recommendation is consistent with the conclusions drawn in the 2010 National Research Council (NRC) Report that stated: "the agencies have not developed a comprehensive modeling strategy that includes the development of new models (e.g., life-cycle and movement models that link behavior and hydrology)" and forms a core conclusion of the Delta ISB.

A major collaborative effort is needed to develop a 3-D open-sourced hydrodynamic model that can be more widely adopted and integrated with generic and species-specific models of fish growth, movement, mortality, and reproduction and with food-web models. This model should be developed from the perspective of fish habitat requirements

Modeling capabilities and ecosystem understanding in the Delta have grown to where development of such a predictive mechanistic approach is possible. Three-dimensional hydrodynamic and water quality models have been successful in other systems to examine fish production processes (e.g., the Chesapeake Bay, Kemp et al. 2005, Boesch 2006, Dalyander and Cerco 2010, Townsend 2013) and are being increasingly applied in the Delta. The hydrodynamic model should capture both natural processes and water management drivers. A key difference being proposed here is that the hydrodynamic models be developed for the purpose of a mechanistic evaluation of biological processes and designed to make testable predictions. Parameter scale, time scale, and space scale should be relevant for both fishes and flows.

The growth rates of individuals within a fish population are important to overall fish production and can be used to illustrate this type of modeling approach. The growth rate of an individual fish is determined directly through a balance of the difference between energy intake (consumption) and energy expenditure (metabolic costs) plus waste products (egestion and excretion). Key factors affecting energy expenditure are activity levels of the fishes, temperature, oxygen, and salinity. Fish consumption rates also are affected by temperature, salinity, oxygen level, and prey availability (prey density, detectability, catchability). Prey density can be affected by the presence of competitors, and production dynamics and habitat requirements of lower trophic levels (e.g., Kimmerer et al. 2005, Kimmerer 2006). Many of the above factors are sensitively affected by changes in flows (e.g., Myrick and Cech 2004, Nislow et al. 2004, Arnekleiv et al. 2006, Davidson et al. 2010, Arismendi et al. 2012, Rose et al. 2014, Fiechter et al. 2015) and these need to be considered in model development and execution.

The development of a generalized fish model portable for different fish species and for different water management decisions is needed to forecast expected consequences and timelines for adaptive management strategies. The life cycle models developed for species such as the Delta smelt (Rose et al. 2014, MAST 2015) and salmonids (Hendrix et al. 2014) provide a solid foundation for this process. General fish vital rate models can be developed (or borrowed) based on fish physiology and behavior, and parameterized separately for each species and life stage (e.g., Wisconsin Bioenergetics model, Chipps and Wahl 2008). Physiological models deal with constraints imposed by the water temperature, water quality (e.g., hypoxia), swimming abilities, and cover types (e.g., root wads, large boulders, shallow water, and vegetation). Currently, available models used in the Delta appear to use only a subset of these without temperature (Myrick and Cech 2004, Arismendi et al. 2012). Model applications should also examine adequate coupling of some critical variables such as species or ecosystem tipping points and thresholds as well as cumulative impacts. The task of such coupling is simplified, given that water flows may affect fishes but not vice versa, and hence only one-way coupling of models is required.

A modeling effort focused specifically on a mechanistic evaluation of how changes in flows affect fish production dynamics will provide an operational tool for adaptive management and forecasting biological outcomes of water decisions. Such modeling will require components of regional climate (hydrology), hydrodynamics, water quality, food availability, and physiological and habitat requirements at various fish life stages across different fish species.

The Delta ISB recognizes the value of one and two-dimensional models that are also used for riverine ecosystem studies and management (e.g. Anderson et al. 2013), but some important physical processes

Modeling focused on a mechanistic evaluation of how changes in flows affect fish production dynamics will provide an operational tool for adaptive management and forecasting outcomes

are eliminated in simplification. For example, 2-D models eliminate the effects of vertical and horizontal density driven (baroclinic) motions, and therefore gravitational circulation (Lucas et al. 2002, Chua and Fringer 2011). Baroclinic circulation is critical in fish recruitment and X2-fish relationships (Monismith et al. 2002). Even inclusion of nonhydrostatic dynamics may not capture the baroclinic circulation accurately because of the dependence of salt mixing on the turbulence (vertical mixing) models used in the 3-D modeling system. Therefore, appropriate turbulence models for Delta hydrodynamics for both shallow and deeper regions is a topic that needs further research.

Although 3-D and 2-D hydrodynamic models that are currently used produce detailed profiles of hydrodynamic parameters, for computational convenience some parameters important for fish are removed from the governing equations. A clear example is omission of the temperature equations while retaining salinity, reflecting the assumption that buoyancy effects are dominated by salinity. Yet, temperature is a key variable for determining fish physiological rates (Cloern et al. 2011), spawning (Bennett 2005), and mortality (Feyrer et al. 2007). Water temperature also is affected by air temperature and water-surface wind mixing, which are usually omitted in water flow models although it is possible to include them through parameterizations. Temperature should be included in models developed for fish-flow studies.

Greater use of individual-based models of fishes in a spatially explicit context can yield spatially,

temporally, and life-stage specific information on fish vital rates, especially when linked to 3-D hydrodynamic models (e.g., Dalyander and Cerco 2010, Rose 2000, Grimm and Railsback 2005, Rose et al. 2013a, 2013b, Stillman et al. 2015). The most direct effect of flows on fishes is through its influence on fish movement (Figure 2) and this can be modeled. Time-varying 3-D models also allow incorporation of fish movement and behavior (e.g., Kimmerer et al. 2014). Individual-based models can follow movement and resultant growth, and survival of a large number of individuals have been effective when coupled with a hydrodynamic model (e.g., Höök et al. 2008, Beletsky et al. 2008, DeAngelis and Grimm 2014, Rose et al. 2014). The basic modeling framework can be scaled to different species by changing movement rules and fish bioenergetic parameters.

Overall, such a modeling framework can help assess the potential responses of different species of fish to management actions, habitat restoration efforts, and different climate conditions. After initial development, continuing development must include model improvements and acquisition of high-resolution benchmark data sets for characteristic flow regimes. Improved indices of ecosystem status and management action set-points will have traceable drivers. Subsequently, reduced (parsimonious) models may be valuable for management support. All such modeling development must be done in the context of assessing uncertainty, hypothesis-based parameter testing, evaluation of parameter sensitivity and continued communication between model developers, model users, managers, and monitoring programs. Long-term support for viable models should be ensured.

Some specific steps forward are needed to ensure that the proposed modeling framework spans across major stakeholder agencies and programs. Hydrodynamic modelers must work directly with fish and lower food web experts as well as decision-makers so essential model parameters and necessary time and space scales are employed and the best biophysical understanding is incorporated. An initial workshop should describe the detailed framework and implementation plan for development of the 3-D model that will include a generic fish model. A suitable taxonomy may identify the model version and application information. Synthesis will help solidify conclusions and interactions. Formation of a well-led standing working group including both hydrodynamic and fish and food web modelers from agencies, academia, NGOs, and consulting should carry this effort forward and provide linkages to other ongoing modeling efforts (e.g., CWEMF, IEP) and with formal adaptive management processes.

Hydrodynamic modelers must work directly with fish experts to ensure that essential model parameters and necessary time and space scales are included

4. Examine causal mechanisms on appropriate time and space scales

A mechanism-based focus will require a close consideration of time, space, and parameter scales relevant to biological processes as well as driving physical (flow) mechanisms. Models with time and space (depth, width, reach and time variation) scales appropriate for water management questions may not be useful to answer fish and ecosystem questions that may require higher temporal and spatial resolution, although progress has been made to link water and fish models (e.g., Rose et al. 2013a, 2013b). Water-management models can provide useful inputs to more detailed hydrodynamics models via model nesting. This points to the need for a comprehensive modeling

framework that can serve diverse modeling needs of Delta environmental management, including fish. Space-time flow variability has important biological consequences that are not necessarily captured in mean monthly flow values or in annual fish population estimates because of the many drivers operating in this ecosystem.

Flows that affect a particular life stage of a fish species may have consequences in later life stages. Of particular importance is the metabolic cost of growth, which deals with energy partition between life support (maintenance of metabolic rate) and growth, for which the energy exerted against the flow is important (Rombough 1994). The relevant time scales of fish processes are often shorter (sometimes on the order of hours) than particular life stages. For example, fish growth rates can change daily based on daily changes in temperature, and a 1°C change in temperature can be significant, particularly near thresholds (e.g. Chipps and Wahl 2008). The sensitivity of fish behavior to salinity and temperature depends on the species and life stage, among other factors, and the models should be able to resolve gradients for optimal nursery habitats for fish species (Hobbs et al. 2006). Timing of flow management and monitoring should reflect major mechanisms that affect fish health across an entire year. Fish responses should be measured at the time and space scales of expected responses (e.g., fish movements and fish growth rates might respond rapidly to changes in flow).

Space, time, and parameter scales must be relevant to fish processes

5. Monitor vital rates of fishes

Monitoring is done to estimate ecosystem conditions or to assess the consequences of specific management actions. To this end, a monitoring program that is organic with model expectations can improve the contribution of science to adaptive management. A specifically designed program is needed to monitor expected first-order responses by which flows affect fishes, linked to multiscale modeling efforts. Monitoring should focus more on factors having immediate effects on fishes and be used to calibrate and test models and specific hypotheses. Fish monitoring should be coordinated with water quality monitoring and water flow monitoring, and perhaps use an integrated data framework. State-of-the-art sensor technologies and data transfer methods can enable routine monitoring data to be useful for comprehensive research purposes and model evaluations.

Rate responses, such as fish growth rate, more aptly reflect response to changing conditions and provide more certain and causal insights than annual indices of population size which integrate across multiple drivers. Additional monitoring for more mechanistically related characteristics, such as growth rates or movement, might provide improved and more relevant information for adaptive management. Techniques such as measuring bioelectrical impedance have shown promise for measuring short-term responses of fish to food availability (Calderone et al. 2012). Field studies on fish growth rates have given major insights into the mechanisms behind successful fish habitats on seasonal floodplains for the Delta (Sommer et al. 2001; Jeffries et al. 2008). Acoustic tagging studies have been valuable to assess fish movements and would be strengthened if linked with hypotheses driven by hydrodynamic models with particle tracking capabilities. Integrating mobile multibeam acoustics with pelagic trawl surveys could strengthen assessments since they can provide detailed measures of fish distributions across environmental gradients. Similarly, monitoring of fish populations should be targeted to factors likely to respond to changes in flow (e.g.,

growth rates, movement). The lack of integrative, coherent, centralized, and quality controlled/assured monitoring data and the unavailability of a modeling and question-driven framework that links fish modeling to water quality and flow parameters hinders synthesis.

A specifically designed program is needed to monitor major mechanisms by which flows affect fishes, linked to the modeling efforts and relevant time and space scales

6. Broaden species focus

Much research in the Delta has been understandably focused on endangered or threatened species and some non-natives such as the Striped bass. Non-native species dominate fish biomass in much of the Delta and have disrupted historic food webs. Ecologically important species of fish are those that dominate the ecosystem and/or play key roles in the food web. Little is known about the impact of flows on many of these species and they likely have important food-web relationships to threatened or endangered species. More generally, little is known about predator and competitor distribution and abundance, the influence of flow on predators and predation rates, and predator impact. A multispecies framework that incorporates food web connections has been adopted elsewhere and should be considered here, particularly given the threat of new invaders. For example, the Chesapeake Bay formally adopted multispecies management goals as part of the Chesapeake Bay 2000 Agreement (Boesch 2006, Townsend 2013 and references cited therein). A 3-D model can be parameterized for multiple fish species to advance this understanding.

The research focus on threatened or endangered species needs to expand to other native species as well as non-native, ecological important fish species that populate the Delta

7. Enhance national and international connections

The problems faced in the Delta are not unique. A wealth of knowledge exists from other ecosystems. To accelerate and improve scientific insights and reduce their costs, agency scientists need access to these other studies and scientists through expanded access to the recent scientific literature and opportunities for travel to conferences, workshops and relevant other field sites. Large U.S. ecosystems heavily impacted by population growth, changes in land use, and multiple stressors include the Great Lakes, Chesapeake Bay, Mississippi Delta, the Everglades, Columbia River, and Puget Sound. The scientists and managers in these ecosystems are addressing many of the same issues that Delta scientists and managers face (e.g., Boesch 2006). Although nominally similar habitats can differ greatly in stressors and dominant mechanisms (e.g., low productivity ecosystems and those impaired by nutrient enrichment), comparisons can yield important insights and shared tools (Malone et al. 1999).

The problems faced in the Delta are not unique. State-agency scientists need better opportunities to assess results and thinking from the perspective of other estuaries

It is especially important that state and federal scientists have convenient access to national and international scientific journals. This might be accomplished with a high-level agreement between the state and/or federal governments and the large library system of the University of California.

8. *Promote timely synthesis of research and monitoring*

Considerable research has addressed the impacts of flows on fishes, but synthesis of this research has been limited, particularly on integration of physical and biological processes and for developing adaptive management scenarios and adaptive science as well. Agencies must recognize the importance and need for routine and timely scientific synthesis for both directing scientific efforts and summarizing scientific results and uncertainties for managers. This requires additional dedicated staff time and resources.

Agency policies are needed that provide synthesis teams with adequate resources to complete their work in a time frame useful for decision-makers and to reward cross-disciplinary, multi-authored scientific efforts, and ensure the maintenance and upgrading, availability, and documentation of sophisticated models and essential databases focusing specifically on the Delta. An overall scientific and modeling approach specifically targeted on the mechanistic understanding of how flows affect fishes could provide an organizing framework and forum for regular interagency and interdisciplinary synthesis.

Synthesis is not the end point – the use of knowledge is. Considerable effort to translate the science to a full range of users including stakeholders, managers, and adaptive management team(s) is needed. Sophisticated but user-friendly management tools that build upon scientific knowledge and modeling are most helpful in this regard.

9. *Improve coordination among disciplines and institutions*

Improved understanding is needed among ecologists, hydrologists, and hydrodynamic modelers and across their various institutions having different missions and priorities to better understand the constraints under which all work. A comprehensive scientific framework and implementation plan will help guide these advances (see recommendation 1). Long-term commitment is needed for science that addresses contentious and fundamental issues that span traditional agency and disciplinary lines. Interdisciplinary, interagency understanding can be facilitated through implementation of the Delta Science Plan, which has been designed to encourage sustained commitment and increased coordination for addressing contentious issues and wicked problems. A management focus on a single controllable feature (e.g., flows) may miss a myriad of underlying ecological processes and management opportunities, so funding and coordination are needed for more integrative programs. Monitoring, research, and adaptive management focused on management-relevant mechanistic understanding should be incorporated into studies.

Conclusions

Overall, modeling capabilities and ecosystem understanding in the Delta have grown to a level that could support development of predictive and causally based approach recommended in this report, given sufficient targeted and purposeful effort. These recommendations are broader than just a suggestion to construct another model. The mechanistic modeling approach should serve as a framework to integrate interactions of scientists and agencies working on water flows with those working on fishes and lower food webs. The goals would be to develop decision-support tools and data, guide monitoring and data collection, conduct specific scientific studies to fill major information gaps, identify important time and space scales, and identify the uncertainties with which policymakers need to work. Adaptive management can be improved through an iterative evaluation process that tests management scenarios and uses modeling to explore the range of possible outcomes.

Additional recommendations that apply to all of the science being done in the Delta have been identified in other Delta ISB reports, workshop panels, and the National Research Council. They include: consideration of environmental uncertainty; coordination of scientific research with planned management decisions, including adaptive management; use of risk analyses; recognition of the importance of long-term sustained research and monitoring; and the need to buffer science from politics and activism. The Delta Science Plan includes many of these recommendations and, if wisely and firmly implemented, should provide a framework for science that establishes research priorities and recognizes the essential role of long-term, sustained research that is not driven to ineffectiveness by short-term crises. A targeted mechanistic focus on the effects of flows on fishes may provide a way forward to increase insights and lessen uncertainties for management and the development of a Delta with healthy fish populations.

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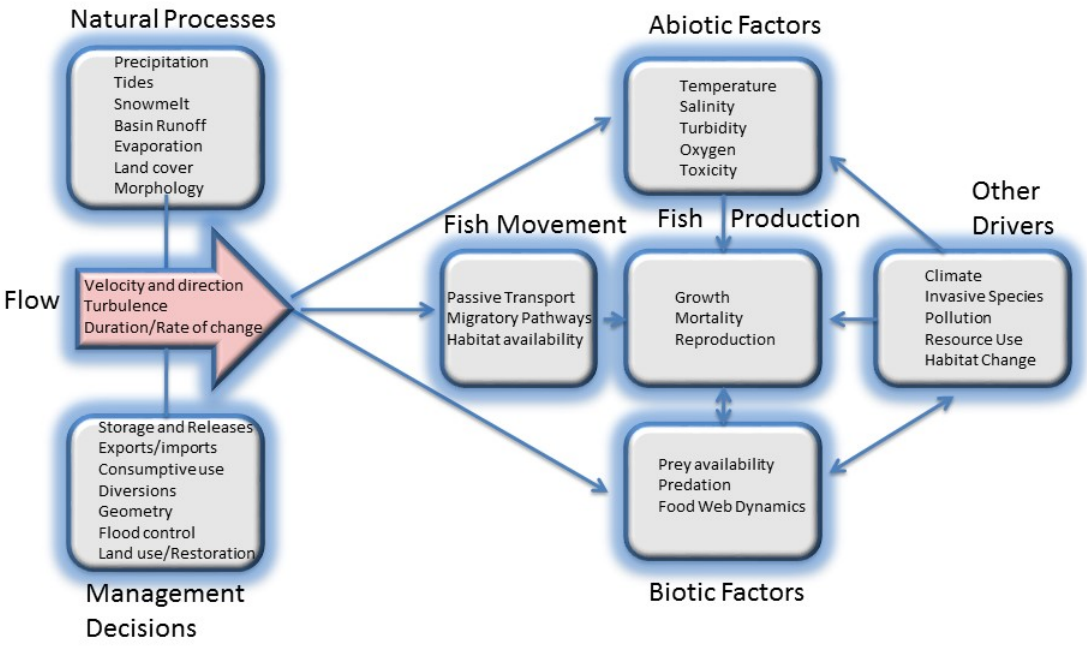
Appendix A: Review Process

The Delta ISB reviewed many specific articles on fishes and flows in the Delta and other ecosystems published in the scientific literature or in extensive reviews including the two reports by the National Research Council linking water management and threatened and endangered species (NRC 20110, 2012) and other reports on specific fish species (e.g., MAST, 2015), groups of fishes (Baxter et al. 2010), specific issues such as entrainment (Grimaldo et al. 2009, Anderson et al. 2015) or assessment of new water transport systems (BDCP 2013). The Delta ISB also attended the "Delta Outflows and Related Stressors" workshop (February 2014) and the "Interior Delta Flows and Related Stressors" workshop (April 2014) conducted by the Delta Science Program for the State Water Resources Control Board, and read related panel reports (Reed et al. 2014, Monismith et al. 2014). The Delta ISB also received presentations on this topic at Delta ISB meetings. The Delta ISB has not tried to duplicate these extensive literature reviews, and cited references are intended to be illustrative.

During the initial stages of the review, the Delta ISB also conducted two sets of interviews (on June 17, 2013 and June 11, 2014) with a wide range of interested and involved parties (16 individuals) holding a variety of perspectives, and included scientists in state and federal agencies, consulting firms, special-interest groups, and academia. The purpose of these one-hour interviews was to gain an initial, broad perspective on current scientific research on the effects of flow on fish populations in the Delta, how that research was organized, collaboration mechanisms and key publications on the topic.

A subset of Delta ISB members undertook the interviews, workshop attendance, and literature review and wrote the first drafts of the report. Initial drafts were revised in response to comments received from individual Delta ISB members and the public, and the final report was approved by the full Delta ISB for release on July 17, 2015.

Appendix B: Detailed Conceptual Diagram of the Linkages Between Flows and Fishes in the Delta



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September 30, 2015

To: Randy Fiorini, Chair, Delta Stewardship Council
Charlton Bonham, Director, California Department of Fish and Wildlife

From: Delta Independent Science Board

Subject: Review of environmental documents for California WaterFix

We have reviewed the partially Recirculated Draft Environmental Impact Report/ Supplemental Draft Environmental Impact Statement for the Bay Delta Conservation Plan/California WaterFix (herein, "the Current Draft"). We focused on how fully and effectively it considers and communicates the scientific foundations for assessing the environmental impacts of water conveyance alternatives. The review is attached and is summarized below.

The Current Draft contains a wealth of information but lacks completeness and clarity in applying science to far-reaching policy decisions. It defers essential material to the Final EIR/EIS and retains a number of deficiencies from the Bay Delta Conservation Plan Draft EIR/EIS. The missing content includes:

1. Details about the adaptive-management process, collaborative science, monitoring, and the resources that these efforts will require;
2. Due regard for several aspects of habitat restoration: landscape scale, timing, long-term monitoring, and the strategy of avoiding damage to existing wetlands;
3. Analyses of how levee failures would affect water operations and how the implemented project would affect the economics of levee maintenance;
4. Sufficient attention to linkages among species, landscapes, and management actions; effects of climate change on water resources; effects of the proposed project on San Joaquin Valley agriculture; and uncertainties and their consequences;
5. Informative summaries, in words, tables, and graphs, that compare the proposed alternatives and their principal environmental and economic impacts.

The effects of California WaterFix extend beyond water conveyance to habitat restoration and levee maintenance. These interdependent issues of statewide importance warrant an environmental impact assessment that is more complete, comprehensive, and comprehensible than the Current Draft.

Review by the Delta Independent Science Board of the

Bay Delta Conservation Plan/California WaterFix Partially Recirculated Draft Environmental Impact Report/ Supplemental Draft Environmental Impact Statement

September 30, 2015

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EXPECTATIONS FOR IMPACT ASSESSMENT OF CALIFORNIA WATERFIX

The Sacramento – San Joaquin Delta presents interconnected issues of water, biological resources, habitat, and levees. Dealing with any one of these problem areas is most usefully considered in light of how it may affect and be affected by the others. The effects of any actions further interact with climate change, sea-level rise, and a host of social, political, and economic factors. The consequences are of statewide importance.

These circumstances demand that the California WaterFix EIR/EIS go beyond legal compliance. This EIR/EIS is more than just one of many required reports. Its paramount importance is illustrated by the legal mandate that singles it out as the BDCP document we must review.

It follows that the WaterFix EIR/EIS requires extraordinary completeness and clarity. This EIR/EIS must be uncommonly complete in assessing important environmental impacts, even if that means going beyond what is legally required or considering what some may deem speculative (below, p. 4). Further, the WaterFix EIR/EIS must be exceptionally clear about the scientific and comparative aspects of both environmental impacts and project performance (p. 9).

These reasonable expectations go largely unmet in the Bay Delta Conservation Plan/California WaterFix Partially Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement Draft (herein, “the Current Draft”). We do not attempt to determine whether this report fulfills the letter of the law. But we find the Current Draft sufficiently incomplete and opaque to deter its evaluation and use by decision-makers, resource managers, scientists, and the broader public.

BACKGROUND OF THIS REVIEW

The Delta Reform Act of 2009, in §85320(c), directs the Delta Independent Science Board (Delta ISB) to review the environmental impact report of the Bay Delta Conservation Plan (BDCP) and to provide the review to the Delta Stewardship Council and the California Department of Fish and Wildlife. On May 14, 2014, we submitted our review of the BDCP’s Draft Environmental Impact Report/Draft Environmental Impact Statement (herein, the “Previous Draft"), which had been posted for review on December 9, 2013. This review[1] contained three main parts: an extended summary, detailed responses to charge questions from the Delta Stewardship Council, and reviews of individual chapters. Although the Previous Draft considered vast amounts of scientific information and analyses to assess the myriad potential environmental impacts of the many proposed BDCP actions, we concluded that the science in the Previous Draft had significant gaps, given the scope and importance of the BDCP.

The proposed BDCP actions have now been partitioned into two separate efforts: water conveyance under California WaterFix[2] and habitat restoration under California EcoRestore[3]. Environmental documents in support of California WaterFix (the Current Draft) were made available for a 120-day comment period that began July 10, 2015. The Current Draft focuses on three new alternatives for conveying Sacramento River water through the Sacramento – San

[1] http://deltacouncil.ca.gov/sites/default/files/documents/files/Attachment-1-Final-BDCP-comments.pdf
[2] http://www.californiawaterfix.com/
[3] http://resources.ca.gov/ecorestore/

Joaquin Delta. One of them, Alternative 4A, is the preferred alternative, identified as California WaterFix.

The Delta Stewardship Council asked us to review the Current Draft and to provide our comments by the end of September 2015. We are doing so through this report and its summary, which can be found in the cover letter.

The review began in July 2015 with a preliminary briefing from Laura King-Moon of California Department of Water Resources (three Delta ISB members present). The Delta ISB next considered the Current Draft in a public meeting on August 13–14 (nine of the ten members present)[4]. The meeting included a briefing on California EcoRestore by David Okita of California Natural Resources Agency and a discussion of the Current Draft and California WaterFix with Cassandra Enos-Nobriga of California Department of Water Resources (DWR) and Steve Centerwall of ICF International.

The initial public draft of this review was based on our study of Sections 1-4 of the Current Draft and on checks of most resource chapters in its Appendix A. This public draft was the subject of a September 16 meeting that included further discussions with Cassandra Enos-Nobriga[5] and comments from Dan Ray of the Delta Stewardship Council staff. Additional comments on that initial draft were provided by DWR in a September 21 letter to the Delta ISB chair[6]. These discussions and comments helped clarify several issues, particularly on expectations of a WaterFix EIR/EIS.

This final version of the review begins with a summary in the cover letter. The body of the report continues first with a section on our understanding of major differences between the BDCP and California WaterFix. Next, after noting examples of improvement in the Current Draft, we describe our main concerns about the current impact assessments. These overlap with main concerns about the Previous Draft, which we revisit to consider how they are addressed in the Current Draft. Finally, we offer specific comments on several major Sections and Chapters.

DIFFERENCES BETWEEN THE BDCP AND CALIFORNIA WATERFIX

The project proposed in the Current Draft differs in significant respects from what was proposed as the BDCP in December 2013. Here we briefly state our understanding of some main differences and comment on their roles on this review:

- The time period for permitting incidental take under Section 7 of the federal Endangered Species Act (ESA) and Section 2081(b) of the California Endangered Species Act (CESA) is substantially less than the 50 years envisioned as part of a Habitat Conservation Plan (HCP) and Natural Community Conservation Plan (NCCP) in BDCP. As a result, the science associated with many impacts of climate change and sea-level rise may seem less relevant. The permitting period for the project proposed in the Current Draft remains in place unless environmental baseline conditions change substantially or other permit requirements are not met. Consequently, long-term effects of the proposed project remain important in terms of operations and expected benefits (p. 8).

[4] http://deltacouncil.ca.gov/docs/delta-isb-meeting-notice-meeting-notice-delta-isb/delta-independent-science-board-isb-august-13

[5] Written version at https://s3.amazonaws.com/californiawater/pdfs/63qnf_Delta_ISB_draft_statement_-_Enos_-_FINAL.pdf

[6] http://deltacouncil.ca.gov/docs/response-letter-dwr

- In this shortened time frame, responsibility for assessing WaterFix's effects on fish and wildlife would fall to resource agencies (National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife). Other impacts would be regulated by a variety of federal and state agencies (Current Draft Section 1).
- The proposed habitat restorations have been scaled back. The Current Draft incorporates elements of 11 Conservation Measures from BDCP to mitigate impacts of construction and operations. Most habitat restoration included in the Previous Draft has been shifted to California EcoRestore. Our review of the Previous Draft contained many comments on the timing of restoration, species interactions, ecological linkages of conservation areas, locations of restoration areas and the science supporting the efficiency and uncertainty of effective restoration. Some of these comments apply less to the Current Draft because of its narrower focus on water conveyance.
- There remains an expected reliance on cooperative science and adaptive management during and after construction.
- It is our understanding that the Current Draft was prepared under rules that disallow scientific methods beyond those used in the Previous Draft. The rules do allow new analyses, however. For example, we noticed evidence of further analyses of contaminants, application of existing methods (e.g. particle tracking) to additional species (e.g., some of the non-covered species), and occasional selection of one model in place of the combined results of two models (e.g., fish life cycle models SALMOD and SacEFT).

IMPROVEMENTS ON THE PREVIOUS DRAFT

A proposed revamping of water conveyance through the Sacramento-San Joaquin Delta involves a multitude of diverse impacts within and outside of the Delta. Unavoidably, the EIR/EIS for such a project will be complex and voluminous, and preparing it becomes a daunting task in its own right. The inherent challenges include highlighting, in a revised EIR/EIS, the most important of the changes.

The new Sections 1 through 4 go a long way toward meeting some of these challenges. Section 1 spells out the regulatory context by discussing laws and agencies that establish the context for the Current Draft. Section 2 summarizes how the Previous Draft was revised in response to project changes and public input. Section 3 describes how the preferred alternative in the Previous Draft (Alternative 4) has been changed. Section 4 presents an impressive amount of detailed information in assessing the sources of habitat loss for various species and discussing how restoration and protection can mitigate those losses. Generally comprehensive lists of "Resource Restoration and Performance Principles" are given for the biological resources that might be affected by construction or operations. For example, page 4.3.8-140 clearly describes a series of measures to be undertaken to minimize the take of sandhill cranes by transmission lines (although the effectiveness of these measures is yet to be determined).

Section 4 also contains improvements on collaborative science (4.1.2.4, mostly reiterated in ES.4.2). This part of the Current Draft draws on recent progress toward collaborative efforts in monitoring and synthesis in support of adaptive management in the Delta. The text identifies the main entities to be involved in an expected memorandum of agreement on a monitoring and adaptive-management program in support of the proposed project.

Appendix A describes revisions to the resource chapters of the Previous Draft. Track-changed versions of the chapters simplify the review process, although this was not done for the

key chapter on aquatic resources (p. 17). We noticed enhanced analyses of contaminants and application of methods such as particle tracking to additional species, including some of the non-covered taxa; a detailed treatment of *Microcystis* blooms and toxicity; more information about disinfection byproducts; improved discussion of vector control arising from construction and operational activities; and revised depiction of surficial geology. Potential exposure of biota to selenium and methylmercury is now considered in greater detail. Evaluations will be conducted for restoration sites on a site-specific basis; if high levels of contaminants cannot otherwise be addressed, alternative restoration sites will be considered (page 4.3.8-118). Incidentally, this is a good example of adaptive management, although it is not highlighted as such. Explanations were provided for why the nitrogen-to-phosphorus ratio was not specifically evaluated, why dissolved vs. total phosphorus was used in the assessment, and how upgrades to the Sacramento Regional Wastewater Treatment Plant would eventually affect phosphorus concentrations.

CURRENT CONCERNS

These and other strengths of the Current Draft are outweighed by several overarching weaknesses: overall incompleteness through deferral of content to the Final EIR/EIS (herein, "the Final Report"); specific incompleteness in treatment of adaptive management, habitat restoration, levees, and long-term effects; and inadequacies in presentation. Some of these concerns overlap with ones we raised in reviewing the Previous Draft (revisited below, beginning on p. 10).

Missing content

The Current Draft lacks key information, analyses, summaries, and comparisons. The missing content is needed for evaluation of the science that underpins the proposed project. Accordingly, the Current Draft fails to adequately inform weighty decisions about public policy. The missing content includes:

1. Details on adaptive management and collaborative science (below, p. 5).
2. Modeling how levee failures would affect operation of dual-conveyance systems (below, p. 7). Steve Centerwall told us on August 14 that modeling of the effects of levee failure would be presented in the Final Report.
3. Analysis of whether operation of the proposed conveyance would alter the economics of levee maintenance (below, p. 7).
4. Analyses of the effects of climate change on expected water exports from the Delta. “[A]n explanation and analysis describing potential scenarios for future SWP/CVP system operations and uncertainties [related to climate change] will be provided in the Final Report” (p. 1-35 of the Current Draft).
5. Potential impacts of climate change on system operations, even during the shortened time period emphasized in the Current Draft (below, p. 8 and 11).
6. Potential effects of changes in operations of the State Water Project (SWP) and Central Valley Project (CVP), or other changes in water availability, on agricultural practices in the San Joaquin Valley (p. 12).
7. Concise summaries integrated with informative graphics (below, p. 9 and 13). The Current Draft states that comparisons of alternatives will be summarized in the Final Report (p. 1-35).

While some of the missing content has been deferred to the Final Report (examples 2, 4, and 7), other gaps have been rationalized by deeming impacts “too speculative” for assessment.

CEQA guidance directs agencies to avoid speculation in preparing an EIR/EIS[7] . To speculate, however, is to have so little knowledge that a finding must be based on conjecture or guesswork. Ignorance to this degree does not apply to potential impacts of WaterFix on levee maintenance (example 3; see p. 7) or on San Joaquin Valley agriculture (example 6; p. 12).

Even if content now lacking would go beyond what is legally required for an EIR/EIS, providing such content could assist scientists, decision-makers, and the public in evaluating California WaterFix and Delta problems of statewide importance (above, p. 1).

Adaptive management

The guidelines for an EIR/EIS do not specifically call for an adaptive-management plan (or even for adaptive management). However, if the project is to be consistent with the Delta Plan (as legally mandated), adaptive management should be part of the design.

The Current Draft relies on adaptive management to address uncertainties in the proposed project, especially in relation to water operations. The development of the Current Draft from the Previous Draft is itself an exercise in adaptive management, using new information to revise a project during the planning stage. Yet adaptive management continues to be considered largely in terms of how it is to be organized (i.e., coordinated with other existing or proposed adaptive-management collaborations) rather than how it is to be done (i.e., the process of adaptive management). Adaptive management should be integral with planned actions and management—the Plan A rather than a Plan B to be added later if conditions warrant. The lack of a substantive treatment of adaptive management in the Current Draft indicates that it is not considered a high priority or the proposers have been unable to develop a substantive idea of how adaptive management would work for the project.

There is a very general and brief mention of the steps in the adaptive management process in Section 4 (p. 4.1-6 to 4.1-7), but nothing more about the process. We were not looking here for a primer on adaptive management. Rather, we expected to find serious consideration of barriers and constraints that have impeded implementation of adaptive management in the Delta and elsewhere (which are detailed in the Delta Plan), along with lessons learned on how adaptive management can be conducted overcome these problems.

The Current Draft contains general statements on how collaborative science and adaptive management under California WaterFix would be linked with the Delta Collaborative Science and Adaptive Management Program (CSAMP) and the Collaborative Adaptive Management Team (CAMT). These efforts, however, have taken place in the context of regulations and permits, such as biological opinions and biological assessments required under the Endangered Species Act. We did not find examples of how adaptive management would be applied to assessing—and finding ways to reduce—the environmental impacts of project construction and operations.

Project construction, mitigation, and operations provide many opportunities for adaptive management, both for the benefit of the project as well as for other Delta habitat and ecosystem initiatives, such as EcoRestore. To be effective in addressing unexpected outcomes and the need for mid-course corrections, an adaptive-management management team should evaluate a broad range of actions and their consequences from the beginning, as plans are being developed, to facilitate the early implementation and effectiveness of mitigation activities.

[7] https://s3.amazonaws.com/californiawater/pdfs/bo0lx_Delta_ISB_Draft_Statement_&_Response_Letter_-_Enos_-_FINAL.pdf

The Current Draft defers details on how adaptive management will be made to work: "An adaptive management and monitoring program will be implemented to develop additional scientific information during the course of project construction and operations to inform and improve conveyance facility operational limits and criteria" (p. ES-17). This is too late. If adaptive management and monitoring are central to California WaterFix, then details of how they will be done and resourced should be developed at the outset (now) so they can be better reviewed, improved, and integrated into related Delta activities. The details could include setting species-specific thresholds and timelines for action, creating a Delta Adaptive Management Team, and capitalizing on unplanned experiments such as the current drought[8]. Illustrative examples could use specific scenarios with target thresholds, decision points, and alternatives. The missing details also include commitments and funding needed for science-based adaptive management and restoration to be developed and, more importantly, to be effective.

The protracted development of the BDCP and its successors has provided ample time for an adaptive-management plan to be fleshed out. The Current Draft does little more than promise that collaborations will occur and that adaptive management will be implemented. This level of assurance contrasts with the central role of adaptive management in the Delta Plan and with the need to manage adaptively as climate continues to change and new contingencies arise.

Restoration as mitigation

Restoration projects should not be planned and implemented as single, stand-alone projects but must be considered in a broader, landscape context. We highlighted the landscape scale in our review of the Previous Draft and also in an earlier review of habitat restoration in the Delta[9]. A landscape approach applies not just to projects that are part of EcoRestore, but also to projects envisioned as mitigation in the Current Draft, even though the amount of habitat restoration included (as mitigation) in the Current Draft has been greatly reduced. On August 13 and 14, representatives of WaterFix and EcoRestore acknowledged the importance of the landscape scale, but the Current Draft gives it little attention. Simply because the CEQA and NEPA guidelines do not specifically call for landscape-level analyses is not a sufficient reason to ignore them.

Wetland restoration is presented as a key element of mitigation of significant impacts (example below in comments on Chapter 12, which begin on p. 18). We noticed little attention to the sequence required for assessing potential impacts to wetlands: first, avoid wetland loss; second, if wetland loss cannot be avoided, minimize losses; and third, if avoidance or minimization of wetland loss is not feasible, compensate. Much of the emphasis in the Current Draft is on the third element. Sequencing apparently will be addressed as part of the permitting process with the US Army Corps of Engineers (USACE) for mitigation related to the discharge of dredged or fill material.[10] However, it is difficult to evaluate the impacts on wetlands in advance of a clarification of sequencing and criteria for feasibility.

Mitigation ratios

Restoring a former wetland or a highly degraded wetland is preferable to creating wetlands from uplands[11]. When an existing wetland is restored, however, there is no net gain of

[8] http://deltacouncil.ca.gov/docs/adaptive-management-report-v-8
[9] http://deltacouncil.ca.gov/sites/default/files/documents/files/HABITAT%20RESTORATION%20REVIEW%20FINAL.pdf
[10] Letter from Cassandra Enos-Nobriga, DWR, September 21, 2015.
[11] http://www.nap.edu/openbook.php?isbn=0309074320

area, so it is unclear whether credits for improving existing wetlands would be considered equivalent to creating wetlands where they did not recently exist.

In view of inevitable shortcomings and time delays in wetland restorations, mitigation ratios should exceed 1:1 for enhancement of existing wetlands. The ratios should be presented, rather than making vague commitments such as "restore or create 37 acres of tidal wetland…." The Final Draft also needs to clarify how much of the wetland restoration is out-of-kind and how much is in-kind replacement of losses. It should examine whether enough tidal area exists of similar tidal amplitude for in-kind replacement of tidal wetlands, and whether such areas will exist with future sea-level rise. We agree that out-of-kind mitigation can be preferable to in-kind when the trade-offs are known and quantified and mitigation is conducted within a watershed context, as described in USACE's 2010 guidance for compensatory wetland mitigation.[12] Since then, many science-based approaches have been developed to aid decision-making at watershed scales, including the 2014 Watershed Approach Handbook produced by the Environmental Law Institute and The Nature Conservancy[13].

Restoration timing and funding

To reduce uncertainty about outcomes, allow for beneficial and economical adaptive management, and allow investigators to clarify benefits before the full impacts occur, mitigation actions should be initiated as early as possible. Mitigation banks are mentioned, but are any operational or planned for operation soon? The potential for landowners to develop mitigation banks could be encouraged so restoration could begin immediately, engendering better use of local knowledge, financial profit, and local support for the project. We are told that the timing of mitigation will be coordinated with other review processes that are currently ongoing.[6]

Levees

A comprehensive assessment of environmental impacts should relate California WaterFix to levee failure by examining the consequences each may have for the other. The interplay between conveyance and levees is receiving additional attention through the Delta Levee Investment Strategy.

On the one hand, the Current Draft fails to consider how levee failures would affect the short-term and long-term water operations spelled out in Table 4.1-2. A rough estimate was proposed under the Delta Risk Management Study[14] and another is part of a cost-benefit analysis for the BDCP[15]. The Final Report should provide analyses that incorporate these estimates.

On the other hand, the Current Draft also fails to consider how implementing the project would affect the basis for setting the State's priorities in supporting Delta levee maintenance. This potential impact is illustrated by a recent scoring system of levee-project proposals that awards points for expected benefits to "export water supply reliability"[16]. Further efforts to quantify these benefits have been recommended as part of a comprehensive risk assessment that

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[12] http://www.sac.usace.army.mil/Portals/43/docs/regulatory/Guidelines_for_Preparing_a_Compensatory_Mitigation_Planf.pdf

[13] https://www.eli.org/sites/default/files/eli-pubs/watershed-approach-handbook-improving-outcomes-and-increasing-benefits-associated-wetland-and-stream_0.pdf

[14] http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/Delta_Seismic_Risk_Report.pdf

[15] http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Draft_BDCP_Statewide_Economic_Impact_Report_8513.sflb.ashx

[16] http://www.water.ca.gov/floodsafe/fessro/docs/special_PSP14_final.pdf

would guide the Delta Levees Investment Strategy[17]. Public safety, a focus of the Delta Flood Emergency Management Plan,[18] is just one asset that levees protect. The Current Draft does not evaluate how the proposed project may affect estimates of the assets that the levees protect.

The Current Draft cites levee fragility mainly as a reason to build isolated conveyance for Sacramento River water (examples, p. 1-1, 1-7, 1-9). In a similar vein, the California WaterFix website states, "Aging dirt levees are all that protect most of California's water supplies from the affects [*sic*] of climate change. Rising sea levels, intense storms, and floods could all cause these levees to fail, which would contaminate our fresh water with salt, and disrupt water service to 25 million Californians"[19]. Neither the Previous Draft nor the Current Draft, however, provides a resource chapter about Delta levees. Such a chapter would be an excellent place to examine interacting impacts of conveyance and levees.

Long-term effects

With the shortened time period, several potential long-term impacts of or on the proposed project no longer receive attention. While these effects may not become problematic during the initial permit period, many are likely to affect project operations and their capacity to deliver benefits over the long operational life of the proposed conveyance facilities. In our view, consideration of these long-term effects should be part of the evaluation of the science foundation of the proposed project.

The No-Action alternative establishes the baseline for evaluating impacts and benefits of the proposed alternative(s). It is therefore important to consider carefully how the baseline is established, as this can determine whether particular consequences of the alternatives have costs or benefits. Climate change, for example, is considered under the No-Action alternative in the Current Draft, as is sea-level rise. Climate change is expected to reduce water availability for the proposed northern intakes, and both climate change and sea-level rise are expected to influence tidal energy and salinity intrusion within the Delta[20]. Changes in water temperature may influence the condition of fishes that are highly temperature-dependent in the current analyses. These environmental effects, in turn, are likely to influence environmental management and regulation; from the standpoint of water quality they may even yield environmental benefits if agricultural acreage decreases and agricultural impacts are reduced.

Rather than consider such effects, however, the Current Draft focuses on how the proposed project would affect "the Delta's resiliency and adaptability to expected climate change" (Current Draft section 4.3.25). Quite apart from the fact that "resiliency" and "adaptability" are scarcely operational terms, the failure to consider how climate change and sea-level rise could affect the outcomes of the proposed project is a concern that carries over from our 2014 review and is accentuated by the current drought (below, p. 11).

The Current Draft states that "Groundwater resources are not anticipated to be substantially affected in the Delta Region under the No Action Alternative (ELT) because surface water inflows to this area are sufficient to satisfy most of the agricultural, industrial, and municipal water supply needs" (p. 4.2-16). This conclusion is built on questionable assumptions; the current drought illustrates how agriculture turns to groundwater when surface-water availability diminishes. Groundwater regulation under the recently enacted Sustainable

[17] http://deltacouncil.ca.gov/docs/delta-levee-investment-strategy/dlis-peer-review-technical-memorandum-31
[18] http://www.water.ca.gov/floodmgmt/hafoo/fob/dreprrp/InterdepartmentalDraftDFEMP-2014.pdf.
[19] http://www.californiawaterfix.com/problem
[20] http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0024465

Groundwater Management Act (SGMA) can also be expected to have long-term effects on the proposed project—effects that the Current Draft does not assess. Ending of more than a million acre-feet of overdraft in the southern Central Valley under the SGMA is likely to increase demand for water exports from the Delta in the coming decades. The Current Draft discusses the potential effects of the project on groundwater (for example, in Sections 4.3.3 and 5.2.2.3), but we found only two brief, descriptive mentions of SGMA in the 235 pages of Section 5. The implications of prolonged droughts (e.g., on levee integrity) and of the consequences of SGMA receive too little attention in the Current Draft.

The Current Draft suggests that unnamed "other programs" that are "separate from the proposed project" will use elements of the Previous Draft to implement long-term conservation efforts that are not part of California WaterFix (Current Draft, p. 1-3). The Final Report should provide assurances that such other programs will step in, and could go further in considering their long-term prospects.

Informative summaries and comparisons

According to guidance for project proponents, "Environmental impact statements shall be written in plain language and may use appropriate graphics so that decision-makers and the public can readily understand them" (Code of Federal Regulations, 40 CFR 1502.8). Far-reaching decisions should not hinge on environmental documents that few can grasp.

This guidance applies all the more to an EIR/EIS of the scope, complexity, and importance of the Current Draft. It demands excellent comparative descriptions of alternatives that are supported by readable tables and high-quality graphics, enumeration of major points, well-organized appendices, and integration of main figures with the text. For policy deliberations, the presentation of alternatives should include explicit comparisons of water supply deliveries and reliabilities as well as economic performance. For decision-makers, scientists, and the public, summaries of impacts should state underlying assumptions clearly and highlight major uncertainties. The Current Draft is inadequate in these regards.

The Previous Draft provided text-only summaries for just the two longest of its resource chapters (Chapters 11 and 12). A fragmentary comparison of alternatives was buried in a chapter on "Other CEQA/NEPA required sections" (part 3 of Chapter 31) but fell far short of what was needed. Both the Previous and Current Drafts have been accompanied by a variety of outreach products for broad audiences (e.g., the descriptive overview of the BDCP Draft EIR/EIS[21]). These products do little to compensate for the overall paucity of readable summaries and comparisons in the Previous and Current Drafts.

For over three years, the Delta ISB has been specifically requesting summaries and comparisons: first in June 2012[22], then in June 2013[23], and again in a review of the Previous Draft in May 2014 (footnote 1, p. 1). Appallingly, such summaries and comparisons remain absent in the Current Draft. The generally clear writing in Sections 1 through 4 shows that the preparers are capable of providing the requested summaries and comparisons. Prescriptions in CEQA and NEPA in no way exclude cogent summaries, clear comparisons, or informative graphics. And three years is more than enough time to have developed them.

[21] Highlights+of+the+Draft+EIS-EIR+12-9-13.pdf
[22] http://deltacouncil.ca.gov/sites/default/files/documents/files/DISB_Letter_to_JMeral_and_DHoffman-Floerke_061212.pdf
[23] http://deltacouncil.ca.gov/sites/default/files/documents/files /DISB%20Comments%20on%20Draft%20BDCP%20Document.doc_.pdf

On August 14, 2015, representatives of California WaterFix assured us that this kind of content would eventually appear, but only in the Final Report. That will be far too late in the EIR/EIS process for content so critical to comprehending what is being proposed and its potential impacts.

PRIOR CONCERNS AND THEIR RELEVANCE TO THE CURRENT DRAFT

The Delta ISB review of May 14, 2014 emphasized eight broad areas of concern about the scientific basis for the Previous Draft. Each is summarized below, followed by a brief appraisal of how (or whether) the concern has been dealt with in the Current Draft. While the reduced scope of the proposed project has reduced the relevance of some issues, particularly habitat restoration and other conservation measures, other concerns persist.

Our persistent concerns include the treatment of uncertainty, the implementation of adaptive management, and the use of risk analysis. These topics receive little or no further attention in the Current Draft. We also found few revisions in response to points we raised previously about linkages among species, ecosystem components, or landscapes; the potential effects of climate change and sea-level rise; and the potential effects of changes in water availability on agricultural practices and the consequent effects on the Delta. Our previous comments about presentation also pertain.

Effectiveness of conservation actions

Our 2014 review found that many of the impact assessments hinged on optimistic expectations about the feasibility, effectiveness, or timing of the proposed conservation actions, especially habitat restoration.

This is arguably less of a concern now, given the substantially shorter time frame of the revised project and narrower range of conservation actions designed for compensatory restoration. Nonetheless, the Current Draft retains unwarranted optimism, as on page 4.3.25-10: “By reducing stressors on the Delta ecosystem through predator control at the north Delta intakes and Clifton Court Forebay and installation of a nonphysical fish barrier at Georgiana Slough, Alternative 4A will contribute to the health of the ecosystem and of individual species populations making them stronger and more resilient to the potential variability and extremes caused by climate change.” A scientific basis for this statement is lacking, and an adaptive or risk-based management framework is not offered for the likely event that such optimism is unfulfilled.

Is it feasible for even the reduced amounts of mitigation and restoration to be completed within the time period proposed? Perhaps yes. Is it feasible that these actions will mitigate impacts over the long term? This is more problematic. To be effective, mitigation actions should deal with both the immediate and long-term consequences of the project. The proposed permitting should allow for monitoring long enough to assess the effectiveness of habitat restoration measures, which will need to extend beyond the initial permitting period.

Uncertainty

The 2014 review found the BDCP encumbered by uncertainties that were considered inconsistently and incompletely. We commented previously that modeling was not used effectively enough in bracketing uncertainties or exploring how they may propagate or be addressed.

In the Current Draft, uncertainties and their consequences remain inadequately addressed, improvements notwithstanding. Uncertainties will now be dealt with by establishing "a robust program of collaborative science, monitoring, and adaptive management" (ES 4.2). No details about this program are provided, so there is no way to assess how (or whether) uncertainties will be dealt with effectively. Although sensitivity modeling was used to address the effects of changes in the footprint and other minor changes of the revised project, full model runs were not carried out to assess the overall effects of the specific changes. Consequently, modeling that would help to bracket ranges of uncertainties or (more importantly) assess propagation of uncertainties is still inadequate.

Many of our prior concerns about uncertainties pertained to impacts on fish. If those uncertainties have now been addressed in Chapter 11, they are difficult to evaluate because changes to that chapter have not been tracked in the public draft (below, p. 17).

There are also uncertainties with the data generated from model outputs, although values are often presented with no accompanying error estimates. This situation could be improved by presenting results from an ensemble of models and comparing the outputs.

Effects of climate change and sea-level rise on the proposed actions

Our 2014 review stated concerns that the Previous Draft underestimated effects of climate change and sea-level rise across the 50-year timeline of the BDCP. With the nominal duration shortened substantially, most of the projected impacts of climate change and sea-level rise may occur later. But climate-related issues remain.

First, the Current Draft is probably outdated in its information on climate change and sea-level rise. It relies on information used in modeling climate change and sea-level rise in the Previous Draft, in which the modeling was conducted several years before December 2013. The absence of the climate-change chapter (Chapter 29) in the Previous Draft from Appendix A in the Current Draft indicates that no changes were made. In fact, the approaches and assumptions in the Current Draft remained unchanged from the Previous Draft in order to ensure consistency and comparability across all the Alternatives, even though newer scientific information had become available.[6] Yet climatic extremes, in particular, are a topic of intense scientific study, illustrated by computer simulations of ecological futures[24] and findings about unprecedented drought[25]. The Current Draft does not demonstrate consideration of recently available climate science, and it defers to the Final Report analysis of future system operations under potential climate and sea-level conditions. In fact, the Current Draft generally neglects recent literature, suggesting a loose interpretation of "best available science."

Second, climate change and sea-level rise are now included in the No-Action Alternative, as they will transpire whether or not WaterFix moves forward. A changed future thus becomes the baseline against which Alternative 4A (and the others) are compared. Changes in outflow from the Delta due to seasonal effects of climate change and the need to meet fall X2 requirements are considered in Section 4.3.1. The difference in outcomes then depends on assumptions about the facility and operations of Alternative 4A and the other Alternatives. Sensitivity analyses indicate that the impacts of the different Alternatives are generally similar in comparison to the No Action Alternative under the range of climate projections considered.[6] Thus, "Delta exports would either remain similar or increase in wetter years and remain similar

[24] http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0024465

[25] Cook, B.I., Ault, T.R., and Smerdon, J.E., 2015, Unprecedented 21st century drought risk in the American Southwest and Central Plains: *Science Advances*, v. 1, doi:10.1126/sciadv.1400082.

or decrease in the drier years under Alternative 4A as compared to the conditions without the project." (p. 4.3.1-4). Such an inconclusive conclusion reinforces the need to be able to adapt to different outcomes. Simply because the Alternatives are expected to relate similarly to a No Action Alternative that includes climate change does not mean that the Alternatives will be unaffected by climate change.

Interactions among species, landscapes, and the proposed actions

The Previous Draft acknowledged the complexities produced by webs of interactions, but it focused on individual species, particular places, or specific actions that were considered in isolation from other species, places, or actions. Potential predator-prey interactions and competition among covered and non-covered fish species were not fully recognized. Confounding interactions that may enhance or undermine the effectiveness of proposed actions were overlooked. In our 2014 review we recommended describing and evaluating the potential consequences of such interactions, particularly in Chapters 11 (Fish and aquatic resources) and 12 (Terrestrial resources).

The Current Draft recognizes that mitigation measures for one species or community type may have negative impacts on other species or communities, and mitigation plans may be adjusted accordingly. But the trade-offs do not seem to be analyzed or synthesized. This emphasizes the need for a broader landscape or ecosystem approach that comprehensively integrates these conflicting effects.

Effects on San Francisco Bay, levees, and south-of-Delta environments

In 2014 we pointed to three kinds of impacts that the Previous Draft overlooked: (1) effects on San Pablo Bay and San Francisco Bay in relation to Delta tides, salinity, and migratory fish; (2) effects of levee failures on the proposed BDCP actions and effects of isolated conveyance on incentives for levee investments; and (3) effects of increased water reliability on crops planted, fertilizers and pesticides used, and the quality of agricultural runoff. The Current Draft responds in part to point 1 (in 11.3.2.7) while neglecting point 2 (above, p. 7) and point 3.

On point 3: Although the Current Draft considers how the project might affect groundwater levels south of the Delta (7.14 to 7.18), it continues to neglect the environmental effects of water use south of (or within) the Delta. Section 4.3.26.4 describes how increased water-supply reliability could lead to increased agricultural production, especially during dry years. Elsewhere, a benefit-cost analysis performed by ICF and the Battle Group[26] calculated the economic benefits of increased water deliveries to agriculture in the Delta. The Current Draft does not fully consider the consequences of these assumptions, or of the projections that the project may enhance water-supply reliability but may or may not increase water deliveries to agriculture (depending on a host of factors). We have been told that to consider such possibilities would be "too speculative" and that such speculations are explicitly discouraged in an EIR/EIS. Yet such consequences bear directly on the feasibility and effectiveness of the project, and sufficient information is available to bracket a range of potential effects. Our previous concerns are undiminished.

The impacts of water deliveries south of the Delta extend to the question of how each intake capacity (3,000, 9,000, or 15,000 cfs) may affect population growth in Southern

[26] Hecht, J., and Sunding, D., Draft Bay Delta Conservation Plan statewide economic impact report, August 2013.

California. Section 4.4.1-9 treats the growth-enabling effects of alternative 2D lightly, saying that additional EIS review would be needed for future developments.

Implementing adaptive management

In the Previous Draft, details about adaptive management were to be left to a future management team. In our 2014 review we asked about situations where adaptive management may be inappropriate or impossible to use, contingency plans in case things do not work as planned, and specific thresholds for action.

Although most ecological restoration actions have been shifted to California EcoRestore (p. 5), we retain these and other concerns about adaptive management under California WaterFix. If the mitigation measures for terrestrial resources are implemented as described, for example, they should compensate for habitat losses and disturbance effects of the project. The test will be whether the measures will be undertaken as planned, be as effective as hoped, and continue long enough to fully mitigate effects. This is where adaptive management and having contingency plans in place becomes critically important. It is not apparent that the mitigation plans include these components.

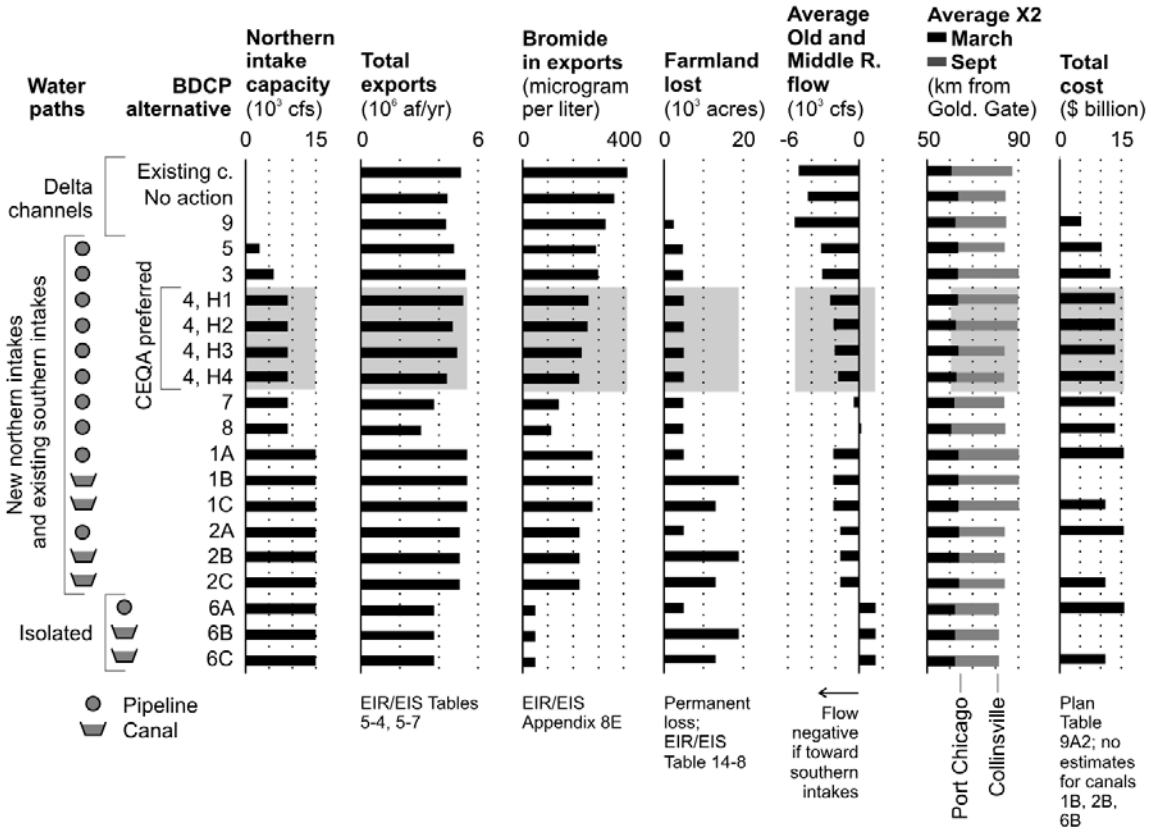
Reducing and managing risk

Our 2014 review advised using risk assessment and decision theory in evaluating the proposed BDCP actions and in preparing contingency plans. We noticed little improvement on this issue, just a mention that it might be considered later. This is not how the process should be used.

Comparing BDCP alternatives

The Previous Draft contained few examples of concise text and supporting graphics that compare alternatives and evaluate critical underlying assumptions. Rudimentary comparisons of alternatives were almost entirely absent. The Current Draft retains this fundamental inadequacy (p. 9).

Our 2014 review urged development and integration of graphics that offer informative summaries at a glance. We offered the example reproduced below. If the Current Draft contains such graphics, they would need to be ferreted out from long lists of individual pdf files. Because they are not integrated into the text where they are referenced in the Current Draft, the figures cannot readily illustrate key points.



COMMENTS ON INDIVIDUAL SECTIONS AND CHAPTERS

This final section of the review contains minimally edited comments on specific points or concerns. These comments are organized by Section or Chapter in the Current Draft. Many are indexed to pages in the section or chapter named in the heading.

Alternatives 4A, 2D, and 5A (Section 4)

It is good that the proposed alternatives are seen as flexible proposals, as it is difficult to imagine that any proposal for such a complex and evolving system could be implemented precisely as proposed. Some initial and ongoing modifications seem desirable, and unavoidable.

The operating guidance for the new alternatives seems isolated from the many other water management and environmental activities in and upstream of the Delta likely to be important for managing environmental and water supply resources related to Delta diversions. While it is difficult to specify detailed operations for such a complex system, more details on the governance of operations (such as the Real Time Operations process) would be useful. The operational details offered seem to have unrealistic and inflexible specificity. Presentations of delivery-reliability for different alternatives remain absent. Environmental regulations on Delta diversions have tended to change significantly and abruptly in recent decades, and seem likely to change in the future. How sensitive are project water supply and environmental performance to changes in operating criteria?

The collaborative science ideas seem philosophically attractive, but are not given much substance. Monitoring is mentioned, but details of organization, intent, and resources seem

lacking. Adequate funding to support monitoring, collaborative science, and adaptive management is a chronic problem. Section ES.4.2 states that "Proponents of the collaborative science and monitoring program will agree to provide or seek additional funding when existing resources are insufficient." This suggests that these activities are lower in priority than they should be.

The three new alternatives, 4A, 2D, and 5A, seem to have modest changes over some previous alternatives, with the exception of not being accompanied by a more comprehensive environmental program. In terms of diversion capacities, they cover a wide range, 3,000 cfs (5A), 9,000 cfs (4A), and 15,000 cfs (2D). The tables comparing descriptions of the new alternatives to previous Alternative 4 are useful, but should be supplemented by a direct comparison of the three new alternatives.

The new Sustainable Groundwater Management Act (SGMA) seems likely to increase demands for water diversions from the Delta to the south to partially compensate for the roughly 1.5-2 maf/year that is currently supplied by groundwater overdraft.

The State seems embarked on a long-term reduction in urban water use, particularly outdoor irrigation. Such a reduction in urban water use is likely to have some modest effects on many of the water-demand and scarcity impacts discussed.

The climate change analysis of changes in Delta inflows and outflows is useful, but isolating the graphs in a separate document disembodies the discussion. The fragmentation of the document by removing each Section 4 figure into a separate file is inconvenient for all, and makes integrated reading practically impossible for many.

The details of the alternative analyses seem mostly relevant and potentially useful. Much can be learned about the system and the general magnitude of likely future outcomes from patient and prolonged reading of this text. An important idea that emerges from a reading of the No Action Alternative is that the Delta, and California water management, is likely to change in many ways with or without the proposed project. The No Action and other alternatives also illustrate the significant inter-connectedness of California's water system. The range of impacts considered is impressive, but poorly organized and summarized.

The discussion of disinfection by-product precursor effects in Delta waters is improved significantly, but could be made more quantitative in terms of economic and public-health impacts.

The discussion on electromagnetic fields is suitably brief, while the tsunami discussion could be condensed.

The effects of the likely listing of additional native fish species as threatened or endangered seems likely to have major effects on project and alternative performance. These seem prudent to discuss, and perhaps analyze.

Is Alternative 2D, with 15,000 cfs capacity, a serious alternative? Does it deserve any space at all?

Table 4.1-8 implies that tidal brackish/*Schoenoplectus* marsh. Should some of this be considered tidal freshwater marsh?

The dynamics of the Delta are largely determined by water flows. The Current Draft acknowledges that water flows and salinity will change in complex ways. There are statements about how inflows, outflows, and exports will change in Alternative 4A in relation to baseline (No-Action) conditions (p. 4.3.8-13). What is the scientific basis on which these changes will be managed? Will models be used? What confidence should we have in current projections? Have the effects of droughts or deluges been considered?

4.3.7-10, line 13: Text on disturbing sediments and releasing contaminants needs to add nitrogen and phosphorus to the concerns.

Water quality (Chapter 8)

8-3, line 13: *Microcystis* is singled out as a cyanobacterium that can (but doesn't always) produce the toxin, myrocystin; however, there are other cyanobacteria that sometimes produce other toxins. Different genera can differ in the nutrient that limits their blooms (see 2014 letter by Hans Paerl in Science 346(6406): 175-176). For example, *Microcystis* blooms can be triggered by N additions because this species lacks heterocysts, while toxin-producing *Anabaena* blooms can be triggered by P additions, because *Anabaena* has heterocysts and can fix N. The frequently repeated discussion of cyanobacteria blooms needs to be updated. Also cite Paerl on page 8-45 line 8. Ditto on page 8-103 and 8-106 line 34.

8-8. In our earlier comments, we recommended that carbon be separated into its dissolved and particulate forms for consideration of water quality impacts because dissolved organic carbon (DOC) is the form most likely to react with chloride and bromide and result in formation of disinfection by-products. The section on bromide focuses on interactions with total organic carbon (TOC), rather than DOC. Carbon is primarily considered with respect to formation of disinfection by-products but carbon plays a central role in the dynamics of the Delta, affecting processes such as metabolism, acidity, nutrient uptake, and bioavailability of toxic compounds. Carbon cycling determines ecosystem structure and function in aquatic systems. It also modifies the influence and consequences of other chemicals and processes in aquatic systems. Dissolved organic carbon (DOC), for example, influences light and temperature regimes by absorbing solar radiation, affects transport and bioavailability of metals, and controls pH in some freshwater systems. Respiration of organic carbon influences dissolved oxygen concentrations and pH.

8-18, line 12 says that salt disposal sites were to be added in 2014; were they?

8-19 and 8-20: "CECs" is not defined and seems to be used incorrectly. Change "CECs" to "EDCs" on page 8-19 and to "PPCPs" on page 8-20.

8-21, line 18-19: Such a statement should be qualified. The conclusion that marine waters are N-limited and inland waters are P-limited is outdated. Recent papers, including the above, find more complex patterns.

8-22, lines 18 and 30: Choose either "cyanobacteria" or "blue-green algae;" using both will confuse readers who may perceive them as different.

8-23, lines 15-16: Say how the N:P ratio changed composition, not just that it did change composition.

8-23 through 8-25: Uncertainties (e.g., standard deviation or standard error of the mean) associated with the mean concentrations of DOC should be presented. It is impossible to interpret differences between the values that are presented without knowledge of the variation around the mean values (e.g., without knowledge of variation around the mean, it is difficult to evaluate whether DOC concentrations at south vs. north-of-Delta stations and Banks headworks differ from one another; 3.9 to 4.2 mg/L vs. 4.3 mg/L).

8-65, line 12: Specify if DO is for daytime or night, and for surface, bottom or mid-water column.

8-75, line 6: The failure to consider dissolved P (DP) should be addressed; there is much greater uncertainty. The adherence of some P to sediment does not prevent considerable

discharge of P as DP. Also on page 8-95 line 40, qualify predictions due to lack of consideration of DP.

8-82, line 4-5: It seems unlikely that current levels of *Microcystis* growth in the Delta are dependent on the exclusive uptake of ammonia. Temperature is one of the primary factors driving *Microcystis* blooms and global warming could promote bloom occurrence. Consider revising this section to, "Because it seems unlikely that current levels of *Microcystis* growth in the Delta are dependent on the exclusive uptake of ammonia, the frequency, magnitude and geographic extent of *Microcystis* under future scenarios is difficult to predict."

8-105, line 8: Would total nitrogen be dominated by nitrate just by increasing ammonia removal? Depending on redox and microbiota, why wouldn't nitrate be converted to ammonium?

A lot of attention is given to factors controlling *Microcystis* blooms in this chapter but little attention is given to its toxicity. Just as factors controlling blooms are not fully understood, the regulating factors of cellular toxin contents remain poorly understood. As a result, the impact of blooms on the environment can vary (e.g., large blooms of non-toxic or low toxin organisms may have impacts on environmental variables such as nutrient uptake and dissolved oxygen consumption while small blooms of highly toxic organisms could impact food webs) [see: Ma et al. (2015) Toxic and non-toxic strains of *Microcystis aeruginosa* induce temperature dependent allelopathy toward growth and photosynthesis of *Chlorella vulgaris*. Harmful Algae 48: 21–29].

Fish and aquatic resources (Chapter 11)

We found individual conclusions or new analyses difficult to identify in this key chapter because changes to it were not tracked in the public version of the Current Draft and there was no table of contents that could have assisted in side-by-side comparison with the Previous Draft.

Effects of temperature

We noticed more emphasis on temperature concerning the fish 'downstream' impacts (but without tracked changes this becomes difficult to document).

The main temperature variable used expresses the percentage of time when monthly mean temperatures exceed a certain rate or fall within a certain boundary. The biological impact, however, is difficult to assess with these numbers. If all of the change occurred just during operations or just during one day, the biological impact could be much different than a small change every day (provided by using means). Graphs of changes and listing of extreme highs and lows during a model run would have more biological meaning. Also, comparisons were made using current baseline conditions and did not consider climate change effects on temperatures.

Fish screens

It is unclear how (and how well) the fish screens would work. The description of fish screens indicates that fish >20 mm are excluded, but what about fish and larvae that are <20 mm, as well as eggs? Table 11-21 seems out of date, because some fish screens appear to have been installed, but data on their effects are not given. Despite the lack of specific data on how well screens function, the conclusion that there will be no significant impact is stated as certain (e.g., page 1-100 line 38).

Here, as in many other places, measures are assumed to function as planned, with no evidence to support the assumptions. The level of certainty seems optimistic, and it is unclear whether there are any contingency plans in case things don't work out as planned. This problem persists from the Previous Draft.

Invasive plants

Cleaning equipment is mentioned, but it is not specifically stated that large machinery must be cleaned before entering the Delta. Section 4.3.8-358 says equipment would be cleaned if being moved within the Delta. Cleaning is essential to reduce transfer of invasive species; a mitigating measure is to wash equipment, but it must also be enforced.

Weed control (fire, grazing) is suggested, but over what time frame? It may be needed in perpetuity. That has been our experience at what is considered the world's oldest restored prairie (the 80-yr-old Curtis Prairie, in Madison, WI).

Weed invasions can occur after construction is completed; how long will the project be responsible for weed control? 3-5 years won't suffice.

4.3.8-347. Herbicides are prescribed to keep shorebird nesting habitat free of vegetation, but toxic effects of herbicides on amphibians etc. are not considered.

4.3.8-354. Impacts of invasive plants seem underestimated. Impact analysis implies that the project disturbance area is the only concern, when dispersal into all areas will also be exacerbated. At the Arboretum, a 1200-ac area dedicated to restoration of pre-settlement vegetation, invasive plants are the main constraint. A judgment of no significant impact over just the disturbance area is overly optimistic.

4.3.8-356. Does not mention need to clean equipment to minimize import of seeds on construction equipment.

Cryptic acronym and missing unit

Figure 2: SLR x year: y axis lacks units; reader has to continue on to table 11-20 to find that it is cm.

Terrestrial biological resources (Chapter 12)

Effects on wetlands and waters of the United States (WOTUS)

Page 12-1, line 18-19 says: "Under Alternatives 2D, 4 , 4A , and 5A, larger areas of non-wetland waters of the United States would be filled due to work in Clifton Court Forebay; however, the Forebay would ultimately expand by 450 acres and thus largely offset any losses there." Is the assumption that, acre for acre, all jurisdictional waters are interchangeable, whether of different type or existing vs. created? The literature does not support this assumption.

The text argues that the wetlands would be at risk with levee deterioration, sea-level rise, seismic activity, etc. But the solution is for "other programs" to increase wetlands and riparian communities. What if this project causes the problem, e.g. via vibration?

CM1 alternative 4A would fill 775 acres of WOTUS (491 wetland acres); Alt 2D would fill 827 (527 wetland) + 1,931 ac temporary fill at Clifton Court Forebay; Alt 5A would fill 750 (470 wetland). That's a lot of area. The timing and details of mitigation measures are not provided. References to the larger Delta Plan suggest that compensations would come at unknown times. Piecemeal losses such as indicated here: "Only 1% of the habitat in the study area would be filled or converted" (Chapter 12, line 29, page 12-22) is how the US has lost its historical wetlands. What are the overall cumulative impacts of wetland losses in the Delta? What is the tipping point beyond which further wetland losses must be avoided? The proposed project is one part of the broader array of management actions in the Delta and should be considered in that broader context.

Habitat descriptions

How will mudflats be sustained for shorebirds? Exposed mud above half-tide can become vegetated rapidly. In the Delta, the bulrush *Schoenoplectus californicus* tolerates nearly continuous tidal submergence.

Are soils clayey enough for the proposed restoration of up to 34 acres of vernal pool and alkali seasonal wetland near Byron? These areas will need to pond water, not just provide depressions.

12-243, line 18: How would adding lighting to electrical wires eliminate any potential impact to black rails? This mitigation is overstated.

Several of the species accounts (e.g., bank swallow) indicate that there is uncertainty about how construction or operations will impact the species. In most cases, monitoring is proposed to assess what is happening. But to be effective, the monitoring results need to be evaluated and fed into decision-making, as visualized in the adaptive-management process. There is little explicit indication of how this will be done or funded.

Land use (Chapter 13)

Alternative 4A would allow water diversion from the northern Delta, with fish screens, multiple intakes, and diversions limited to flows that exceed certain minima, e.g., 7000 cfs. This would reduce flood-pulse amplitudes and, presumably, downstream flooding. How does this alter opportunities for riparian restoration? Which downstream river reaches are leveed and not planned to support riparian restoration? Where would riparian floodplains still be restorable?

Over what surface area does the pipeline transition to the tunnel? At some point along the pipeline-tunnel transition, wouldn't groundwater flow be affected?

Up to 14 years of construction activities were predicted for some areas (e.g., San Joaquin Co.); this would have cumulative impacts (e.g., dewatering would affect soil compaction, soil carbon, microbial functions, wildlife populations, and invasive species). What about impacts of noise on birds; e.g., how large an area would still be usable by greater sandhill cranes?

State how jurisdictional wetlands have been mapped and how the overall project net gain or net loss of wetland area has been estimated. If mitigation consists only of restoration actions in areas that are currently jurisdictional wetlands, then there would be an overall net loss of wetland area due to the project. A mitigation ratio >1:1 would be warranted to compensate for reduced wetland area. This was also a concern for Chapter 12.

Up to 277 ac of tidal wetlands are indicated as restorable; text should indicate if these are tidal freshwater or tidal brackish wetlands (or saline, as is the typical use of "tidal wetlands").

13-19. On the need to store removed aquatic vegetation until it can be disposed: there are digesters for this purpose, and they might be efficient means of mitigation if management of harvested aquatic plants will be long-term. A waste product could be turned into a resource (methane fuel).

13-19, line 12: Text says that "predator hiding spots" will be removed. What are these?

13-19, line 20: What are the E16 nonphysical fish barriers? An electrical barrier?

13-20, line 19: Boat-washing stations are mentioned; would these discharge pollutants (soap, organic debris?)

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY EDMUND G. BROWN JR., Governor

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

August 24, 2015

Mr. Michael Jewell
Chief, Regulatory Branch
U.S. Army Corps of Engineers
Sacramento District
1325 J Street
Sacramento, California 95814

Dear Mr. Jewell:

Pursuant to Section 404 of the Clean Water Act (CWA) (33 U.S.C. 1344) and Section 10 of the Rivers and Harbors Act (33 U.S.C. 403), the California Department of Water Resources (DWR) submits the attached application to the U.S. Army Corps of Engineers (Corps) for a Department of the Army individual permit (33 C.F.R 325) to allow for the implementation of key components of the State's California WaterFix program. Specifically, DWR is seeking authorizations from the Corps necessary for the construction and operation of new water conveyance facilities that will be part of the State Water Project (SWP) and operated in coordination with the U.S. Bureau of Reclamation's (Reclamation's) operation of the Central Valley Project (CVP). The California WaterFix is a critical element of a broader State effort to meet the goals of providing for a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem.

Background

The proposed project reflects the culmination of a multiyear planning process that began in 2006 between DWR, the California Natural Resources Agency, Reclamation, public water agencies, State and federal fish and wildlife agencies, non-governmental organizations, agricultural interests, and the public. The planning process, which was called the Bay Delta Conservation Plan (BDCP) program, was initiated in response to the increasingly significant and escalating conflict between the needs of a range of at-risk Delta species and natural communities adversely affected by a wide range of human activities and the need for more reliable water supplies in California for communities, agriculture, and industry.

Nearly ten years later, the ecological health of the Delta continues to be at risk, and the conflicts between species protection and Delta water exports have become more pronounced, as evidenced by years of litigation regarding the intersection of endangered species laws and the operational criteria of the SWP and CVP. Other factors, such as the continuing subsidence of lands within the Delta, increasing seismic risks and levee vulnerabilities, and rising sea levels caused by climate change, have served to further exacerbate these conflicts. The actions proposed by DWR in this permit application, which are referred to as the California WaterFix, would bring about fundamental, systemic change to the current system, putting the State on a course to

"[a]chieve the two coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem." (California Public Resources Code Section 29702, subd. [a]).

Proposed Conveyance Facilities

The new SWP water conveyance facilities proposed under the California WaterFix and reflected in DWR's application would introduce new operational flexibility into the SWP and CVP, enabling SWP or CVP water to be diverted from the Sacramento River in the north Delta and conveyed to the south Delta or to be directly diverted in the south Delta at existing SWP and CVP facilities. Water would be diverted through one of three new fish-screened intakes located on the east bank of the Sacramento River between Clarksburg and Courtland. These intakes, each with a capacity of 3,000 cfs, would be situated on the river bank and would range from 1,259 to 1,667 feet in length. The intakes would consist of a reinforced concrete structure subdivided into individual bays that would be isolated from each other and operated independently. Two tunnels would be constructed to convey water by gravity from the intake facilities to the south Delta where it would flow into the north cell of a redesigned Clifton Court Forebay. This redesign of the forebay would allow for water flowing from the north Delta facilities to be isolated from water entering Clifton Court Forebay from the south Delta.

Ecological and Water Supply Benefits

The proposed project would result in substantially improved conditions in the Delta for endangered and threatened species and afford greater water supply reliability for the State. With respect to at-risk species, the new conveyance facilities would provide the following benefits:

- Increased operational flexibility for the SWP/CVP through a "dual conveyance" system that allows water managers to shift between intakes to minimize entrainment of at-risk fish species

- Reduction in reverse Old and Middle River flows through adjustments to water operations to better reflect natural seasonal flow patterns

- Siting of new diversions in areas outside of the primary habitat for Delta Smelt and Longfin Smelt

- Integration of state-of-the-art fish screens at each intake to minimize entrainment

The proposed project would also advance the State's water supply goals by:

- Upgrading the SWP/CVP water conveyance system in a manner that improves the ability to capture water during wet years

- Protecting against water supply disruptions associated with catastrophic system failures caused by earthquakes or failed levees

- Protecting against water supply disruptions associated with sea level rise caused by climate change

Based on the foregoing benefits, the implementation of the California WaterFix would represent an important step forward in the State's efforts to resolve the longstanding conflicts within the Delta.

Consistency with Requirements of CWA Section 404 and RHA Section 10

DWR believes that the attached application is complete and consistent with the regulatory requirements of CWA Section 404 and RHA Section 10. As set out in the application, DWR has designed the proposed project to avoid impacts to waters of the United States to the maximum extent practicable and has developed measures to minimize any unavoidable impacts. DWR will submit a plan to the Corps that sets out an approach to mitigating for any unavoidable impacts to waters, including an assessment of the functions and values that will be provided by such mitigation to meet the "no net loss" goal established by the Corps and the Environmental Protection Agency. DWR will also submit to the Corps an analysis of alternatives to the proposed project to assist the Corps in its determination that the Section 404 Guidelines have been met.

National Environmental Policy Act (NEPA) Environmental Review

As you know, DWR and Reclamation recently released for public review and comment the *BDCP/California WaterFix Partially Recirculated Draft Environmental Impact Report / Supplemental Draft Environmental Impact Statement (RDEIR/SDEIS)*. The comment period is scheduled to end on October 30, 2015. It is DWR and Reclamation's expectation that the final EIR/EIS will be sufficiently comprehensive to satisfy the Corps' environmental review responsibilities under NEPA regarding the issuance of permits pursuant to this application. We understand that the Corps intends to issue a Public Notice of the application to coincide with the public review period on the RDEIR/SDEIS.

DWR has provided the following supporting documents to Zach Simmons, Corps point of contact for this project, in both hard copy and digital format:

- TAB A - Form 4345, Application for Department of the Army Permit

- TAB B - Continuation sheet for Form 4345

- TAB C - Table of impacts

- TAB D - Map book showing impacts
- TAB E - Figures
  - Fig 1 – ES1 from project Conceptual Engineering Report
  - Fig 2 – 3-1 from project Conceptual Engineering Report
- TAB F - Project Conceptual Engineering Report (on disk)

DWR looks forward to continuing to work with the Corps as it develops further documentation to support this application and comply with the regulatory requirements of CWA Section 404 and RHA Section 10. We appreciate the effort that the Corps has invested in the BDCP/California WaterFix programs and we look forward to successful completion of this critical endeavor.

If you have any questions regarding the accompanying permit application, please contact Michael Bradbury, California WaterFix Permit Manager, at 916-651-2987 or mike.bradbury@water.ca.gov.

Sincerely,

Cassandra Enos
Program Manager
BDCP/California WaterFix

cc. Zachary Simmons, USACE

Attachments

U.S. ARMY CORPS OF ENGINEERS

APPLICATION FOR DEPARTMENT OF THE ARMY PERMIT

33 CFR 325. The proponent agency is CECW-CO-R.

Form Approved - OMB No. 0710-0003 Expires: 30-SEPTEMBER-2015

Public reporting for this collection of information is estimated to average 11 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters, Executive Services and Communications Directorate, Information Management Division and to the Office of Management and Budget, Paperwork Reduction Project (0710-0003). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. Please DO NOT RETURN your form to either of those addresses. Completed applications must be submitted to the District Engineer having jurisdiction over the location of the proposed activity.

PRIVACY ACT STATEMENT

Authorities: Rivers and Harbors Act, Section 10, 33 USC 403; Clean Water Act, Section 404, 33 USC 1344; Marine Protection, Research, and Sanctuaries Act, Section 103, 33 USC 1413; Regulatory Programs of the Corps of Engineers; Final Rule 33 CFR 320-332. Principal Purpose: Information provided on this form will be used in evaluating the application for a permit. Routine Uses: This information may be shared with the Department of Justice and other federal, state, and local government agencies, and the public and may be made available as part of a public notice as required by Federal law. Submission of requested information is voluntary, however, if information is not provided the permit application cannot be evaluated nor can a permit be issued. One set of original drawings or good reproducible copies which show the location and character of the proposed activity must be attached to this application (see sample drawings and/or instructions) and be submitted to the District Engineer having jurisdiction over the location of the proposed activity. An application that is not completed in full will be returned.

(ITEMS 1 THRU 4 TO BE FILLED BY THE CORPS)

1. APPLICATION NO.	2. FIELD OFFICE CODE	3. DATE RECEIVED	4. DATE APPLICATION COMPLETE

(ITEMS BELOW TO BE FILLED BY APPLICANT)

5. APPLICANT'S NAME	8. AUTHORIZED AGENT'S NAME AND TITLE (agent is not required)
First - Michael Middle - Last - Bradbury	First - Karen Middle - Last - Shaffer
Company - Department of Water Resources	Company - Gibson & Skordal, LLC
E-mail Address - mike.bradbury@water.ca.gov	E-mail Address - kshaffer@gibsonandskordal.com
6. APPLICANT'S ADDRESS:	9. AGENT'S ADDRESS:
Address- 901 P Street, Suite 411b	Address- 2617 K Street, Suite 175
City - Sacramento State - CA Zip - 95814 Country - USA	City - Sacramento State - CA Zip - 95816 Country - USA
7. APPLICANT'S PHONE NOs. w/AREA CODE	10. AGENTS PHONE NOs. w/AREA CODE
a. Residence b. Business c. Fax	a. Residence b. Business c. Fax
916-651-2987	916-822-3230 916-822-3231

STATEMENT OF AUTHORIZATION

11. I hereby authorize, Karen Shaffer to act in my behalf as my agent in the processing of this application and to furnish, upon request, supplemental information in support of this permit application.

_____ _____

SIGNATURE OF APPLICANT DATE

NAME, LOCATION, AND DESCRIPTION OF PROJECT OR ACTIVITY

12. PROJECT NAME OR TITLE (see instructions)

California WaterFix

13. NAME OF WATERBODY, IF KNOWN (if applicable)

Sacramento/San Joaquin Delta (see Continuation Sheet)

14. PROJECT STREET ADDRESS (if applicable)

Address N.A.

15. LOCATION OF PROJECT

Latitude: ◦N See Continuation Sheet Longitude: ◦W

City - State- Zip-

16. OTHER LOCATION DESCRIPTIONS, IF KNOWN (see instructions)

State Tax Parcel ID See Continuation Sheet Municipality

Section - Township - Range -

17. DIRECTIONS TO THE SITE
See Continuation Sheet

18. Nature of Activity (Description of project, include all features)
The construction and operation of the California WaterFix water conveyance project and the associated habitat creation, restoration and enhancement.

See Continuation Sheet for project details, including details on each of the project components, and construction timing.

19. Project Purpose (Describe the reason or purpose of the project, see instructions)
See Continuation Sheet for detail of the reason for the project.

USE BLOCKS 20-23 IF DREDGED AND/OR FILL MATERIAL IS TO BE DISCHARGED

20. Reason(s) for Discharge
Discharge of fill material into waters of the United States is required to construct various components of the proposed project.

See Continuation Sheet for details.

21. Type(s) of Material Being Discharged and the Amount of Each Type in Cubic Yards:

Type	Type	Type
Amount in Cubic Yards	Amount in Cubic Yards	Amount in Cubic Yards

See Continuation Sheet.

22. Surface Area in Acres of Wetlands or Other Waters Filled (see instructions)
Acres See Continuation Sheet.
or
Linear Feet

23. Description of Avoidance, Minimization, and Compensation (see instructions)
See Continuation Sheet.

24. Is Any Portion of the Work Already Complete? ☐ Yes ☒ No IF YES, DESCRIBE THE COMPLETED WORK

25. Addresses of Adjoining Property Owners, Lessees, Etc., Whose Property Adjoins the Waterbody (if more than can be entered here, please attach a supplemental list).

a. Address- See Continuation Sheet.

City - State - Zip -

b. Address-

City - State - Zip -

c. Address-

City - State - Zip -

d. Address-

City - State - Zip -

e. Address-

City - State - Zip -

26. List of Other Certificates or Approvals/Denials received from other Federal, State, or Local Agencies for Work Described in This Application.

AGENCY	TYPE APPROVAL*	IDENTIFICATION NUMBER	DATE APPLIED	DATE APPROVED	DATE DENIED
USFWS	Continuation Sheet				
NMFS					
SRWCB					
CDFWS					

* Would include but is not restricted to zoning, building, and flood plain permits

27. Application is hereby made for permit or permits to authorize the work described in this application. I certify that this information in this application is complete and accurate. I further certify that I possess the authority to undertake the work described herein or am acting as the duly authorized agent of the applicant.

SIGNATURE OF APPLICANT DATE SIGNATURE OF AGENT DATE

The Application must be signed by the person who desires to undertake the proposed activity (applicant) or it may be signed by a duly authorized agent if the statement in block 11 has been filled out and signed.

18 U.S.C. Section 1001 provides that: Whoever, in any manner within the jurisdiction of any department or agency of the United States knowingly and willfully falsifies, conceals, or covers up any trick, scheme, or disguises a material fact or makes any false, fictitious or fraudulent statements or representations or makes or uses any false writing or document knowing same to contain any false, fictitious or fraudulent statements or entry, shall be fined not more than $10,000 or imprisoned not more than five years or both.

California WaterFix

Clean Water Act Section 404 Application
Continuation Sheet for ENG FORM 4345

A. Background

In October 2006, various state and federal agencies, water contractors, and other stakeholders initiated a process to develop the Bay Delta Conservation Plan (BDCP) to advance the planning goal of restoring ecological functions to the Delta and improving water supply reliability in the State of California. In July 2012, Governor Edmund G. Brown, Jr. and United States Secretary of the Interior Ken Salazar reaffirmed both the State and federal commitment to the BDCP as a comprehensive solution to achieve the dual goals of a reliable water supply for California and a healthy California Bay Delta ecosystem that supports the State's economy.

In December 2013, after several years of preparation, DWR, Reclamation, USFWS, and NMFS, acting as joint Lead Agencies, published a draft of the BDCP and an associated Draft Environmental Impact Report/Environmental Impact Statement (Draft EIR/EIS). The Draft EIR/EIS analyzed a total of 15 action alternatives, including Alternative 4, which was identified as DWR's preferred alternative. The 14 other action alternatives varied from Alternative 4 with respect to such factors as the number of proposed North Delta intakes, the types of conveyance facilities (e.g., surface canals versus underground pipelines), operational rules, and amounts of proposed habitat restoration.

Alternative 4 included three new intakes located in the North Delta and two parallel underground pipelines which would convey diverted water to the existing export facilities in the South Delta. The proposed operations for Alternative 4 reflected the outcome of many years of collaboration between DWR, Reclamation, the water contractors, USFWS, NMFS, and CDFW. By July 2014, at the end of the public review period, the Lead Agencies had received comments on the proposed BDCP from other agencies and members of the public. Many of these comments suggested improvements that could be made to the proposed project (i.e., Alternative 4, the BDCP). For example, some of the comments urged that the Lead Agencies reduce the level and scope of the construction activities, such as number of intakes, as means of reducing air quality and noise impacts. Other comments noted that Alternative 4 contemplated intensive construction activity on Staten Island, which is important wintering habitat for the Greater Sandhill Crane. Many commenters argued that, because the proposed project would lead to significant, unavoidable water quality effects, DWR could not obtain various approvals needed for the project to succeed (e.g., approval by the State Water Resources Control Board for new points of diversion for the north Delta intakes). Others suggested that DWR should pursue a permit with a term shorter than 50 years due to the level of uncertainty regarding both the future effects of climate change and the long-term effectiveness of habitat restoration in restoring fish populations. Still other comments suggested that the proposed conveyance facilities should be separated from the habitat restoration components of the BDCP, with the latter to be pursued separately.

Taking this public and agency input into account, the Lead Agencies substantially modified Alternative 4 and formulated three new sub-alternatives (2D, 4A, 5A). These sub-alternatives assume that incidental take authorizations would be issued for shorter durations than 50 years and propose habitat mitigation and restoration commensurate with impacts of the water conveyance facilities. Other important changes include: (i) the elimination of three pumping plants associated with new intake facilities; (ii) associated reductions in construction-related air pollutant emissions at intake sites; (iii) substantial reductions in the amount of construction occurring on Staten Island; and (iv) reductions in water quality effects.

California WaterFix

Clean Water Act Section 404 Application
Continuation Sheet for ENG FORM 4345

The proposed project (Alternative 4A), as well as two other sub-alternatives (2D, and 5A), were developed by the Lead Agencies to embody a different implementation strategy, in which State and federal endangered species incidental take authorizations would not be obtained through Section 10 of the Endangered Species Act (ESA) or through the Natural Community Conservation Planning Act (NCCPA), but rather through Section 7 of the ESA and Section 2081(b) of the California Endangered Species Act (CESA). These new sub-alternatives consist of the construction and operation of new north Delta intakes and habitat restoration actions necessary to address the effects associated with the new facilities. This alternative implementation strategy contemplates that other State and federal programs will address broader habitat restoration goals identified for species recovery. Alternative 4A, which is known as "The California WaterFix" is identified as DWR and Reclamation's preferred alternative in the Partially Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement (RDEIR/SDEIS) released for public comment in July 2015.

The construction and operation of new conveyance facilities would help resolve many of the concerns with the current south Delta conveyance system, including reducing impacts to endangered and threatened species in the Delta through operational changes to the SWP and CVP and state of the art fish screens to reduce entrainment. Implementing a dual conveyance system, in which water could be diverted from either the north or the south or both, depending on the needs of aquatic organisms, would align water operations to better reflect natural seasonal and east-west flow patterns. The new system is designed to reduce the impacts that occur through sole reliance on the southern diversion facilities and to allow for greater operational flexibility to enhance fish protection. The new conveyance facilities would also help protect critical water supplies against the threats of sea level rise and earthquakes.

Although Alternatives 4A, 2D, and 5A include only those habitat restoration measures necessary to mitigate for the effects of the new conveyance facilities, habitat restoration is still recognized as a critical component of the State's long-term plans for the Delta. Such larger endeavors, however, will likely be implemented over time under actions separate and apart from the proposed project. The primary habitat restoration program is called California EcoRestore (EcoRestore), which will be overseen by the California Natural Resources Agency and implemented under the California Water Action Plan. Under EcoRestore, the State will pursue restoration of more than 30,000 acres of fish and wildlife habitat by 2020.

B. Design Overview

The proposed project consists of the construction and operation of a dual-conveyance water delivery system that would modernize the hub of California's aging water supply system in a way that balances the needs of the Delta ecosystem and California's water supplies. The design of the new facilities has evolved over the years, due primarily to additional engineering analyses, environmental considerations, landowner concerns, and public comment. The original concept was the All Tunnel Option (ATO), which relied primarily on tunnels to convey the water through the Delta. The next concept was the Pipeline Tunnel Option (PTO), which included a combination of pipelines and tunnels. The third concept was the Modified Pipeline Tunnel Option (MPTO), which made significant changes to the earlier concepts, including reducing the number of intakes, increasing the size of the tunnels in the gravity-feed portion of the system, decreasing the size of the intermediate forebay, and eliminating an intermediate pumping plant.

California WaterFix

Clean Water Act Section 404 Application
Continuation Sheet for ENG FORM 4345

The conveyance facility alignment in the proposed project (Alternative 4A) is identified as the "Dual Conveyance Facility Modified Pipeline/Tunnel Option – Clifton Court Forebay Pumping Plant Option," or "MPTO/CCO" in DWR's Conceptual Engineering Report which analyzes the project. This latest configuration optimizes the earlier MPTO design concept to better utilize the Clifton Court Forebay. Changes to the conveyance facilities resulting from the optimization in alignment and features, include the following:

- Larger north tunnels for gravity feed system;
- Reduction of the internal hydrostatic head within the tunnel system;
- Optimized intermediate forebay;
- Relocation of RTM sites off of Staten Island
- Consolidated pumping plant at Clifton Court Forebay (CCF);
- Modification to the CCF; and
- Elimination of the pumping plants at the intakes.

The proposed project also includes the installation of a permanent barrier at the Head of Old River (HORB) to ensure fish remain in the San Joaquin River, rather than enter the South Delta through Old River.

Based on the construction schedule, DWR will seek CWA Section 404 and RHA Section 10 authorizations in phases. It is understood that the components of the project which will require 408 authorization cannot be approved under Section 404 of the Clean Water Act or Section 10 of the Rivers and Harbors Act until the 408 authorization is obtained. Based on current information, DWR expects to seek permits pursuant to the following phases :

- Phase 1 – Construction of the Pumping Plant at Clifton Court Forebay
- Phase 2 – Construction of the North Tunnels, Intermediate Forebay, and Dual Main Tunnels; Disposal of Tunnel Material; CCF Dredging; and the modification of the existing CCF to create two forebays
- Phase 3 – Construction of the Intakes and Head of Old River Barrier

C. Additional Application Form 4345 Data

The following information is provided as a supplement to **ENG FORM 4345** and is provided in the same order in which information is requested on the form.

Block 13. NAME OF WATERBODY

The proposed project is located in the Sacramento/San Joaquin Delta and crosses several waterways and wetland features within the Delta. A comprehensive list of each waterbody/wetland affected by the proposed project can be found at **TAB C, Table of Impacts**, and **TAB D, Map Book of Impacts**. Named waterbodies include Italian Slough, Old River, West Canal, San Joaquin River, North Victoria Canal, Potato Slough, Connection Slough, Middle River, Snodgrass Slough, and the Sacramento River.

California WaterFix

Clean Water Act Section 404 Application
Continuation Sheet for ENG FORM 4345

Block 15. LOCATION OF PROJECT

The location of the proposed project is shown on **Figure 1** of **TAB E, Project Figures**. The northern most component of the project is located at approximate Latitude 38.42° North and Longitude 121.51° West, while the southern-most component is located at approximate Latitude 37.80° North and Longitude 121.58° West. The location of each waterway and wetland crossing is included on the Table of Impacts at TAB C.

Block 16. OTHER LOCATION DESCRIPTIONS

The components of the proposed project are located within Sacramento, San Joaquin, Contra Costa and Alameda Counties.

Block 17. DIRECTIONS TO THE SITE

Portions of the proposed project work area can be accessed by public roads such as State Route 160, Highway 12, and Highway 4; but much of the project area is currently accessible only by private roadway. See the figures at TAB E for locational information.

Block 18. NATURE OF ACTIVITY

The proposed project will include the following:

- Three Intake Facilities along the Sacramento River in the north Delta with fish-screened on-bank intake structures.
- Two gravity-flow water conveyance tunnels (North Tunnels) that connect the intakes to an Intermediate Forebay.
- The Intermediate Forebay (IF) which receives water from the North Tunnels, equalizes pressure, and passes the water to the dual gravity-flow Main Tunnels.
- Dual Main Tunnels connecting the IF to Clifton Court Forebay (CCF).
- A Pumping Plant located at the northeast corner of CCF.
- Eleven disposal sites for tunnel material excavated from the North Tunnels and Dual Main Tunnels.
- Division of CCF into two parts: North Clifton Court Forebay (NCCF) and South Clifton Court Forebay (SCCF).
- A permanent operational barrier at the Head of Old River.

The water conveyance facilities included in the proposed project assume the following:

- The MPTO/CCO delivers up to 9,000 cubic feet per second (cfs) from the Sacramento River in the north Delta to the south Delta export pumping plants.
- The proposed project is engineered to:
  - Transport water through conveyance facilities isolated from existing rivers and sloughs.
  - Divert water from the Sacramento River through fish-screened intakes.
  - Deliver water to the SWP and CVP export pumping plants' intake channels downstream of their respective fish collection facilities.
- Withstand a 200-year flood event taking into account the sea level rise (SLR) predicted from climate change.

- Use gravitational flow through the Main Tunnels.

The physical characteristics of each of the proposed project's components are described below.

Intakes
The three Intake Facilities (Intakes No. 2, 3, and 5) will each have a capacity of 3,000 cfs as proposed by DWR and a team of experts, including State and federal fish agency biologists, called the Fish Facilities Technical Team (FFTT). The Intake Facilities are proposed for sites along the Sacramento River which were selected in coordination with the FFTT. Intake numbering is consistent with the earlier Pipeline/Tunnel Option (PTO) CER numbering system.

Each Intake Facility will consist of the following:

- A fish-screened intake structure that employs state-of-the-art on-bank fish screens.
- Twelve large gravity collector box conduits that will extend through the levee to convey flow to the sedimentation system.
- A sedimentation system consisting of gravity settling basin to capture sand-sized sediment and a drying lagoon for sediment drying and disposal.

Water will pass through baffled fish screens and flow under the modified levee and rerouted Highway 160 through gated box conduits. Water will exit the box conduits into one of two sediment basins, then flow through an afterbay to the discharge shaft that leads to the tunnel system. Electric power will be supplied through a substation with transformers and switching equipment that will be located at each site.

North and Main Tunnel Alignments
The proposed conveyance tunnels consist of the North Tunnels, which consist of three separate tunnel reaches totaling approximately 14 miles that connect the three Intake Facilities to the IF, and two parallel Main Tunnels to the NCCF, each approximately 30 miles long. The North Tunnels are two single-bore 28-foot and one single-bore 40-foot inside diameter (ID) tunnels. The Main Tunnels are twin-bore 40-foot inside diameter tunnels. The inlets and outlets would be equipped with isolation structures to allow the tunnels to be dewatered, maintained, and inspected.

As part of the construction of the tunnels, five temporary barge landings would be constructed at locations adjacent to construction work areas for the delivery of construction materials. Each of the five proposed barge landings would include in-water and over-water structures, such as piling dolphins, docks, ramps, and possibly conveyors for loading and unloading materials; and vehicles and other machinery. Construction of the five barge landings would involve piles at each landing.

Disposal of Tunnel Material
The material excavated from both the North Tunnels and the Dual Main Tunnels will be disposed of near the tunnel boring machines' launch shafts. Proximity to the tunnel shafts is required to reduce truck traffic associated with the transport the material to a remote disposal site. There are currently 11 disposal sites identified, and excavated tunnel material will be transported to spoil sites a maximum of 16,000 feet from launch shafts, primarily by conveyor. The daily volume of tunnel material withdrawn

from the tunneling operations at any one shaft location would vary, with an average volume of approximately 6,000 cubic yards per day. Transport of the material to the RTM storage sites would be nearly continuous during mining or advancement of the TBM. The material would be carried on a conveyor belt from the tunnel boring machines to the base of the launching shaft and then to a work area. The material would be segregated for transport to treatment area as appropriate. The material would be stacked to a height of between six and 15 feet, depending on storage location. If feasible, the tunnel material will be reused during the construction of various habitat restoration and creation efforts within the Delta.

Intermediate Forebay

The proposed Intermediate Forebay (IF) would be located on the Glanville Tract, east of the Pearson District and west of Interstate 5. The IF serves as an atmospheric break in the system from the inlet to the dual Main Tunnels. This break in the system allows the flows from each Intake to merge and be distributed equally to each barrel of the Main Tunnels, improving operational stability in the Clifton Court pumping plant, and allowing for independent operation of each of the North Tunnels and the Main Tunnels. The IF would have no regulating gates controlling gravitational flow to the Main Tunnels; therefore, no daily operational storage would be necessary at IF beyond that necessary to accommodate water surface changes at the downstream NCCF. The IF would have a bottom elevation of -20 feet and would be 28 acres in size. The sizing of the facility reflects the smallest practicable area that would accommodate construction of the inlet and outlet structures and provide sufficient reduction in velocity to capture sand-sized sediment not otherwise captured at the Intake Facilities.

Clifton Court Forebay

The Clifton Court Forebay (CCF), which has a water surface area of approximately 2215 acres, will be expanded by approximately 590 acres to the southeast of the existing forebay to create a new overall footprint of approximately 2805 acres. The existing CCF will be dredged, and the expansion area excavated, to design depths of -8 feet for the north cell (the NCCF) and -10 feet for the south cell (the SCCF). A new embankment would be constructed around the perimeter of the forebay, and coffer dam would divide the forebay into two sections, the NCCF and the SCCF; the new forebay sections would have a surface area of 822 acres and 1756 acres, respectively. Water from the Dual Main Tunnels would be pulled from the tunnels' terminus by the Clifton Court Pumping Plant at the northeastern end of the NCCF, south of Victoria Island, and enter the NCCF. Water flow from the tunnels into the NCCF by gravity only would be feasible when the Sacramento River is at exceptionally high stages.

The NCCF provides the daily operational storage required to equalize and balance differences between the south Delta inflow and water exported by the SWP and CVP pumps. Preliminary calculations indicate an operational storage capacity range of approximately 4,300 to 10,200 acre-feet (AF), with an approximate water storage surface area of 822 acres, depending on depth. Constraints on the exporting pumping plants fixed a normal forebay operating range of 7.0 feet (elevation +0.50 to +7.5 feet). This operating range would allow for approximately 4,300 AF of potential active storage in the NCCF. Additional operating storage up to 10,200 AF may be obtained by operating NCCF at a range of up to 9.0 feet, which would be within the efficient operating range of both NCCF and the export pumping plants.

The SCCF has been designed to be hydraulically dependent on Delta waterways and to be operated under the same criteria as the existing CCF. The SCCF would incorporate part of Byron Tract located on

the south side of the existing CCF. The SCCF would draw its supply from the West Canal using intake gates and would provide flow to Banks PP. SCCF would have an approximate water storage surface area of 1756 acres at maximum water elevation. Constraints on the exporting pumping plants limit the normal operating range to 7.0 feet (elevation +1.1 to +8.1 feet). This operating range would allow for approximately 14,000 AF of potential active storage in SCCF. Additional operating storage could be created with increase to the existing operating range.

An emergency spillway would be constructed in the NCCF east side embankment, south of the CCPP fill pad. The spillway has been sized to carry emergency overflow (9,000 cfs, the maximum inflow) to the Old River, so a containment area is not necessary. The shallow foundation beneath this existing structure requires improvements to prevent strength loss and seismic settlement. The ground improvement would be to elevation -50.0 feet within the footprint of the structure and beyond the structure by a distance of approximately 25 feet. The work would be performed within the sheet pile installed for embankment filling.

Head of Old River Barrier
The proposed project includes the construction of a barrier at the Head of Old River, which would consist of fish and flow control gates as well as a small boat lock to allow recreational boat passage during operation of the gates. The barrier gates would be operated from October 1 through June 15 each year. From June 16 through September 30, the gates would be open.

Additional information and figures regarding the engineering details of the proposed project can be found on the compact disk at **TAB F, Conceptual Engineering Report**, Modified Pipeline/Tunnel Option – Clifton Court Forebay Pumping Plant, Volume 1, dated April 1, 2015.

Block 19. PROJECT PURPOSE
Consistent with the information requested on FORM 4345, this section sets out the purpose and need for the proposed project. Applicant will submit a separate Basic and Overall Project Purpose Statement as part of the analysis of alternatives it conducts to assist the Corps in making determinations pursuant to the Section 404(b)(1) Guidelines.

One of the primary challenges facing California is how to comprehensively address the increasingly significant and escalating conflict between the ecological needs of a range of at-risk Delta species and natural communities that have been and continue to be adversely affected by a wide range of human activities, while providing for more reliable water supplies for people, communities, agriculture, and industry.

This challenge must be addressed, in decisions made by DWR, CDFW, and the State Water Resources Control Board (State Water Board), as they endeavor to strike a reasonable balance between these competing public policy objectives and various actions taken within the Delta, including the proposed project. State policy regarding the Delta is summarized in the Sacramento–San Joaquin Delta Reform Act of 2009, which states:

> "it is the intent of the Legislature to provide for the sustainable management of the Sacramento-San Joaquin Delta ecosystem, to provide for a more reliable water supply for the state, to protect and enhance the quality of water supply from the Delta, and to establish a governance structure that will direct efforts across state agencies to develop a legally enforceable Delta Plan." (California Water Code, Section 85001, subd. [c]).
>
> The Delta "serves Californians concurrently as both the hub of the California water system and the most valuable estuary and wetland ecosystem on the west coast of North and South America." (California Water Code, Section 85002).

The ecological health of the Delta continues to be at risk, and the conflicts between species protection and Delta water exports have become more pronounced. Other factors, such as the continuing subsidence of lands within the Delta, increasing seismic risks and levee failures, and sea level rise associated with climate change, serve to further exacerbate these conflicts. Simply put, the overall system as it is currently designed and operated does not appear to be sustainable from an environmental perspective, and so a proposal to implement a fundamental, systemic change to the current system is necessary. This change is necessary if California is to "[a]chieve the two coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem." (California Public Resources Code Section 29702, subd. [a]).

This section presents the Lead Agencies' Project Objectives, which are required by the State CEQA Guidelines, and the Purpose and Need Statement, which is required by the CEQ NEPA Regulations.

Purpose and Need

Just as CEQA requires an EIR to include a statement of "project objectives" as described above, NEPA requires that an EIS include a statement of "purpose and need" to which the federal agency is responding in proposing the alternatives, including the proposed action (40 CFR 1502.13). This purpose statement of the proposed action and project need described below, are consistent with the above project objectives in Section 1.1.4.1.

Purpose Statement

The purposes of the proposed actions are to achieve the following:

1. Construction and operation of facilities and/or improvements for the movement of water entering the Delta from the Sacramento Valley watershed to the existing SWP and CVP pumping plants located in the southern Delta.
2. Operation of the existing and potential new SWP facilities and existing CVP Delta facilities.
3. The activities described in 1) and 2) occurring in a manner that minimizes or avoids adverse effects to listed species, and allows for the protection, restoration and enhancement of aquatic, riparian and associated terrestrial natural communities and ecosystems.
4. Restore and protect the ability of the SWP and CVP to deliver up to full contract amounts, when hydrologic conditions result in the availability of sufficient water, consistent with the requirements of state and federal law and the terms and conditions of water delivery contracts held by SWP

contractors and certain members of San Luis Delta Mendota Water Authority, and other existing applicable agreements.

The above Purpose statement reflects the intent to advance the coequal goals set forth in the Sacramento–San Joaquin Delta Reform Act of 2009 of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The above phrase—restore and protect the ability of the SWP and CVP to deliver up to full contract amounts—is related to the upper limit of legal CVP and SWP contractual water amounts and delineates an upper bound for development of EIR/EIS alternatives, not a target. It is not intended to imply that increased quantities of water will be delivered under the proposed project. As indicated by the "up to full contract amounts" phrase, alternatives need not be capable of delivering full contract amounts on average in order to meet the project purposes. Alternatives that depict design capacities or operational parameters that would result in deliveries of less than full contract amounts are consistent with this purpose.

Project Need

The need for the action is derived from the multiple, and sometimes conflicting, challenges currently faced within the Delta. The Delta has long been an important resource for California, providing municipal, industrial, agricultural and recreational uses, fish and wildlife habitat, and water supply for large portions of the state. However, by several key criteria, the Delta is now widely perceived to be in crisis. There is an urgent need to improve the conditions for threatened and endangered fish species within the Delta. Improvements to the conveyance system are needed to respond to increased demands upon and risks to water supply reliability, water quality, and the aquatic ecosystem.

Delta Ecosystem Health and Productivity

Variability in the location and timing of flows, salinity, and habitat was common in the pre-European Delta. But for the past 70 years, the Delta has been managed as a tidal/freshwater system. During the same period, the ecological productivity for Delta native species and their habitats has been in decline. Removal of much of the variable pre-European heterogeneous mix of fresh and brackish habitats, necessary to support various life stages of some of the Delta native species, has had a limiting effect on the diversity of native habitat within the Delta. In addition, urban development, large upstream dams and storage reservoirs, diversions, hydraulic mining, and the development of a managed network of navigation, flood control, and irrigation canals have all affected water flow patterns and altered fish and wildlife habitat availability. Most of the original tidal wetlands and many miles of sloughs in the Delta were removed by channelization and levee construction between the 1850s and 1930s. These physical changes, coupled with higher water exports and declines in water quality from urban and agricultural discharges and changes in constituent dilution capacity from managed inflows and diversions, have stressed the natural system and led to a decline in ecological productivity.

Significant declines have been reported in economically important fish species such as Chinook salmon. Delta smelt, considered by many to be an indicator species for the health of the Delta ecosystem, is just one component species in the community-wide pelagic organism decline. Fishery resource changes may

be attributable to numerous factors, including water management systems and facilities, water quality/chemistry alterations, and nonnative species introductions.

Water Supply Reliability

The distribution of precipitation and water demand in California is unbalanced. Most of the state's precipitation falls in the north, yet substantial amounts of water demand are located south and west of the Delta, including irrigation water for southern Central Valley agriculture, and municipal and industrial uses in southern California and the Bay Area. This supply/demand imbalance led to development of two major water projects: the SWP and the CVP.

Together, the SWP and CVP systems are two of the largest and most complex water projects in the nation and provide the infrastructure for the movement of water throughout much of California. They function under a suite of Congressional authorizations, interagency agreements, regulatory requirements, and contractual obligations that govern daily operations and seasonal performance. These include various authorizing legislation, the USFWS and NMFS Biological Opinions, including the Reasonable and Prudent Alternatives, and the water right permits issued by the State Water Board, among others. Regulations for the combined SWP and CVP operations are intended to protect the beneficial uses of Delta water, which include municipal, industrial, and agricultural water uses, fish and wildlife uses, environmental protection, flood management, navigation, water quality, power, and recreation.

The water rights of the SWP and CVP are conditioned by the State Water Board to protect the beneficial uses of water within the Delta under each respective project's water rights. In addition, under the COA, DWR and Reclamation coordinate their reservoir releases and Delta exports to enable each project to achieve benefit from their water supplies and to operate in a manner protective of beneficial uses as required by their water right permits. It is the responsibility of the SWP and CVP to meet these obligations regardless of hydrologic conditions. In 2006, Governor Schwarzenegger's Executive Order S-17-06 created the Delta Vision Task Force to address some of the issues facing the Delta. In the closing days of the Task Force's work, the State Water Board presented information indicating that quantities totaling several times the average annual unimpaired flows in the Delta watershed could be available to water users based on the face value of water permits already issued. However, the hydrology, the SWP and CVP water contracts, and environmental regulations control actual quantities that could be made available for use and diversion.

The current and projected future inability of the SWP and CVP to deliver water to meet the demands of certain south of Delta CVP and SWP water contractors is a very real concern. More specifically, there is an overall declining ability to meet defined water supply delivery volumes and water quality criteria to support water users' needs for human consumption, manufacturing uses, recreation, and crop irrigation.

Delta Hydrology and Water Quality

Generally, Delta hydrodynamics are defined by complex interactions between tributary inflows, tides, in-Delta diversions, and SWP and CVP operations, including conveyance, pumping plants, and operations of

channel barriers and gates. The degree to which each variable impacts the overall hydrology of the Delta varies daily, seasonally, and from year to year, depending on the magnitude of inflows, the tidal cycle, and the extent of pumping occurring at the SWP and CVP pumping plants. Changes in water inflow and outflow throughout the Delta affect the water quality within the Delta, particularly with regard to salinity. It has been estimated that seawater is pushing 3 to 15 miles farther inland since development began in the Delta over 150 years ago (Contra Costa Water District 6 2010).

Additionally, other water constituents of concern in the Delta have been identified through ongoing regulatory, monitoring, and environmental planning processes such as CALFED, planning functions of the State Water Board, and the CWA Section 303(d) list of state water bodies that do not meet applicable water quality standards. In June 2007 (with updates in February and May 2009), EPA gave final approval of a list of 18 chemical constituents identified in the Section 303(d) list for impaired Delta waters (State Water Resources Control Board 2007). Included in this list are dichlorodiphenyltrichloroethane (DDT) and other pesticides, mercury, polychlorinated biphenyls (PCBs), and selenium.

To further compound these challenges, fundamental changes to the Delta are certain to occur; the Delta is not a static ecological system. The anticipated effects of climate change will result in elevated sea levels, altered annual and inter-annual hydrological cycles, changed salinity and water temperature regimes in and around the Delta, and accelerated shifts in species composition and distribution. These changes add to the difficulty of resolving the increasingly intensifying conflict between the ecological needs of a range of at-risk Delta species and natural communities and the need to provide adequate and reliable water supplies for people, communities, agriculture, and industry. Anticipating, preparing for, and adapting to these changes are key underlying drivers for the proposed project.

Block 20. REASON FOR DISCHARGE

The construction of the proposed project would result in the discharge of fill material. Discharge of fill material would be associated with the construction of the intake facilities on the banks of the Sacramento River; grading at intake locations, construction of the intermediate forebay, pumping plant, and at tunnels (drive, vent, and reception shafts); disposal of excavated tunnel material; and installation of the HOR Barrier. In addition, fill would be placed into the existing CCF to create two separate forebays. Both forebays are proposed to be dredged.

Block 21. TYPE OF MATERIAL BEING DISCHARGED AND AMOUNT IN CUBIC YARDS

The material proposed for discharge consists of clean soil, rock, concrete, grout, sheet piles, and reusable tunnel material. The total amount of fill material to be discharged into Waters of the U.S. during construction of the conveyance facilities, and disposal of excavated material, is estimated to be 15,022,645 cubic yards. The amount of fill material to be discharged in Waters of the U.S. at given locations for the specific facilities is estimated below in Table 1.

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Table 1. Estimate of Fill into Waters of the U.S.

Facility-- Hybrid Constructability	CY Fill	Estimate Assumptions	Fill Material
Barge Unloading Facility	260000	Engineering calculation	Clean soil and rock
Work Areas	97009	1 foot deep	Clean soil, rock, concrete
Concrete Batch Plant	7464	1 foot deep	Clean soil, rock, concrete
Control Structure	9759	1 foot deep	Clean soil, rock, concrete
Forebay and Spillway	1793	1 foot deep	Clean soil, rock, concrete
Forebay Embankment	11192500	Engineering calculation	Clean soil and rock
Forebay Overflow Structure	9689	Engineering calculation	Concrete and rock
Fuel Station	1490	1 foot deep	Clean soil, rock, concrete
Intake	141675	Engineering calculation	Concrete
Intake end curves/walls	180000	Engineering calculation	Clean soil and rock
Operable Barrier	12230	Engineering calculation	Clean rock and grout
Operable barrier sheet piles		Engineering calculation	Sheet piles 32,146 sq feet
Power trans/PGE	8029	1 foot deep	Clean soil, rock, concrete
Reusable Tunnel Material	2099259	6 feet deep	Reusable tunnel material
additional dredge material from CCF	241193	additional 13 feet	Dredged material
Road Interchange	15917	1 foot deep	Clean soil, rock, concrete
Shaft Locations	53724	1 foot deep	Clean soil, rock, concrete
additional at Pumping Plant	660000	Engineering calculation	Clean soil, rock, concrete
Transmission Line	27427	1 foot deep, assume max 17.08 acre footprint	Clean soil, rock, concrete
Tunnel Conveyor Facility	3487	1 foot deep	Clean soil, rock, concrete
Canal		Excavation, no fill needed	
Forebay		Excavation, no fill needed	
Forebay Dredging Area		Excavation, no fill needed	
New Forebay		Excavation, no fill needed	
Total Fill	**15022645**		

Block 22. SURFACE AREA IN ACRES OF WETLANDS OR OTHER WATERS FILLED

Construction of the proposed project would result in the unavoidable fill of waters of the U.S. DWR has mapped several types of waters of the United States that are located within the project area. Descriptions of the mapped waters are provided below, including general characterizations of the associated vegetation expected to occur within each type of aquatic habitat.

Perennial Wetlands

Perennial wetlands are dominated by persistent hydrophytic vegetation. Three types of perennial wetlands were mapped in the Project Area based on the growth form of the vegetation.

- **Emergent Wetland -** Emergent wetlands are dominated by emergent marsh plants such as tules and cattails, or native or ruderal hydrophytic herbaceous forbs. Nontidal emergent wetlands occur above the waterline in ditches or other nontidal channels, at the edge of ponds or lakes, or where seepage occurs on the landside of levees. Tidal emergent wetlands occur in the

vegetated zone along tidal or muted tidal channels, in areas such as mud flats, waterside levee toes, and in-channel islands.

- **Scrub-Shrub Wetlands -** Scrub-shrub wetlands are dominated by woody vegetation that is less than 6 m tall and includes riparian shrubs such as native blackberries, dogwoods, buttonbush, and California wild rose, as well as willow and cottonwood seedlings or saplings. Scrub-shrub wetlands may occur in depressions or other nontidal areas such as the banks of ditches and the edges of ponds or lakes. This plant community also occurs in tidally influenced areas along tidal channels and on in-channel islands.
- **Forested Wetlands -** Forested wetlands are defined by woody vegetation that is 6 m tall or taller. Riparian trees in the study area include: Goodding's willow, arroyo willow, sandbar willow, and Fremont's cottonwood. Forested wetlands are found in areas with tidal and nontidal water regimes, as described for scrub-shrub wetlands.

Seasonal Wetlands

Three types of seasonal wetlands were mapped in the study area. Seasonal wetlands are usually dry for part of the year and therefore exhibit vegetation that is patchy or not persistent throughout the year. Strongly alkaline or saline conditions may also cause the soil to be barren of vegetation in some areas.

- **Vernal Pool -** Vernal pool wetlands are depressions with an impervious soil horizon close to the surface. These depressions fill with rainwater and may remain inundated through spring or early summer; they often occur in complexes of many small pools that are hydrologically interconnected. Vernal pools support distinct plant species adapted to the characteristic flooding and drying cycles of the habitat. The vernal pools in the project area are located south and west of Clifton Court Forebay and have been somewhat disturbed by past land use activities.
- **Seasonal Wetland -** A type of seasonal wetland occurs in the central Delta within plowed agricultural fields. Although a system of pumps and drainage ditches controls water levels on the subsided islands, a high water table persists in some areas. Upland crops are planted in the surrounding fields but hydrophytic ruderal forbs become established in the wet areas, and crops usually fail if planted there. The vegetation in these wetlands consists mostly of annual weedy wetland species.
- **Alkaline Wetland** - Alkaline wetlands are a type of seasonal wetland influenced by strongly alkaline or saline soils. Alkaline wetlands support alkaline or saline tolerant species such as iodine bush and alkali heath, but may also have large unvegetated areas that are seasonally ponded or saturated.

Nontidal Waters

In the Delta five types of nontidal waters were mapped as the open water portion of either naturally occurring features or unnatural features that were excavated and/or diked. Nontidal waters may occur in depressions of various sizes or in channels with either intermittent or perennially flowing water. The vegetation associated with these waters is discussed separately in the Wetlands section.

- **Agricultural Ditches -** Throughout the Delta there are many ditches constructed for the purpose of irrigating and/or draining agricultural land. The mapped ditches range in size from one to 22

meters wide. They are generally unvegetated with mud bottoms, but may support floating species such as duckweed or water hyacinth.

- **Natural Channels -** Nontidal natural channels exist on the northeast and southwest edges of the Project Area. These include a section of the Cosumnes River and several small channels linking other water features. All of these features flow intermittently. The substrate in natural channels may be mud, or sand, gravel, and cobbles. These channels are generally unvegetated, but may have inclusions of emergent wetland, scrub-shrub, or forest wetlands. However, if these inclusions were large enough to be mapped, they were included in the delineation under those specific habitat types.
- **Depressions -** Depressions are ponds that are permanently, seasonally, or artificially wet, with little to no rooted vegetation on a mud or sand bottom. They may be artificially filled or result from a high water table. Depressions are less than 20 acres in size with a depth of less than 2 meters. These water bodies are often created in grazing lands for use as stock ponds, and may be diked or otherwise artificially impounded.
- **Lakes -** Lakes have characteristics similar to depressions, but are greater than 20 acres in size and may have a wave-formed shoreline.

Tidal Waters

Tidal waters are the open water portions of aquatic features that are influenced by the rise and fall of the tides. Man-made structures such as gates or culverts may restrict tidal influence to various degrees.

- **Tidal Channels -** Tidal channels may be naturally occurring perennial riverine waterways, though most have been modified with leveed banks and often reinforced with rock revetment. Water velocity and depth fluctuates under tidal influence, and the channel bottom is generally comprised of mud or sand. Tidal channels that have been created by excavation are usually straight rather than sinuous, and usually have heavily diked or reinforced banks. These excavated channels were often created to provide for navigation, water conveyance, material for levees, or to raise the land surface on adjacent property. Tidal channels are largely unvegetated, or may support floating or submerged aquatic vegetation.
- **Conveyance channels -** Several large rock-lined conveyance channels were mapped in the study area. These constructed water features were mapped along with all other aquatic resources in the Project Area because they may be subject to some tidal effects and therefore may be considered jurisdictional by the Army Corps of Engineers. These features are unvegetated.
- **Clifton Court Forebay -** Clifton Court Forebay, a constructed reservoir, is a highly modified perennial water body which is semi-enclosed by land, and engineered to be periodically open to tidal influences via a moveable gate structure. The Forebay is characterized by an artificial rock shore (rock revetment) and an aquatic bed of varying depths. The forebay is largely unvegetated, however, emergent perennials such as cattails and tules are found in shallow areas, and submerged aquatics such as Brazilian waterweed are found in areas of moderate depth.

The proposed project will result in permanent impact to approximately 774 acres of waters of the United States and temporary impact to approximately 1,931 acres of waters. The impacts are shown in detail in Table 2 below.

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Table 2. Approximate Impact Acreages

Habitat Type	Permanent Impact	Temporary Impacts Treated as Permanent[1]	Temporary Impact[2]
Agricultural Ditch	46	17	0
Alkaline Wetland	20	0	0
Clifton Court Forebay	258	0	1931
Conveyance Channel	8	3	0
Depression	29	7	0
Emergent Wetland	57	32	0
Forest	8	9	0
Lake	23	0	0
Scrub-Shrub	13	5	0
Seasonal Wetland	115	25	0
Tidal Channel	19	81	0
Vernal Pool	0.3	0	0
Total[3]	596.3	179	1931

Of the permanent impacts, 179 acres are temporary impacts treated as permanent because the temporary impacts are expected to last over one year. These impact sites will eventually be restored to pre-project conditions; however, due to the duration of effect, the impacts are treated as permanent. Impacts to 52 acres of pond and lake habitat is actually conversion from open water to a mosaic of wetlands types (e.g. seasonal wetland, scrub-shrub, riparian, emergent marsh) at four lakes that were created as a result of the construction of Interstate 5 in 1979. This conversion is a part of the planned

[1] Temporary impacts treated as permanent are temporary impacts expected to last over one year. These impact sites will eventually be restored to pre-project conditions; however, due to the duration of effect, compensatory mitigation will be included for these areas.

[2] Temporary impacts are due to dredging Clifton Court Forebay.

[3] Some of these impact totals are overestimated. For example, transmission lines have been mapped as a 150-foot wide corridor, although the actual footprint would be 100' X150' for power pole pads that are spaced 450' apart for 69kV lines and 750' apart for 230kV lines; a narrow access road may also follow the transmission line alignment. The location of some pads may be changed to avoid wetlands. Impacts to Tidal Channels are also overestimated due to errors in mapping access roads on levees; the project footprint is not intended to impact the channels.

mitigation for Phase 2, as discussed in Block 23, Compensatory Mitigation, below. All of the temporary impact is due to the dredging of Clifton Court Forebay.

Wetlands and other aquatic features provide many functions, such as providing habitat, storing and conveying water, and trapping sediment. Wetlands that are undisturbed, with natural hydrologic connections and native species, tend to have a higher functional value than disturbed wetlands. A qualitative functional assessment of the mapped wetlands in the Project Area sorted the impacted wetlands into three functional value groups:

Low functional value: most agricultural ditches, seasonal and emergent wetlands within agricultural fields, Clifton Court Forebay, and constructed conveyance channels and other highly disturbed aquatic features.

Medium functional value: emergent, forest, scrub-shrub, depressions, and alkaline wetlands that are moderately disturbed or fragmented aquatic features and agricultural ditches that have developed adjacent marsh or riparian habitat.

High functional value: tidal channels, lakes, emergent, forest, scrub-shrub, depressions, alkaline wetlands and vernal pools that are relatively undisturbed.

The qualitative functional assessment of the impacted aquatic features is summarized in Table 3. The majority of the permanent impacts (approximately 72%) are to either low or moderate functional habitats. The largest single permanent impact (258 acres) is to Clifton Court Forebay, which as described above, is a man-made feature with extremely limited habitat function. The second largest permanent impact (115 acres) is to seasonal wetlands, which occur within plowed agricultural fields.

Table 3. Qualitative Functional Assessment of Impacted Aquatic Features

Type	Total impacted acres	High Function	Medium Function	Low Function
Agricultural Ditch	*63*		7	56
Alkaline Wetland	*20*	9	9	2
Clifton Court Forebay	*258*			258
Conveyance Channel	*11*			11
Depression	*36*	29	7	
Emergent Wetland	*89*	36	26	27
Forest	*17*	11	6	
Lake	*23*	23		
Scrub-Shrub	*18*	10	6	3
Seasonal Wetland	*140*			140
Tidal Channel	*100*	100		
Vernal Pool	*0.3*	0.2		<0.1
Totals	*775.3*	218	61	497
Percent of Total		28%	8%	64%

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Block 23. DESCRIPTION OF AVOIDANCE, MINIMIZATION, AND COMPENSATION

The proposed project conforms to the general rule that avoidance, minimization, and compensation are to be applied in a sequential fashion. The applicant has designed the proposed project to avoid waters of the United States where practicable and minimize any unavoidable impacts. The applicant will provide compensatory mitigation for any remaining impacts.

In 2008, the Corps and the EPA issued regulations, known as the "Mitigation Rule", governing compensatory mitigation for activities authorized by permits issued by the Corps (33 CFR §§325, 332). In 2015, the Corps' South Pacific Division issued "Regional Compensatory Mitigation and Monitoring Guidelines (Final January 12, 2015)" (Division Guidelines) to supplement the Mitigation Rule. Compensatory mitigation under the Mitigation Rule and Division Guidelines fulfill the long standing national goal of replacing the loss of wetland and other aquatic resource acreages and functions, known as the "no net loss" goal (National Wetlands Mitigation Action Plan (December 24, 2002)). To achieve the no net loss goal, the Corps and EPA have concluded that, where appropriate and practicable, compensatory mitigation "should provide, at a minimum, one for one functional replacement (i.e., no net loss of values), with an adequate margin of safety."[4] The long-term objective of the no net loss policy is to increase wetland acreages and functions nationally.

The Mitigation Rule defines compensatory mitigation as (1) restoring existing wetlands or reestablishing former wetlands; (2) creating new wetlands in upland areas; (3) enhancing the functional values of degraded wetlands; and (4) preserving existing aquatic resources. Restoration is generally the preferable form of compensatory mitigation because the likelihood of success is greater while the impacts to potentially ecologically important uplands are less, as compared to creation. Moreover, the potential gains in terms of aquatic resources functions are often greater with restoration as compared to enhancement and preservation (33 CFR §332.3(a)(2)). The Mitigation Rule and Division Guidelines stress the benefits of a watershed approach to compensatory mitigation, and the preference for compensatory mitigation to be located in the same watershed as the site of the impact site and where it is most likely to successfully replace lost functions and services (33 CFR §332.3; Division Guidelines, §3.2).

Avoidance and Minimization Measures

The proposed project has been designed to avoid impacts to waters of the United States to the maximum extent practicable. Numerous iterations of footprint locations for each of the conveyance components were evaluated to maximize the use of upland areas. Once construction begins, measures will be implemented to further avoid and minimize impacts to waters of the United States as well as to special status species. The AMMs will be implemented at all phases of the project, including siting, design, construction, and operations and maintenance. The AMMs that pertain specifically to waters of the United States are summarized in the Table 3 below.

[4] Memorandum of Agreement between the Environmental Protection Agency and the USACE concerning the Determination of Mitigation under the Clean Water Act Section 404(b)(1) Guidelines, 55 Fed. Reg. 9210, 9212 (1990) ("Mitigation MOA").

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Table 3. Summary of the Avoidance and Minimization Measures

Number	Title	Summary
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.
AMM3	Stormwater Pollution Prevention Plan	Includes measures that will be implemented to minimize pollutants in stormwater discharges during and after construction, 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 waters of the United States, including navigable waters, as well as 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.
AMM10	Restoration of Temporarily Affected Natural Communities	Restore and monitor natural communities in the Plan Area that are temporarily affected by construction 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.
AMM12	Vernal Pool Crustaceans	Includes provisions to require project design to minimize indirect effects on vernal pool habitat, avoid effects on core recovery areas, minimize ground disturbing activities or alterations to hydrology, conduct protocol-level surveys, and redesign the project to ensure that habitat loss is minimized where practicable.
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.
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.
AMM36	Notification of Activities in Waterways	Before in-water construction or maintenance activities begin, notify appropriate agency representatives if these activities could affect water quality or aquatic species.

Measures that will be implemented to avoid and minimize impacts to aquatic species and species which utilize aquatic habitats such as California tiger salamander, giant garter snake, California red legged frog, western pond turtle, riparian woodrat, riparian brush rabbit, Suisun shrew, and salt marsh harvest mouse, will also serve to reduce project impacts to waters of the United States.

Wetland Functions

Mitigation will be provided to compensate for the loss of acreage and functions associated with unavoidable construction-related impacts to waters of the United States. Wetland functions are defined

as a process or series of processes that take place within a wetland, such as those related to the storage of water, transformation of nutrients, growth of living matter, and diversity of wetland plants. Functions can be grouped broadly as habitat, hydrologic, or water quality.

Not all wetlands perform all functions nor do they perform all functions equally well. The location and size of a wetland may determine the nature of the wetland function. For example, the geographic location may determine habitat functions, and the location of a wetland within a watershed may determine its hydrologic or water-quality functions. Many factors determine how well a wetland will perform these functions: climatic conditions, quantity and quality of water entering the wetland, and disturbances or alteration within the wetland or the surrounding ecosystem. Wetland disturbances may be the result of natural conditions, such as an extended drought, or of human activities, such as land clearing, dredging, or the introduction of nonnative species. Wetlands are among the most productive habitats in the world, providing food, water, and shelter for fish, shellfish, birds, and mammals, and serving as a breeding ground and nursery for numerous species. Many endangered plant and animal species are dependent on wetland habitats for their survival. Hydrologic functions are those related to the quantity of water that enters, is stored in, or leaves a wetland. These functions include such factors as the reduction of flow velocity, the role of wetlands as ground-water recharge or discharge areas, and the influence of wetlands on atmospheric processes. Water-quality functions include the trapping of sediment, pollution control, and the biochemical processes that take place as water enters, is stored in, or leaves a wetland.

The applicant has conducted a qualitative functional assessment to assign a relative ranking system to the wetlands and other waters for which a discharge is being proposed. Additional analysis may be conducted during development of a compensatory mitigation plan. The assessment of existing functions will be compared to the functions expected to result from the proposed mitigation for the purpose of demonstrating that the compensatory mitigation will, at a minimum, fully replace the function of the waters proposed to be filled.

Compensatory Mitigation

Compensatory mitigation will be proposed to off-set the impacts associated with the physical construction of the project. In some cases, restoration actions designed to provide habitat for species may also serve as compensatory mitigation for the loss of waters of the United States (e.g. created emergent marsh may function as both habitat for delta smelt, as well as compensatory mitigation for physical impacts to emergent marsh habitat). The proposed compensatory mitigation will be subject to specific success criteria, success monitoring, long-term preservation, and long-term maintenance and monitoring pursuant to the requirements of the Mitigation Rule. In some cases, proposed mitigation is likely to afford significantly higher function and value than that of waters proposed for discharge.

Compensation ratios, which are developed by the Corps, are guided by type, condition, and location of replacement habitat as compared to type, condition and location of impacted habitat. Compensatory mitigation usually includes restoration, creation, or rehabilitation of aquatic habitat. The Corps does not typically accept preservation as the only form of mitigation; use of preservation as mitigation typically

requires a very high ratio of replacement to impact. It is anticipated that mitigation ratios will be at a minimum of 1:1, depending on the factors listed above. Based on preliminary discussions with the Corps, it is anticipated that ratios will be developed for each affected habitat type, and further, for each functional ranking (see Table 2 above) within each habitat type.

Typically, impacted habitat is replaced with in-kind habitat; consistent with this approach, for example, the applicant expects to mitigate for permanent impacts to Clifton Court Forebay with waters created through the expansion of CCF into North CCF and South CCF. Impacts to some lower functioning habitat types, such as seasonal wetland and agricultural ditches may be mitigated out-of-kind with higher functioning habitat types.

The applicant will propose compensatory mitigation using one or more of the following methods:

- Purchase of credits for restored/created/rehabilitated habitat at an approved wetland mitigation bank;
- On-site (adjacent to the project footprint) restoration or rehabilitation of wetlands converted to uplands due to past land use activities (such as agriculture) or functionally degraded by such activities;
- On-site (adjacent to the project footprint) creation of aquatic habitat;
- Off-site (within the Delta) restoration or rehabilitation of wetlands converted to uplands due to past land use activities (such as agriculture) or functionally degraded by such activities;
- Off-site (within the Delta) creation of aquatic habitat;
- Payment into the Corps' Fee-in-Lieu program.

<u>Purchase of Credits or Payment into In-lieu Fee Program</u>
The applicant may purchase bank credits and/or make payments into an in-lieu fee program to compensate for impacts. The applicant would utilize programs that have been Corps-approved and have service areas that encompass areas impacted by the proposed project.

<u>On-Site Restoration, Rehabilitation and/or Creation</u>
Much of the Delta consists of degraded or converted habitat that is generally functioning as upland. The applicant would seek opportunities to conduct on-site restoration, rehabilitation, and/or creation in areas adjacent to project footprints. It is anticipated that some of the compensatory mitigation would fall into this category.

<u>Off-Site Restoration, Rehabilitation and/or Creation</u>
Within the immediate vicinity of the project area, much of the land has been subject to agricultural or other land uses which have degraded or even converted wetlands that existed historically. The applicant would evaluate sites within the Delta to determine their potential for restoration, rehabilitation, and/or creation. It is anticipated that most of the compensatory mitigation obligation would be satisfied through this approach.

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DWR will submit to the Corps its approach to compensatory mitigation that contemplates implementation in several phases. Phase 1 mitigation would address the construction of the pumping plant at CCF, which will impact approximately 34 acres of wetlands and waters. Phase 2 mitigation would compensate for impacts associated with the construction of the north tunnels, intermediate forebay, dual main tunnels; disposal of tunnel material; dredging of CCF and construction of two forebays. These activities would result in 698.3 acres of impact. Phase 3 mitigation would cover impacts associated with the construction of the intakes and the Head of Old River Barrier, which would impact approximately 43 acres of waters and wetlands.

It is anticipated that the impacts associated with Phase 1 would be mitigated through the purchase of credits at an existing Corps-approved mitigation bank. The 34 acres of impact consists of 24 acres of emergent wetland, 7 acres of scrub-shrub, 2 acres of forest, and one acre of depression (pond). DWR proposes to purchase floodplain mosaic wetland credits (which include perennial emergent marsh, scrub shrub wetland, riparian forest, and waters of the US (non-wetland)) at a ratio of 1:1 to appropriate compensate for Phase 1 impacts. The service area for the Consumnes Floodplain Mitigation Bank, operated by Westervelt Ecological Services, incorporates the areas where impacts would occur at CCF, providing one potential option for DWR to purchase credits from an approved mitigation bank.

DWR is currently assessing two privately held tracts of land for their potential to support restoration and creation of waters to satisfy most of the compensatory mitigation necessary for Phases 2 and 3. One tract is located in the north Delta, while the other is located in the central Delta. Both are currently farmed.

Construction of wetlands at the tract in the north Delta would likely include sculpting the interior of the tract to elevations that would support a mosaic of habitat types, including woody riparian, scrub-shrub, seasonal wetland, emergent wetland, and open water. One or more breach or notch in the existing (non-project) levee at the lowest end of the island would be excavated to allow for water to enter the island. Much of the island would be subject to the ebb and flow of the tide and created habitats would mimic that of natural habitats in the area. The sculpting would be designed to ensure that no fish would be entrapped as water receded at low tide.

Construction of wetlands at the tract in the central Delta would utilize the low elevation of the interior of the island to create seasonal wetland and emergent marsh habitat through excavation. In other locations on this island, setback levees might be constructed such that the existing (non-project) levees could be removed or breached in multiple locations resulting in the creation of riparian, scrub-shrub, and emergent wetlands. If portions of the existing levee can be left intact, the result would be the creation of new in-channel islands which would be an important, high function resource within the Delta where existing in-channel islands are subject to erosion and degradation.

DWR also proposes to provide additional compensatory mitigation from within the four lakes that were created during the construction of Interstate 5. Currently each of the lakes is open water with sparse or no edge vegetation (either emergent wetland or riparian vegetation). It is envisioned that excavated

tunnel material would be used to partially fill the open water, resulting in a mosaic of open water, emergent wetland, seasonal wetland, scrub-shrub, and riparian habitats.

As mentioned above, the permanent impacts associated with work at Clifton Court Forebay would be mitigated through the expansion of CCF into North CCF and South CCF.

A comprehensive conceptual mitigation plan for the proposed project is currently being developed and will be submitted to the Corps for review and comment upon completion. At this time, it is expected that there will be two final mitigation plans; one for Phase 1, and one for Phases 2 and 3. The final mitigation plan for Phase 1 will identify the bank where credits would be purchased and include an analysis of the functional value of those credits in relationship to the functions lost at CCF through the construction of the pumping plant. The final mitigation plan for Phases 2 and 3 will identify the location, type, and amount of habitat to be created and will include all thirteen components identified in the Mitigation Rule.

Impacts Resulting from the Construction of Compensatory Mitigation

The restoration, rehabilitation, and/or creation of aquatic habitat during the construction of the compensatory mitigation would result in relatively minor environmental impacts. Expected impacts include noise and air quality during construction, the conversion of upland to aquatic habitat, and potential changes to existing channel hydraulics where levees will be breeched or lowered to create weirs.

Block 25. ADDRESSES OF ADJOINING PROPERTY OWNERS

Please see **TAB G, Adjacent Landowner Mailing List**.

Block 26. LIST OF OTHER CERTIFICATES/APPROVALS

AGENCY	TYPE OF APPROVAL	STATUS
USFWS	Biological Opinion/Take Statement	Pending
NMFS	Biological Opinion/Take Statement	Pending
CDFW	2081(b) Take Permit	Pending
CDFW	Streambed Alteration Agreement	Pending
SWRCB	New Point of Diversion	Pending
SWRCB	Water Quality Certification/WDR	Pending

D. Additional Information

In addition to the supplemental data above, the following **additional information** is provided to assist the Corps in the permit process. Much of this information was presented in Appendix E of the Partially Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement (RDEIR/SDEIS) for the Bay Delta Conservation Plan.

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1. RIVERS AND HARBORS ACT SECTION 10

The Applicant has examined potential impacts to navigation both during construction and during the operation of the conveyance facilities described as the proposed project. These effects are set out in the RDEIR/SDEIS and include assessments regarding changes in water surface elevation and sedimentation associated with the proposed project.

Potential Effects to Water Surface Elevations Caused During Construction of the Intakes

The construction of Intakes 2, 3, and 5 will require the installation of coffer dams at each location. Coffer dams will be used to isolate construction areas from the Sacramento River and allow for the sites to be dewatered. The installation of the coffer dams will likely cause localized water elevation changes upstream of and adjacent to each coffer dam. These localized surface elevation changes will not exceed a 0.10 foot increase above existing conditions at any intake location even at high river flows (when surface elevation changes would be expected to be highest). Because this maximum increase in elevation would be entirely localized, downstream surface elevation changes during intake construction would be insignificant and changes to river depth and width at any location would also be insignificant. Consequently, boat passage and river use in the Sacramento River and its tributaries would not be affected.

Potential Effects to Water Surface Elevations Caused by Intakes During Operation

The hydraulic modeling scenario for this analysis assumed five intakes because that is the maximum number of intakes included under any alternative evaluated in the RDEIR/SDEIS. The modeling also assumed the highest North Delta diversion capacity allowed under any alternative. The proposed project consists of fewer intakes and lower diversion capacity (three intakes and 9,000 cfs maximum diversion capacity), and as such, would have a smaller effect on surface water elevations than the model indicates. Under the proposed project, operation of Intakes 2, 3 and 4 may potentially have localized effects on water surface elevation during certain operational regimes and at certain river flows. While intake operations and pumping levels would be dictated by many factors, Sacramento River diversions would be limited during low flows by operational rules. To further minimize the intake effects on river surface elevations, intakes were designed as on-bank structures and were placed so that river flood and flow characteristics would be minimally altered.

Based on hydrologic modelling, even at the lowest river flows (taking into account both seasonal and tidal variations) and at maximum intake operation (full diversions at each of five alternative intakes), estimates are that boat draft depths of at least 16.5 feet would be maintained within the Sacramento River. This river depth has occurred historically and has been adequate to support navigation along the Sacramento River. Additionally, under these same intake divisions/river flows, water surface elevations would be lowered by no more than 0.7 feet, which represents a localized and maximum estimate. Surface elevations downstream of the intakes would be affected less, and during higher river flow and lower intake diversions, river depths would be greater than the minimum estimate.

The minimal changes in surface water elevation anticipated under the proposed project, even assuming a maximum lowering of 0.7 feet, would not likely expose any currently unexposed natural or man-made

features that would affect or impede navigation. There would be no new snags or obstructions that would impede navigation.

Moreover, even when operating at maximum capacity, the intakes would not alter flows in a way that would affect commercial vessels or recreational watercraft. The intakes are designed to ensure pumping velocities would have minimal impacts to aquatic species. It is unlikely that changes in flow velocity would be perceptible to operators of marine vessels or recreational watercraft or otherwise affect navigation.

Potential Effects on Navigation Caused by Sedimentation, Facility Construction

Intakes

Construction for Intakes 2, 3, and 5 would require the installation of coffer dams at each location. Coffer dams would be used to isolate each construction area from the Sacramento River and to allow for the de-watering of the construction area. Construction of coffer dams require sheet pile driving that would cause an incremental increase in suspension of bed sediments. These effects would be temporary and would not have an effect on navigation. Sheet piles at the edge of the levee embankment would likely change eddy currents locally, but rock slope in the transition zone would limit those currents and potential changes to bed load dynamics. As a result, erosion and sedimentation into the Sacramento River during intake construction would be minimal.

Any potential increases in sedimentation would be further minimized by limiting the duration of in-water construction activities and through the implementation of the environmental commitments identified in the RDEIR/SDEIS pertaining to water quality. Such commitments would serve to control short-term and long-term erosion and sedimentation effects and ensure the restoration of soils and vegetation in areas affected by construction activities following construction (AMM4, as described above in Table 2). Erosion and sediment control plans would be prepared for construction activities, each taking into account site-specific conditions such as proximity to surface water, erosion potential, drainage, etc. These plans would meet all applicable regulatory requirements regarding erosion control, including BMPs for erosion and sediment control.

Implementation of Mitigation Measure SW-4 identified in the RDEIR/SDEIS (Implement Measures to Reduce Runoff and Sedimentation) will further ensure that impacts from sedimentation are minimal.

Barge Facilities

Under the proposed project, five temporary barge landings would be constructed at locations adjacent to construction work areas to facilitate the delivery of construction materials. Each of the five proposed barge landings would include in-water and over-water structures, such as piling dolphins, docks, ramps, and possibly conveyors for loading and unloading materials; and vehicles and other machinery. Construction of the five barge landings would involve placing piles at each landing.

To address potential erosion and sedimentation impacts from barge facility construction associated with the proposed project, the applicant would effectuate the development and implementation of a Barge

Operations Plan for facility construction. The components of the Barge Operations Plan are described in the RDEIR/SDEIS Appendix 3B, *Environmental Commitments*. This commitment is reflected in AMM7, *Barge Operations Plan*, as described in Table 2 above. This plan would be developed and implemented by the construction contractors per standard DWR contract specifications. Fleeting facilities would be either docking facilities built through pile and wharves or loaded and unloaded using landward positioned cranes. In either case, through AMM7 and the Environmental Commitments, impacts to sedimentation through construction related activities would be localized and minimal. Implementation of Mitigation Measure SW-4 would further ensure that impacts from sedimentation are minimal.

Clifton Court Forebay
Clifton Court Forebay would be dredged and redesigned to provide an area where water flowing from the new north Delta facilities would be isolated from water diverted from south Delta channels. Clifton Court Forebay is a "navigable water" because it is subject to the ebb and flow of the tide. The use of the forebay is limited to maintenance operations and is not open to commercial or recreational navigation.

Potential Effects on Navigation Caused by Sedimentation, During Operations
Intakes
Sediment loads are present in the Sacramento River as bed loads or distributed within the water column. The Sacramento River is sediment "starved" for most of the year since upstream reservoirs act as settling basins for suspended sediments. In most cases, sediment load is concentrated on the river bed and this bed load depends on several factors including particle size, particle density and flow velocity. To exclude bed loads from entering intake structures during operation, design criteria for the intakes require that the lowest point of the screen be placed above the river bed in such a way that there is no change in bed sediment erosion/distribution patterns. Additionally, screen locations would be placed on the outer bends of the river to minimize scour, erosion and sediment loading at those locations. Flow control baffles at intakes would be adjusted to control sedimentation near the screens as needed and air jets at screens are proposed to re-suspend sediments as needed.
Implementation of Mitigation Measure SW-4 (Implement Measures to Reduce Runoff and Sedimentation) would further ensure that impacts from sedimentation are minimal.

Potential Navigation Impacts from Construction and Operations of Head of Old River Barrier
The project proposes work at the Head of Old River including the construction of fish and flow control gates as well as a small boat lock to allow recreational boat passage. An analysis of potential impacts of this work on navigation was completed in 2005 by Jones and Stokes (*South Delta Improvements Program Vol I: Environmental Impact Statement/Environmental Impact Report*. Draft. October. (J&S 020533.02.) State Clearinghouse #2002092065. Sacramento, CA.) ("SDIP EIR/EIS"). The SDIP EIR/EIS analyzed whether the proposed barrier/gates facility and locks would cause a change in south Delta flows or water level, river flows or surface water elevations that would result in substantial changes to existing recreational or commercial boating activity and opportunities.

The changes in access to Delta waterways by boats and other vessels during construction and operation of the gates, during channel dredging activities, and attributable to changes in water levels/depths were

addressed. Most of the waterways in the immediate project vicinity are public waterways navigable by recreational craft, including rowboats, large houseboats, and cabin cruisers. These waterways are also navigable by smaller commercial vessels, including towing and salvage vessels, clamshell dredges, dredges for repair and maintenance of levees and channels, and pile-driving vessels. Boat access points in the project area include River's End Marina, located south of the confluence of the DMC with Old River; Tracy Oasis Marina Resort, located west of Tracy Boulevard, on the south side of Grant Line/Fabian and Bell Canal; and possibly at Heinbockel Harbor, located on the west side of Tracy Boulevard and the north side of Old River

According to a California Department of Parks and Recreation (DPR) survey, minimal boat launching and use occurs in the project area. The channels within the project area are too small to accommodate large commercial vessels, and because the channels are also part of an existing temporary barriers project, larger vessels cannot use these channels when the barriers are in place. A boat lock at the proposed facility would ensure boat access upstream of the gate regardless of gate operations. In this regard, upstream boat access could improve over current conditions. Additionally, from June 16 through September 30, the gates will be open and no boat lock operations will be necessary.

With respect to both recreational and commercial navigation, and based on analysis provided in the SDIP EIR/EIS, boat access impacts during facility construction would be less than significant (p. 5.8-14, 5.8-18, 5.8-21), impacts to navigation caused by water level changes during barrier operation would be less than significant (p. 5.8-15. 5.8-19, 5.8-22), impact to non-recreational boaters due to temporary dredging operation would be less than significant (p. 5.8-16, 5.8-19, 5.8-22), and impacts on recreation as a result of constructing and operating any of the alternatives would not be significant (p. 7.4-1).

Construction of the operable barrier could result in increased sedimentation near the gates. Maintenance dredging around the gate would be necessary to clear out sediment deposits. Dredging around the gates would be conducted using a sealed clamshell dredge. Depending on the rate of sedimentation, maintenance would occur every 3 to 5 years. A formal dredging plan with further details on specific maintenance dredging activities will be developed prior to dredging activities. Guidelines related to dredging activities, including compliance with in-water work windows and turbidity standards are described further in the RDEIR/SDEIS Appendix 3B, *Environmental Commitments*, under *Disposal and Reuse of Spoils, Reusable Tunnel Material (RTM), and Dredged Material*. These activities would ensure that sedimentation would not result in an adverse impact to navigation.

Potential Cumulative Effects on Navigation

As explained above and with respect to the construction and operation of these facilities, the proposed project would not result in adverse effects to navigation due to water level elevation changes or altered sedimentation patterns. It is highly unlikely that other projects would combine with these impacts of the project to result in cumulative effects on navigation. This is because the minimal effects of these elements of the project on navigation are localized and would combine only with probable future projects if the projects were located immediately adjacent to the project components. There are no other reasonably foreseeable projects proposed to be located near or adjacent to the planned facilities.

California WaterFix

Clean Water Act Section 404 Application
Continuation Sheet for ENG FORM 4345

2. NEPA

The California Department of Water Resources and the U.S. Bureau of Reclamation, as state and federal lead agencies under CEQA and NEPA, respectively, released the Partially Recirculated Draft Environmental Impact Report / Supplemental Draft Environmental Impact Statement (RDEIR/SDEIS) for the project in July 2015.

The RDEIR/SDEIS provides supplemental analysis and information regarding the various alternatives analyzed in the previously circulated Draft EIR/EIS and introduces three new sub-alternatives – 4A, 2D, and 5A. As explained in the RDEIR/SDEIS, the proposed project (the California WaterFix), which was developed in response to public and agency input, replaced Alternative 4 (the proposed Bay Delta Conservation Plan) as the CEQA Preferred Alternative. The proposed project is also the NEPA Preferred Alternative, a designation that was not attached to any of the alternatives presented in the Draft EIR/EIS. The entire environmental analysis for the proposed project is included in the RDEIR/SDEIS.

Also included as part of the RDEIR/SDEIS is Appendix E, *Supplemental Information for USACE Permitting Requirements*, which includes information and analysis relevant to the Corps' permitting for the proposed project. Appendix E was developed specific to informational needs to facilitate USACE decision-making under the Clean Water Act and Rivers and Harbors Act, and associated authorizations. The purpose of the Appendix is to present all information relevant to the Corps' permitting for the proposed project as efficiently as possible. Additionally, the RDEIR/SDEIS carries forward informational needs to facilitate USACE decision-making for all other alternatives considered.

Appendix E provides an overview of the material needed for the Corps' permitting process under the authority of Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act and identifies the stage of the permitting process at which the material will be available and presented.

Appendix E also provides specific environmental review information for the proposed project regarding impacts to waters of the United States, a conceptual description of compensatory mitigation, compliance with Section 106 of the National Historic Preservation Act, Section 10 of the Rivers and Harbor Act, and Section 14 of the Rivers and Harbors Act (codified in 33 USC 408 and commonly referred to as "Section 408").

3. ENDANGERED SPECIES

Section 7 of the ESA provides that each federal agency must ensure, in consultation with the Secretary of the Interior and/or Commerce, that any actions authorized, funded, or carried out by the agency are not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of areas determined to be critical habitat (16 USC 1536(a)(2)). Section 7 requires federal agencies to engage in formal consultation with USFWS or NMFS for any proposed actions that are likely to adversely affect listed species.

DWR is responsible for the operations and maintenance of the State Water Project (SWP) and the Bureau of Reclamation (Reclamation), an agency of the U. S. Department of the Interior, is responsible for operations and maintenance of the Central Valley Project (CVP). DWR and Reclamation coordinate the operations of these water conveyance systems. DWR has proposed certain modifications and

improvements to the SWP, including the construction and operation of three supplemental intakes and associated conveyance facilities and a new head of Old River barrier. Once constructed, these new facilities will result in changes to the operations of both CVP and SWP. As described in this Application, the construction and operation of the new facilities will require USACE authorizations under Section 404 of the Clean Water Act and Section 10 and Section 14 of the Rivers and Harbors Act.

Reclamation will serve as the lead federal agency for the Section 7 consultation. In conjunction with DWR, Reclamation will initiate formal consultation with both the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) regarding the potential effect of the construction and operation of the new facilities on federally listed species and designated critical habitat. The Section 7 consultation regarding these new facilities is intended to cover all potential ESA-related impacts associated with construction and new operations, including impacts that may occur as a result of the issuance of USACE permits.

4. CULTURAL RESOURCES

The National Historic Preservation Act (NHPA), 16 U.S.C. §§ 470a to 470w-6, is the primary federal law governing the preservation of cultural and historic resources in the United States. The law establishes a national preservation program and a system of procedural protections which encourage the identification and protection of cultural and historic resources of national, state, tribal and local significance. Primary components of the act include:

- Articulation of a national policy governing the protection of historic and cultural resources.
- Establishment of a comprehensive program for identifying historic and cultural resources for listing in the National Register of Historic Places.
- Creation of a federal-state/tribal-local partnership for implementing programs established by the act.
- Requirement that federal agencies take into consideration actions that could adversely affect historic properties listed or eligible for listing on the National Register of Historic Places, known as the Section 106 Review Process.
- Establishment of the Advisory Council on Historic Preservation, which oversees federal agency responsibilities governing the Section 106 Review Process.
- Placement of specific stewardship responsibilities on federal agencies for historic properties owned or within their control (Section 110 of the NHPA).

Section 106 of the National Historic Preservation Act of 1966 (NHPA) requires federal agencies to take into account the effects of their undertakings on historic properties, and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment. The historic preservation review process mandated by Section 106 is outlined in regulations issued by ACHP. Revised regulations, "Protection of Historic Properties" (36 CFR Part 800), became effective August 5, 2004, and are summarized below. The responsible federal agency first determines whether it has an undertaking that is a type of activity that could affect historic properties. Historic properties are properties that are included in the National Register of Historic Places or that meet the criteria for the National Register. If so, it must identify the appropriate State Historic Preservation Officer/Tribal Historic Preservation Officer (SHPO/THPO) to consult with during the process. It should also plan to involve the public, and identify other potential

consulting parties. If it determines that it has no undertaking, or that its undertaking is a type of activity that has no potential to affect historic properties, the agency has no further Section 106 obligations.

Programmatic Agreement (PA)

The US Army Corps of Engineers (USACE), as the federal lead agency for CWA Section 404 permitting the water conveyance facility, is responsible for Section 106 compliance. When a project is complex, such that the normal Section 106 review process is not appropriate, the Section 106 implementing regulations (36 CFR 800.14(b)) allow for the development of a programmatic agreement (PA) to ensure Section 106 compliance. Relative to the currently proposed conveyance facility, preparation of a PA is applicable when effects on historic properties cannot be fully determined prior to approval of an undertaking (36 CFR 800.14(b)(1)(ii)), or when nonfederal parties are delegated major decision-making responsibilities (36 CFR 800.14(b)(1)(iii)).

USACE, in collaboration with DWR, is developing a draft Section 106 PA for the conveyance facility. The PA provides for the identification of historic properties within the Area of Potential Effect (APE) of the selected Project alternative prior to construction initiation, and the development of avoidance, protection, or mitigation measures for those historic properties that could be adversely affected by the Project. Treatment plans will be prepared to address impacts to NRHP-eligible archaeological, built environment, and Traditional Cultural Property (TCP) resources within the APE. The PA details how many of the day-to-day responsibilities for Section 106 compliance are delegated to DWR by USACE.

Tribal Consultation

An important element of the PA involves consultation with Native American tribes and members of the public who have a demonstrated interest in the undertaking, as required under 36 CFR 800.2(c)(2) and 36 CFR 800.2(d), respectively. Native American tribes are those tribal entities who are federally recognized (36 CFR 800.16(m)). Native American tribes who have not received federal recognition, or individuals of Native American descent who are not affiliated with any tribal organization, are considered members of the interested public, as are other entities such as historical societies, local governments, or businesses and individuals. The PA ensures that USACE will fully involve federally recognized tribes at a government-to-government level throughout the Section 106 process. Similarly, the PA delegates responsibility for consultation with tribes and individuals without federal recognition to DWR.

Participation in the Section 106 process by Native American tribes or individuals with an ancestral affiliation with the Project area is described in the PA. Native Americans will be invited to participate in the development and implementation of the terms of the PA, including inventory reports, evaluation plans and reports, and during the resolution of adverse effects through the development of treatment plans for those resources within the APE that are either exclusively or partially affiliated with prehistoric or ethnographic resources. Participation may take place during public meetings, at meetings organized only for Native American tribes as a group, or at meetings with single tribes or individuals; meetings may be informal or may be identified as formal government-to-government consultations, depending on the participants involved. Native American tribes, both federally recognized and those without federal

recognition, and with individuals with a demonstrated ancestral tie to the project area will be invited to be concurring parties to the PA. However, these entities are not required to be concurring parties in order to participate in the processes described in the PA, and they may request to become concurring parties at any time during the process.

5. ANALYSIS OF ALTERNATIVES

The Applicant is in the process of developing an analysis of alternatives pursuant to the Section 404(b)(1) Guidelines (40 C.F.R. section 230.10(a)-(d)). The analysis of alternatives will be submitted to the Corps separate from this application.

6. 408 AUTHORIZATION

The purpose of review under Section 408 is to ensure that an action would not impair the usefulness of a federal civil work under the Corps' authority, and would not be injurious to the public interest. Specifically related to this project, the primary issue is to maintain the integrity of the SRFCP and SJRFCP and their function for flood risk reduction. Section 408 review provides that alteration of any one part of the system would not substantially increase flood risk for any part of the system.

The elements of the requester's preferred alternative for a new water conveyance facility that may trigger Section 408 permission specific to federal civil works for flood risk reduction are:

- 3 new water intake structures on the east levee of the Sacramento River, a federal project levee (part of the SRFCP)
- channel margin habitat enhancement to mitigate for habitat effects resulting from the intakes
- tunnel construction under the San Joaquin River Deep Water Channel
- Head of Old River Barrier, an in-channel structure placed between federal project levees (part of the SJRFCP)
- barge landing on the San Joaquin River Deep Water Channel

A detailed hydraulic study per Corps' standards for Section 408 NEPA analysis is not available at this time. The informational requirements under the Section 408 process necessarily includes a detailed level of engineering design, as well as a detailed level of analysis related to effects to the Corp's civil works projects and indirect hydraulic effects. The information contained in the current CEQA/NEPA documents will not fully meet this level of detail and additional informational submittals and analysis may be necessary. As a result of these submittals, prior to final 408 permission, additional NEPA compliance by the Corps may be required. It is understood that the components of the project which would require 408 authorization cannot be approved under Section 404 of the Clean Water Act or Section 10 of the Rivers and Harbors Act until the 408 authorization is obtained.

OBJECTID *	LABEL	Type_Name	Cowardin	Acres	Description	Relative Condition	Impacting Feature	latitude	longitude
422	FO-1	Forest	PFO	0.156	narrow band along ag ditch	M	Work Area	38.41887	-121.5125
421	FO-2	Forest	PFO	0.092	narrow band along ag ditch	M	Work Area	38.41875	-121.5125
424	SS-1	Scrub-Shrub	PSS	0.054	narrow band along ag ditch	M	Work Area	38.4178	-121.5102
423	SS-2	Scrub-Shrub	PSS	0.049	narrow band along ag ditch	M	Work Area	38.41771	-121.5102
418	SS-3	Scrub-Shrub	PSS	0.097	narrow band along ag ditch	M	Work Area	38.41768	-121.5116
419	SS-4	Scrub-Shrub	PSS	0.052	narrow band along ag ditch	M	Work Area	38.41757	-121.5117
417	FO-3	Forest	PFO	0.033	narrow band along ag ditch	M	Work Area	38.41749	-121.5111
473	AD-1	Agricultural Ditch	R4	1.841	narrow-riparian vegetation	M	Work Area	38.41742	-121.5102
415	SS-5	Scrub-Shrub	PSS	0.289	narrow band along ag ditch	M	Work Area	38.41694	-121.5128
416	FO-4	Forest	PFO	0.813	narrow band along ag ditch	M	Work Area	38.41667	-121.5141
420	FO-5	Forest	PFO	0.244	narrow band along ag ditch	M	Work Area	38.41618	-121.5156
472	AD-2	Agricultural Ditch	R4	0.143	narrow-riparian vegetation	M	Reusable Tunnel Material	38.40861	-121.5072
664	TC-1	Tidal Channel	R1UB	2.309	Sacramento River	H	Intake	38.40533	-121.5145
667	TC-2	Tidal Channel	R1UB	11.903	Sacramento River	H	Work Area	38.40511	-121.5151
453	SS-6	Scrub-Shrub	PSS	0.084	medium wide along ditch	M	Transmission Line	38.40371	-121.508
363	AD-3	Agricultural Ditch	R4	0.016	narrow-riparian vegetation	M	Transmission Line	38.40364	-121.508
452	SS-7	Scrub-Shrub	PSS	0.042	medium wide along ditch	M	Transmission Line	38.40361	-121.508
75	DE-1	Depression	PUB	0.009	cutoff slough	H	Intake	38.39952	-121.5115
449	FO-6	Forest	PFO	0.111	along cutoff slough	H	Intake	38.39952	-121.5116
76	DE-2	Depression	PUB	0.099	cutoff slough	H	Work Area	38.39951	-121.5113
450	FO-7	Forest	PFO	0.103	along cutoff slough	H	Work Area	38.3995	-121.5113
77	DE-3	Depression	PUB	0.116	cutoff slough	H	Transmission Line	38.39946	-121.5087
451	FO-8	Forest	PFO	0.127	along cutoff slough	H	Transmission Line	38.39945	-121.5087
357	AD-4	Agricultural Ditch	R4	0.046	narrow-little vegetation	L	Concrete Batch Plant	38.38247	-121.5157
358	AD-5	Agricultural Ditch	R4	0.014	narrow-little vegetation	L	Work Area	38.38223	-121.516
663	TC-4	Tidal Channel	R1UB	1.633	Sacramento River	H	Intake	38.38203	-121.5199
355	AD-6	Agricultural Ditch	R4	0.138	narrow-little vegetation	L	Intake	38.38152	-121.517
356	AD-7	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Intake	38.3815	-121.517
666	TC-3	Tidal Channel	R1UB	9.188	Sacramento River	H	Work Area	38.38021	-121.5202
361	AD-8	Agricultural Ditch	R4	0.047	narrow-little vegetation	L	Work Area	38.37974	-121.5137
359	AD-9	Agricultural Ditch	R4	0.201	narrow-little vegetation	L	Intake	38.3797	-121.5158
360	AD-10	Agricultural Ditch	R4	0.085	narrow-little vegetation	L	Work Area	38.37818	-121.5162
362	AD-11	Agricultural Ditch	R4	0.238	narrow-little vegetation	L	Transmission Line	38.37688	-121.5148
412	SS-8	Scrub-Shrub	PSS	0.291	along Sacramento River	H	Work Area	38.37304	-121.522
409	FO-9	Forest	PFO	0.385	along Sacramento River	H	Work Area	38.37188	-121.5216
487	EM-1	Emergent Wetland	PEM	0.292	along cutoff slough	H	Transmission Line	38.36516	-121.5131
354	AD-12	Agricultural Ditch	R4	0.116	narrow-riparian vegetation	M	Work Area	38.36247	-121.5116
353	AD-13	Agricultural Ditch	R4	0.061	narrow-riparian vegetation	M	Transmission Line	38.35815	-121.5168
411	SS-9	Scrub-Shrub	PSS	1.350	along Sacramento River	H	Work Area	38.35452	-121.5287
665	TC-5	Tidal Channel	R1UB	7.978	Sacramento River	H	Work Area	38.35244	-121.5313
410	SS-10	Scrub-Shrub	PSS	1.521	along Sacramento River	H	Intake	38.35216	-121.5311
471	AD-14	Agricultural Ditch	R4	0.042	narrow-little vegetation	L	Transmission Line	38.35122	-121.5166
662	TC-6	Tidal Channel	R1UB	2.107	Sacramento River	H	Intake	38.35047	-121.533
464	AD-15	Agricultural Ditch	R4	0.125	narrow-little vegetation	L	Intake	38.34944	-121.5283
413	SS-11	Scrub-Shrub	PSS	0.070	along Sacramento River	H	Intake	38.34857	-121.535
414	SS-12	Scrub-Shrub	PSS	0.090	along Sacramento River	H	Work Area	38.34846	-121.5352
466	AD-16	Agricultural Ditch	R4	0.181	narrow-little vegetation	L	Work Area	38.34799	-121.5279
467	AD-17	Agricultural Ditch	R4	0.017	narrow-little vegetation	L	Work Area	38.34655	-121.5293
465	AD-18	Agricultural Ditch	R4	0.028	narrow-little vegetation	L	Work Area	38.34622	-121.5296
84	FO-10	Forest	PFO	0.059	along Snodgrass Slough	H	Work Area	38.34514	-121.536
470	AD-19	Agricultural Ditch	R4	0.060	narrow-little vegetation	L	Transmission Line	38.34427	-121.5263
468	AD-20	Agricultural Ditch	R4	0.049	narrow-little vegetation	L	Transmission Line	38.34302	-121.5167
469	AD-21	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	38.33526	-121.5184
351	AD-22	Agricultural Ditch	R4	0.032	narrow-little vegetation	L	Transmission Line	38.32908	-121.3744
352	AD-23	Agricultural Ditch	R4	0.037	narrow-little vegetation	L	Transmission Line	38.32751	-121.5176
350	AD-24	Agricultural Ditch	R4	0.031	narrow-little vegetation	L	Transmission Line	38.32618	-121.3781
349	AD-25	Agricultural Ditch	R4	0.033	narrow-riparian vegetation	M	Transmission Line	38.32199	-121.3898
347	AD-26	Agricultural Ditch	R4	0.549	narrow-some vegetation	L	Transmission Line	38.32198	-121.3862
90	DE-4	Depression	PUB	0.001	degraded	L	Transmission Line	38.32174	-121.3944
348	AD-27	Agricultural Ditch	R4	0.009	narrow-some vegetation	L	Transmission Line	38.32165	-121.3997
346	AD-28	Agricultural Ditch	R4	0.050	narrow-some vegetation	L	Transmission Line	38.32153	-121.3957
345	AD-29	Agricultural Ditch	R4	0.068	narrow-some vegetation	L	Transmission Line	38.32149	-121.3985
89	EM-2	Emergent Wetland	PEM	0.155	in ag field	L	Transmission Line	38.32148	-121.3944
344	AD-30	Agricultural Ditch	R4	0.005	narrow-little vegetation	L	Transmission Line	38.32133	-121.4001
490	AD-31	Agricultural Ditch	R4	0.021	narrow-little vegetation	L	Transmission Line	38.32119	-121.4111
489	EM-3	Emergent Wetland	PEM	0.063	narrow band along ag ditch	M	Transmission Line	38.32106	-121.4237
488	AD-32	Agricultural Ditch	R4	0.236	narrow-little vegetation	L	Transmission Line	38.32102	-121.4305
342	AD-33	Agricultural Ditch	R4	0.491	narrow-some vegetation	L	Transmission Line	38.32094	-121.4308
343	AD-34	Agricultural Ditch	R4	0.097	narrow-some vegetation	L	Transmission Line	38.32093	-121.4358
341	AD-35	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	38.32067	-121.4389
340	AD-36	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	38.32056	-121.4442
91	EM-4	Emergent Wetland	PEM	0.020	degraded	L	Transmission Line	38.32056	-121.4704
339	AD-37	Agricultural Ditch	R4	0.008	narrow-little vegetation	L	Transmission Line	38.32054	-121.4387
485	AD-38	Agricultural Ditch	R4	1.597	narrow-little vegetation	L	Transmission Line	38.32048	-121.4684
10	FO-11	Forest	PFO	0.637	along Snodgrass Slough	H	Transmission Line	38.32034	-121.498
432	SS-13	Scrub-Shrub	PSS	0.192	medium wide along ditch	M	Transmission Line	38.32031	-121.4961
385	EM-5	Emergent Wetland	PEM	0.183	along Snodgrass Slough	H	Transmission Line	38.32029	-121.5008
8	DE-5	Depression	PUB	0.072	pond with some vegetation	M	Transmission Line	38.32028	-121.5032
9	FO-13	Forest	PFO	0.723	along Snodgrass Slough	H	Transmission Line	38.32025	-121.5009
431	SS-14	Scrub-Shrub	PSS	0.146	along ag ditch	L	Transmission Line	38.32024	-121.4961
426	EM-6	Emergent Wetland	PEM	0.225	pond with some vegetation	M	Transmission Line	38.32023	-121.5031
427	FO-12	Forest	PFO	0.345	along Snodgrass Slough	H	Transmission Line	38.32019	-121.4993

1	FO-14	Forest	PFO	0.059	along Snodgrass Slough	H	Transmission Line	38.32013	-121.5022
661	TC-7	TIdal Channel	R1UB	2.227	Snodgrass Slough	H	Transmission Line	38.31781	-121.5012
337	AD-40	Agricultural Ditch	R4	0.246	narrow-little vegetation	L	Reusable Tunnel Material	38.31509	-121.4972
338	AD-42	Agricultural Ditch	R4	0.106	narrow-little vegetation	L	Transmission Line	38.31467	-121.5105
462	AD-39	Agricultural Ditch	R4	0.573	narrow-riparian vegetation	M	Transmission Line	38.31385	-121.493
461	AD-41	Agricultural Ditch	R4	0.196	narrow-little vegetation	L	Reusable Tunnel Material	38.31381	-121.496
386	EM-7	Emergent Wetland	PEM	0.171	edge of I-5 pond	H	Reusable Tunnel Material	38.30399	-121.4886
486	EM-8	Emergent Wetland	PEM	0.163	adjacent to I-5 pond	H	Reusable Tunnel Material	38.30377	-121.4877
336	AD-43	Agricultural Ditch	R4	0.024	narrow-little vegetation	L	Transmission Line	38.30258	-121.5038
2	DE-6	Depression	PUB	11.064	I-5 pond	H	Reusable Tunnel Material	38.30185	-121.4866
3	EM-9	Emergent Wetland	PEM	0.043	edge of I-5 pond	H	Reusable Tunnel Material	38.29979	-121.4845
335	AD-44	Agricultural Ditch	R4	0.035	narrow-little vegetation	L	Transmission Line	38.29842	-121.5016
11	FO-15	Forest	PFO	0.016	narrow band-forest	M	Transmission Line	38.29449	-121.4992
430	FO-16	Forest	PFO	0.177	narrow band-forest	M	Transmission Line	38.29382	-121.499
333	AD-45	Agricultural Ditch	R4	0.014	medium-riparian	M	Transmission Line	38.29346	-121.499
429	FO-17	Forest	PFO	0.083	narrow band-forest	M	Transmission Line	38.29328	-121.4989
631	TC-8	Tidal Channel	R1UB	1.514	cutoff slough	H	Transmission Line	38.29316	-121.4986
12	FO-18	Forest	PFO	0.686	narrow band-forest	M	Transmission Line	38.29231	-121.4982
367	EM-10	Emergent Wetland	PEM	0.010	edge of I-5 pond	H	Reusable Tunnel Material	38.289	-121.4757
428	FO-19	Forest	PFO	0.504	narrow band-forest	M	Reusable Tunnel Material	38.28862	-121.4983
14	SS-15	Scrub-Shrub	PSS	0.009	edge I-5 pond	H	Reusable Tunnel Material	38.28759	-121.4757
460	AD-47	Agricultural Ditch	R4	0.005	narrow-riparian vegetation	M	Fuel Station	38.28716	-121.4902
459	AD-48	Agricultural Ditch	R4	0.046	narrow-riparian vegetation	M	Forebay/Spillway	38.28677	-121.4954
458	AD-49	Agricultural Ditch	R4	0.008	narrow-riparian vegetation	M	Forebay/Spillway	38.28672	-121.4961
456	AD-46	Agricultural Ditch	R4	0.124	narrow-riparian vegetation	M	Concrete Batch Plant	38.28653	-121.4874
15	FO-20	Forest	PFO	0.511	narrow band-forest	M	Reusable Tunnel Material	38.28645	-121.4736
13	DE-7	Depression	PUB	11.711	I-5 pond	H	Reusable Tunnel Material	38.28641	-121.4741
334	AD-50	Agricultural Ditch	R4	0.014	narrow-little vegetation	L	Tunnel Conveyor	38.28405	-121.4764
463	AD-51	Agricultural Ditch	R4	0.660	narrow-little vegetation	L	Tunnel Conveyor	38.284	-121.4806
331	AD-52	Agricultural Ditch	R4	0.234	narrow-little vegetation	L	Tunnel Conveyor	38.28389	-121.4782
332	AD-53	Agricultural Ditch	R4	0.347	medium-riparian	M	Reusable Tunnel Material	38.28278	-121.4695
16	FO-21	Forest	PFO	0.119	medium wide along ditch	M	Reusable Tunnel Material	38.28265	-121.4698
82	FO-22	Forest	PFO	0.338	along cutoff slough	H	Reusable Tunnel Material	38.28198	-121.4972
425	EM-11	Emergent Wetland	PEM	1.852	levee on one side	M	Reusable Tunnel Material	38.28165	-121.4978
7	DE-8	Depression	PUB	0.190	ponded area in marsh	H	Reusable Tunnel Material	38.28163	-121.4975
19	FO-23	Forest	PFO	0.199	narrow band-forest	M	Reusable Tunnel Material	38.28128	-121.47
6	FO-24	Forest	PFO	0.092	along Snodgrass Slough	H	Barge Unloading Facility	38.28118	-121.498
365	FO-25	Forest	PFO	0.330	levee on one side, marsh/water other	M	Reusable Tunnel Material	38.28112	-121.4974
660	TC-9	TIdal Channel	R1UB	0.593	Snodgrass Slough	H	Barge Unloading Facility	38.28103	-121.4982
330	AD-54	Agricultural Ditch	R4	0.199	narrow-little vegetation	L	Reusable Tunnel Material	38.28089	-121.4704
366	EM-12	Emergent Wetland	PEM	0.009	levee on one side, forest on other	M	Reusable Tunnel Material	38.28076	-121.4971
5	FO-26	Forest	PFO	0.057	along Snodgrass Slough	H	Reusable Tunnel Material	38.28075	-121.4973
630	TC-10	Tidal Channel	R1UB	0.008	cutoff slough	H	Reusable Tunnel Material	38.28061	-121.4967
83	FO-27	Forest	PFO	0.038	along cutoff slough	H	Reusable Tunnel Material	38.28047	-121.4963
4	FO-28	Forest	PFO	0.013	along Snodgrass Slough	H	Reusable Tunnel Material	38.28034	-121.4963
17	DE-9	Depression	PUB	5.664	I-5 pond	H	Reusable Tunnel Material	38.2803	-121.4692
18	EM-13	Emergent Wetland	PEM	0.921	edge of I-5 pond	H	Reusable Tunnel Material	38.2795	-121.4689
457	AD-57	Agricultural Ditch	R4	1.058	narrow-riparian vegetation	M	Forebay/Spillway	38.27937	-121.4899
329	AD-55	Agricultural Ditch	R4	0.021	narrow-some vegetation	L	Reusable Tunnel Material	38.27858	-121.4667
436	FO-29	Forest	PFO	1.207	along Snodgrass Slough	H	Reusable Tunnel Material	38.27618	-121.4662
328	AD-56	Agricultural Ditch	R4	0.348	narrow-some vegetation	L	Reusable Tunnel Material	38.27614	-121.468
20	LA-1	Lake	L1UB	23.241	I-5 pond	H	Reusable Tunnel Material	38.27456	-121.4646
435	FO-30	Forest	PFO	0.166	edge of I-5 pond	H	Reusable Tunnel Material	38.27328	-121.4628
327	AD-58	Agricultural Ditch	R4	0.154	medium-little vegetation	L	Work Area	38.25256	-121.4826
326	AD-59	Agricultural Ditch	R4	0.011	narrow-some vegetation	L	Work Area	38.21318	-121.5014
325	AD-60	Agricultural Ditch	R4	0.149	narrow-little vegetation	L	Work Area	38.21178	-121.4984
324	AD-61	Agricultural Ditch	R4	0.006	narrow-some vegetation	L	Work Area	38.18282	-121.5096
491	EM-14	Emergent Wetland	PEM	1.213	in ag field	L	Work Area	38.18137	-121.5069
321	AD-62	Agricultural Ditch	R4	0.038	narrow-some vegetation	L	Shaft Location/Access Road	38.14921	-121.516
322	AD-63	Agricultural Ditch	R4	0.057	narrow-some vegetation	L	Work Area	38.14921	-121.516
323	AD-64	Agricultural Ditch	R4	0.023	medium-some vegetation	L	Shaft Location/Access Road	38.14906	-121.5186
320	AD-65	Agricultural Ditch	R4	0.087	narrow-little vegetation	L	Work Area	38.12584	-121.527
572	SW-1	Seasonal Wetland	PEM	5.080	in ag field	L	Road Interchange	38.11398	-121.5364
573	SW-2	Seasonal Wetland	PEM	3.826	in ag field	L	Road Interchange	38.11382	-121.5333
626	AD-67	Agricultural Ditch	R4	0.122	narrow-little vegetation	L	Road Interchange	38.11316	-121.5378
627	AD-66	Agricultural Ditch	R4	0.224	narrow-little vegetation	L	Road Interchange	38.11304	-121.533
628	AD-68	Agricultural Ditch	R4	0.202	narrow-little vegetation	L	Road Interchange	38.11271	-121.5362
571	SW-3	Seasonal Wetland	PEM	0.016	in ag field	L	Road Interchange	38.10925	-121.5349
629	AD-69	Agricultural Ditch	R4	0.006	narrow-little vegetation	L	Shaft Location/Access Road	38.10766	-121.5394
625	AD-70	Agricultural Ditch	R4	0.006	narrow-little vegetation	L	Shaft Location/Access Road	38.10708	-121.5401
593	EM-15	Emergent Wetland	PEM	2.929	in ag field	L	Concrete Batch Plant	38.10202	-121.5414
592	EM-16	Emergent Wetland	PEM	0.155	in ag field	L	Shaft Location/Access Road	38.10118	-121.5425
578	AD-71	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Shaft Location/Access Road	38.1009	-121.5425
591	EM-17	Emergent Wetland	PEM	1.765	in ag field	L	Reusable Tunnel Material	38.10023	-121.5404
621	AD-72	Agricultural Ditch	R4	0.028	narrow-little vegetation	L	Reusable Tunnel Material	38.1002	-121.5431
570	SW-4	Seasonal Wetland	PEM	2.469	in ag field	L	Reusable Tunnel Material	38.0999	-121.5408
623	AD-73	Agricultural Ditch	R4	0.057	narrow-little vegetation	L	Shaft Location/Access Road	38.0992	-121.543
624	AD-74	Agricultural Ditch	R4	0.019	narrow-little vegetation	L	Shaft Location/Access Road	38.0983	-121.5429
569	SW-5	Seasonal Wetland	PEM	0.861	in ag field	L	Reusable Tunnel Material	38.09732	-121.4997
622	AD-75	Agricultural Ditch	R4	0.068	narrow-little vegetation	L	Reusable Tunnel Material	38.09727	-121.5429
619	AD-76	Agricultural Ditch	R4	0.448	narrow-little vegetation	L	Reusable Tunnel Material	38.09631	-121.5035
588	EM-18	Emergent Wetland	PEM	0.104	in ag field	L	Reusable Tunnel Material	38.09542	-121.543
590	EM-19	Emergent Wetland	PEM	0.808	in ag field	L	Reusable Tunnel Material	38.09534	-121.5426

529	SW-6	Seasonal Wetland	PEM	10.424	in ag field	L	Reusable Tunnel Material	38.09518	-121.5233
589	EM-20	Emergent Wetland	PEM	2.909	in ag field	L	Reusable Tunnel Material	38.09509	-121.5419
565	SW-7	Seasonal Wetland	PEM	1.789	in ag field	L	Reusable Tunnel Material	38.09452	-121.5338
613	AD-77	Agricultural Ditch	R4	0.112	narrow-some vegetation	L	Reusable Tunnel Material	38.09438	-121.5315
567	SW-8	Seasonal Wetland	PEM	8.036	in ag field	L	Reusable Tunnel Material	38.09422	-121.5359
612	AD-78	Agricultural Ditch	R4	0.124	narrow-some vegetation	L	Reusable Tunnel Material	38.09421	-121.5276
616	AD-79	Agricultural Ditch	R4	0.146	narrow-some vegetation	L	Reusable Tunnel Material	38.0942	-121.5296
620	AD-84	Agricultural Ditch	R4	0.351	narrow-little vegetation	L	Reusable Tunnel Material	38.09415	-121.511
617	AD-80	Agricultural Ditch	R4	0.167	narrow-some vegetation	L	Reusable Tunnel Material	38.09394	-121.5255
564	SW-9	Seasonal Wetland	PEM	0.319	in ag field	L	Reusable Tunnel Material	38.09381	-121.5093
618	AD-81	Agricultural Ditch	R4	0.189	narrow-little vegetation	L	Reusable Tunnel Material	38.09367	-121.5216
566	SW-11	Seasonal Wetland	PEM	9.487	in ag field	L	Reusable Tunnel Material	38.09359	-121.5027
611	AD-82	Agricultural Ditch	R4	0.123	narrow-some vegetation	L	Reusable Tunnel Material	38.09359	-121.5235
568	SW-10	Seasonal Wetland	PEM	34.256	in ag field	L	Reusable Tunnel Material	38.09356	-121.5171
615	AD-83	Agricultural Ditch	R4	0.204	narrow-some vegetation	L	Reusable Tunnel Material	38.09352	-121.5371
561	SW-13	Seasonal Wetland	PEM	0.326	in ag field	L	Reusable Tunnel Material	38.09286	-121.529
560	SW-12	Seasonal Wetland	PEM	0.900	in ag field	L	Reusable Tunnel Material	38.09283	-121.5102
562	SW-14	Seasonal Wetland	PEM	0.850	in ag field	L	Reusable Tunnel Material	38.0928	-121.5302
563	SW-16	Seasonal Wetland	PEM	1.100	in ag field	L	Reusable Tunnel Material	38.09277	-121.5141
558	SW-15	Seasonal Wetland	PEM	0.260	in ag field	L	Reusable Tunnel Material	38.09273	-121.5316
587	EM-21	Emergent Wetland	PEM	0.429	in ag field	L	Reusable Tunnel Material	38.09255	-121.5007
614	AD-85	Agricultural Ditch	R4	0.246	narrow-little vegetation	L	Reusable Tunnel Material	38.09226	-121.5057
586	EM-22	Emergent Wetland	PEM	0.290	in ag field	L	Reusable Tunnel Material	38.09212	-121.5023
556	SW-17	Seasonal Wetland	PEM	0.633	in ag field	L	Reusable Tunnel Material	38.09202	-121.5123
557	SW-18	Seasonal Wetland	PEM	3.582	in ag field	L	Reusable Tunnel Material	38.09182	-121.5184
555	SW-19	Seasonal Wetland	PEM	0.216	in ag field	L	Reusable Tunnel Material	38.09171	-121.526
559	SW-24	Seasonal Wetland	PEM	5.640	in ag field	L	Reusable Tunnel Material	38.09135	-121.5351
553	SW-20	Seasonal Wetland	PEM	0.347	in ag field	L	Reusable Tunnel Material	38.09128	-121.5138
552	SW-21	Seasonal Wetland	PEM	0.602	in ag field	L	Reusable Tunnel Material	38.09122	-121.5238
554	SW-22	Seasonal Wetland	PEM	1.299	in ag field	L	Reusable Tunnel Material	38.09116	-121.5224
551	SW-23	Seasonal Wetland	PEM	0.918	in ag field	L	Reusable Tunnel Material	38.09085	-121.5241
550	SW-25	Seasonal Wetland	PEM	0.298	in ag field	L	Reusable Tunnel Material	38.09071	-121.5215
577	AD-86	Agricultural Ditch	R4	2.794	narrow-little vegetation	L	Reusable Tunnel Material	38.09063	-121.5137
585	EM-23	Emergent Wetland	PEM	0.742	in ag field	L	Reusable Tunnel Material	38.09024	-121.5362
548	SW-26	Seasonal Wetland	PEM	0.550	in ag field	L	Reusable Tunnel Material	38.09017	-121.5208
547	SW-27	Seasonal Wetland	PEM	0.724	in ag field	L	Reusable Tunnel Material	38.09008	-121.5183
546	SW-28	Seasonal Wetland	PEM	0.313	in ag field	L	Reusable Tunnel Material	38.08979	-121.5375
549	SW-29	Seasonal Wetland	PEM	3.637	in ag field	L	Reusable Tunnel Material	38.08947	-121.5444
581	EM-24	Emergent Wetland	PEM	2.576	in ag field	L	Reusable Tunnel Material	38.08842	-121.5444
580	EM-25	Emergent Wetland	PEM	5.478	in ag field	L	Reusable Tunnel Material	38.08809	-121.5049
545	SW-30	Seasonal Wetland	PEM	3.152	in ag field	L	Reusable Tunnel Material	38.08801	-121.5169
650	TC-11	Tidal Channel	R1UB	1.211	Potato Slough	H	Reusable Tunnel Material	38.08779	-121.5447
652	TC-12	Tidal Channel	R1UB	4.965	Potato Slough	H	Barge Unloading Facility	38.08766	-121.5453
583	EM-26	Emergent Wetland	PEM	0.419	in ag field	L	Reusable Tunnel Material	38.08749	-121.5427
582	EM-28	Emergent Wetland	PEM	4.659	in ag field	L	Reusable Tunnel Material	38.08724	-121.5405
584	EM-27	Emergent Wetland	PEM	0.024	in ag field	L	Transmission Line	38.08724	-121.5425
544	SW-31	Seasonal Wetland	PEM	0.451	in ag field	L	Reusable Tunnel Material	38.08715	-121.5078
651	TC-13	Tidal Channel	R1UB	0.131	Potato Slough	H	Reusable Tunnel Material	38.08678	-121.5427
543	SW-32	Seasonal Wetland	PEM	1.640	in ag field	L	Reusable Tunnel Material	38.08615	-121.5149
542	SW-33	Seasonal Wetland	PEM	1.099	in ag field	L	Reusable Tunnel Material	38.08479	-121.506
55	EM-29	Emergent Wetland	PEM	2.868	on instream island	H	Transmission Line	38.0842	-121.5426
540	SW-34	Seasonal Wetland	PEM	0.244	in ag field	L	Reusable Tunnel Material	38.08392	-121.5077
541	SW-35	Seasonal Wetland	PEM	0.838	in ag field	L	Reusable Tunnel Material	38.08379	-121.5129
609	AD-88	Agricultural Ditch	R4	0.080	narrow-some vegetation	L	Reusable Tunnel Material	38.08332	-121.506
653	TC-14	Tidal Channel	R1UB	5.025	Potato Slough	H	Transmission Line	38.08319	-121.5427
610	AD-87	Agricultural Ditch	R4	0.594	narrow-some vegetation	L	Reusable Tunnel Material	38.0831	-121.5074
538	SW-36	Seasonal Wetland	PEM	0.608	in ag field	L	Reusable Tunnel Material	38.0829	-121.5127
539	SW-37	Seasonal Wetland	PEM	3.586	in ag field	L	Reusable Tunnel Material	38.08246	-121.51
608	AD-89	Agricultural Ditch	R4	0.040	narrow-some vegetation	L	Reusable Tunnel Material	38.08063	-121.5049
492	SW-38	Seasonal Wetland	PEM	0.430	in ag field	L	Transmission Line	38.0798	-121.5427
607	AD-90	Agricultural Ditch	R4	0.065	narrow-some vegetation	L	Reusable Tunnel Material	38.07961	-121.5064
319	AD-91	Agricultural Ditch	R4	0.040	narrow-some vegetation	L	Transmission Line	38.07956	-121.5427
579	EM-30	Emergent Wetland	PEM	0.013	in ag field	L	Reusable Tunnel Material	38.07955	-121.5025
536	SW-39	Seasonal Wetland	PEM	0.275	in ag field	L	Reusable Tunnel Material	38.07922	-121.5043
537	SW-40	Seasonal Wetland	PEM	0.942	in ag field	L	Reusable Tunnel Material	38.07922	-121.5077
535	SW-41	Seasonal Wetland	PEM	0.608	in ag field	L	Reusable Tunnel Material	38.0784	-121.5081
606	AD-92	Agricultural Ditch	R4	0.097	narrow-some vegetation	L	Reusable Tunnel Material	38.07821	-121.5056
318	AD-93	Agricultural Ditch	R4	0.155	narrow-some vegetation	L	Transmission Line	38.07798	-121.5428
534	SW-42	Seasonal Wetland	PEM	0.611	in ag field	L	Reusable Tunnel Material	38.07764	-121.5077
533	SW-43	Seasonal Wetland	PEM	0.227	in ag field	L	Reusable Tunnel Material	38.07756	-121.5071
532	SW-44	Seasonal Wetland	PEM	0.165	in ag field	L	Reusable Tunnel Material	38.07735	-121.5038
605	AD-94	Agricultural Ditch	R4	0.092	narrow-some vegetation	L	Reusable Tunnel Material	38.07699	-121.5052
493	SW-45	Seasonal Wetland	PEM	0.226	in ag field	L	Transmission Line	38.07697	-121.5425
531	SW-46	Seasonal Wetland	PEM	0.076	in ag field	L	Reusable Tunnel Material	38.07674	-121.504
317	AD-95	Agricultural Ditch	R4	0.056	medium-some vegetation	L	Transmission Line	38.07644	-121.5427
604	AD-96	Agricultural Ditch	R4	0.065	narrow-little vegetation	L	Reusable Tunnel Material	38.07612	-121.505
316	AD-97	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	38.07561	-121.5427
315	AD-98	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	38.07494	-121.5427
494	SW-47	Seasonal Wetland	PEM	0.279	in ag field	L	Transmission Line	38.07419	-121.5427
530	SW-48	Seasonal Wetland	PEM	1.255	in ag field	L	Reusable Tunnel Material	38.07397	-121.504
310	AD-100	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	38.07383	-121.5427
314	AD-99	Agricultural Ditch	R4	0.117	narrow-some vegetation	L	Transmission Line	38.07234	-121.5427
496	SW-49	Seasonal Wetland	PEM	0.053	in ag field	L	Transmission Line	38.07118	-121.5428

497	SW-50	Seasonal Wetland	PEM	0.025	in ag field	L	Transmission Line	38.07076	-121.5429
495	SW-51	Seasonal Wetland	PEM	0.022	in ag field	L	Work Area	38.06999	-121.5444
500	SW-52	Seasonal Wetland	PEM	0.242	in ag field	L	Work Area	38.06967	-121.5441
498	SW-53	Seasonal Wetland	PEM	0.130	in ag field	L	Work Area	38.06966	-121.5423
499	SW-54	Seasonal Wetland	PEM	0.009	in ag field	L	Work Area	38.06964	-121.5424
311	AD-103	Agricultural Ditch	R4	0.025	narrow-some vegetation	L	Work Area	38.06963	-121.5423
313	AD-101	Agricultural Ditch	R4	0.045	narrow-some vegetation	L	Work Area	38.06963	-121.5427
312	AD-102	Agricultural Ditch	R4	0.129	narrow-some vegetation	L	Work Area	38.06963	-121.5437
501	SW-55	Seasonal Wetland	PEM	0.372	in ag field	L	Work Area	38.06933	-121.544
502	SW-56	Seasonal Wetland	PEM	0.458	in ag field	L	Work Area	38.06903	-121.544
306	AD-104	Agricultural Ditch	R4	0.012	narrow-some vegetation	L	Work Area	38.06891	-121.5423
308	AD-105	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Work Area	38.06891	-121.5427
307	AD-106	Agricultural Ditch	R4	0.064	narrow-some vegetation	L	Work Area	38.0689	-121.5437
504	SW-58	Seasonal Wetland	PEM	0.392	in ag field	L	Work Area	38.06877	-121.5437
503	SW-57	Seasonal Wetland	PEM	0.177	in ag field	L	Work Area	38.06877	-121.5443
305	AD-107	Agricultural Ditch	R4	0.006	narrow-some vegetation	L	Work Area	38.0681	-121.541
309	AD-108	Agricultural Ditch	R4	0.027	narrow-some vegetation	L	Transmission Line	38.06747	-121.5416
304	AD-109	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	38.0671	-121.5413
645	TC-15	Tidal Channel	R1UB	1.479	San Joaquin	H	Barge Unloading Facility	38.06682	-121.5403
646	TC-16	Tidal Channel	R1UB	0.878	San Joaquin	H	Barge Unloading Facility	38.06649	-121.5408
644	TC-17	Tidal Channel	R1UB	3.412	San Joaquin	H	Barge Unloading Facility	38.06589	-121.5419
388	FO-31	Forest	PFO	0.815	on instream island	H	Transmission Line	38.06347	-121.539
647	TC-18	Tidal Channel	R1UB	5.975	San Joaquin	H	Transmission Line	38.06124	-121.5411
56	EM-31	Emergent Wetland	PEM	7.570	on instream island	H	Transmission Line	38.06102	-121.5401
303	AD-110	Agricultural Ditch	R4	0.073	narrow-some vegetation	L	Transmission Line	38.05504	-121.5437
505	SS-16	Scrub-Shrub	PSS	2.317	duck club?	M	Transmission Line	38.05388	-121.5437
506	SW-59	Seasonal Wetland	PEM	2.104	in ag field	L	Transmission Line	38.04881	-121.5437
302	AD-111	Agricultural Ditch	R4	0.039	narrow-some vegetation	L	Transmission Line	38.04796	-121.5437
508	SW-60	Seasonal Wetland	PEM	2.848	in ag field	L	Transmission Line	38.04677	-121.5437
300	AD-112	Agricultural Ditch	R4	0.038	narrow-some vegetation	L	Transmission Line	38.04559	-121.5437
507	SW-61	Seasonal Wetland	PEM	0.891	in ag field	L	Transmission Line	38.04522	-121.5437
301	AD-113	Agricultural Ditch	R4	0.087	wide-some vegetation	L	Transmission Line	38.04448	-121.5437
510	EM-32	Emergent Wetland	PEM	0.080	in ag field	L	Transmission Line	38.04411	-121.5435
509	AD-114	Agricultural Ditch	R4	0.030	narrow-some vegetation	L	Transmission Line	38.04406	-121.5436
441	EM-33	Emergent Wetland	PEM	0.003	duck club?	M	Transmission Line	38.04331	-121.5435
443	EM-34	Emergent Wetland	PEM	0.592	duck club?	M	Work Area	38.04287	-121.5433
444	EM-36	Emergent Wetland	PEM	0.537	duck club?	M	Work Area	38.04287	-121.5436
518	FO-32	Forest	PFO	1.055	duck club?	M	Work Area	38.04282	-121.5425
442	EM-35	Emergent Wetland	PEM	0.261	duck club?	M	Work Area	38.04274	-121.5443
299	AD-115	Agricultural Ditch	R4	0.126	narrow-riparian vegetation	M	Work Area	38.04266	-121.5425
656	TC-19	Tidal Channel	R1UB	0.689	Middle River	H	Barge Unloading Facility	38.04265	-121.5318
440	EM-37	Emergent Wetland	PEM	0.152	duck club?	M	Work Area	38.0424	-121.5427
68	DE-10	Depression	PUB	1.132	duck club?	M	Work Area	38.04227	-121.5442
70	DE-11	Depression	PUB	1.889	duck club?	M	Work Area	38.04202	-121.5437
69	DE-12	Depression	PUB	2.741	duck club?	M	Work Area	38.042	-121.543
437	EM-38	Emergent Wetland	PEM	0.017	duck club?	M	Work Area	38.04182	-121.5422
439	EM-39	Emergent Wetland	PEM	0.020	duck club?	M	Work Area	38.04175	-121.5441
67	DE-13	Depression	PUB	0.345	duck club?	M	Transmission Line	38.04104	-121.5438
298	AD-116	Agricultural Ditch	R4	0.167	narrow-riparian vegetation	M	Work Area	38.04061	-121.541
71	DE-14	Depression	PUB	0.188	duck club?	M	Transmission Line	38.03997	-121.5439
297	AD-117	Agricultural Ditch	R4	0.005	narrow-little vegetation	L	Work Area	38.03965	-121.5347
519	FO-33	Forest	PFO	0.301	narrow band along ag ditch	M	Work Area	38.03869	-121.5396
438	EM-40	Emergent Wetland	PEM	5.875	duck club?	M	Transmission Line	38.03851	-121.5437
296	AD-118	Agricultural Ditch	R4	0.195	narrow-riparian vegetation	M	Work Area	38.03777	-121.5389
295	AD-119	Agricultural Ditch	R4	0.023	narrow-riparian vegetation	M	Transmission Line	38.03613	-121.5438
513	EM-41	Emergent Wetland	PEM	0.575	duck club?	M	Transmission Line	38.03571	-121.5437
294	AD-120	Agricultural Ditch	R4	0.029	narrow-some vegetation	L	Transmission Line	38.03235	-121.5438
293	AD-121	Agricultural Ditch	R4	0.024	narrow-some vegetation	L	Transmission Line	38.02982	-121.5438
512	EM-42	Emergent Wetland	PEM	0.309	duck club?	M	Transmission Line	38.02946	-121.5439
292	AD-122	Agricultural Ditch	R4	0.031	narrow-riparian vegetation	M	Transmission Line	38.02933	-121.5439
511	EM-43	Emergent Wetland	PEM	2.462	duck club?	M	Transmission Line	38.02822	-121.5438
291	AD-123	Agricultural Ditch	R4	0.035	narrow-riparian vegetation	M	Transmission Line	38.02716	-121.5438
447	DE-15	Depression	PUB	0.312	duck club?	M	Transmission Line	38.02685	-121.5438
445	EM-44	Emergent Wetland	PEM	4.272	duck club?	M	Transmission Line	38.02508	-121.5439
446	DE-16	Depression	PUB	0.158	duck club?	M	Transmission Line	38.02358	-121.544
290	AD-124	Agricultural Ditch	R4	0.029	narrow-riparian vegetation	M	Transmission Line	38.02313	-121.5439
455	FO-34	Forest	PFO	0.084	narrow band along ag ditch	M	Transmission Line	38.02308	-121.5439
288	AD-125	Agricultural Ditch	R4	0.008	narrow-little vegetation	L	Transmission Line	38.02272	-121.5441
289	AD-126	Agricultural Ditch	R4	0.035	narrow-little vegetation	L	Transmission Line	38.02073	-121.5439
287	AD-127	Agricultural Ditch	R4	0.034	narrow-riparian vegetation	M	Transmission Line	38.01865	-121.5439
454	FO-35	Forest	PFO	0.196	narrow band along ag ditch	M	Transmission Line	38.01856	-121.5439
286	AD-128	Agricultural Ditch	R4	0.030	narrow-little vegetation	L	Transmission Line	38.01644	-121.544
515	SW-62	Seasonal Wetland	PEM	3.330	in ag field	L	Transmission Line	38.01385	-121.544
284	AD-129	Agricultural Ditch	R4	0.039	narrow-some vegetation	L	Transmission Line	38.0126	-121.5439
514	SW-63	Seasonal Wetland	PEM	0.141	in ag field	L	Transmission Line	38.01235	-121.5438
285	AD-130	Agricultural Ditch	R4	0.095	medium-some vegetation	L	Transmission Line	38.01168	-121.5439
517	SW-64	Seasonal Wetland	PEM	0.555	in ag field	L	Transmission Line	38.01012	-121.544
516	SW-65	Seasonal Wetland	PEM	0.124	in ag field	L	Transmission Line	38.0099	-121.5438
283	AD-131	Agricultural Ditch	R4	0.024	narrow-little vegetation	L	Transmission Line	38.00978	-121.544
659	TC-24	Tidal Channel	R1UB	4.194	Middle River	H	Work Area	38.00878	-121.5229
448	EM-45	Emergent Wetland	PEM	0.071	on instream island	H	Transmission Line	38.00761	-121.5438
658	TC-20	Tidal Channel	R1UB	4.633	Connection Slough	H	Transmission Line	38.00707	-121.544

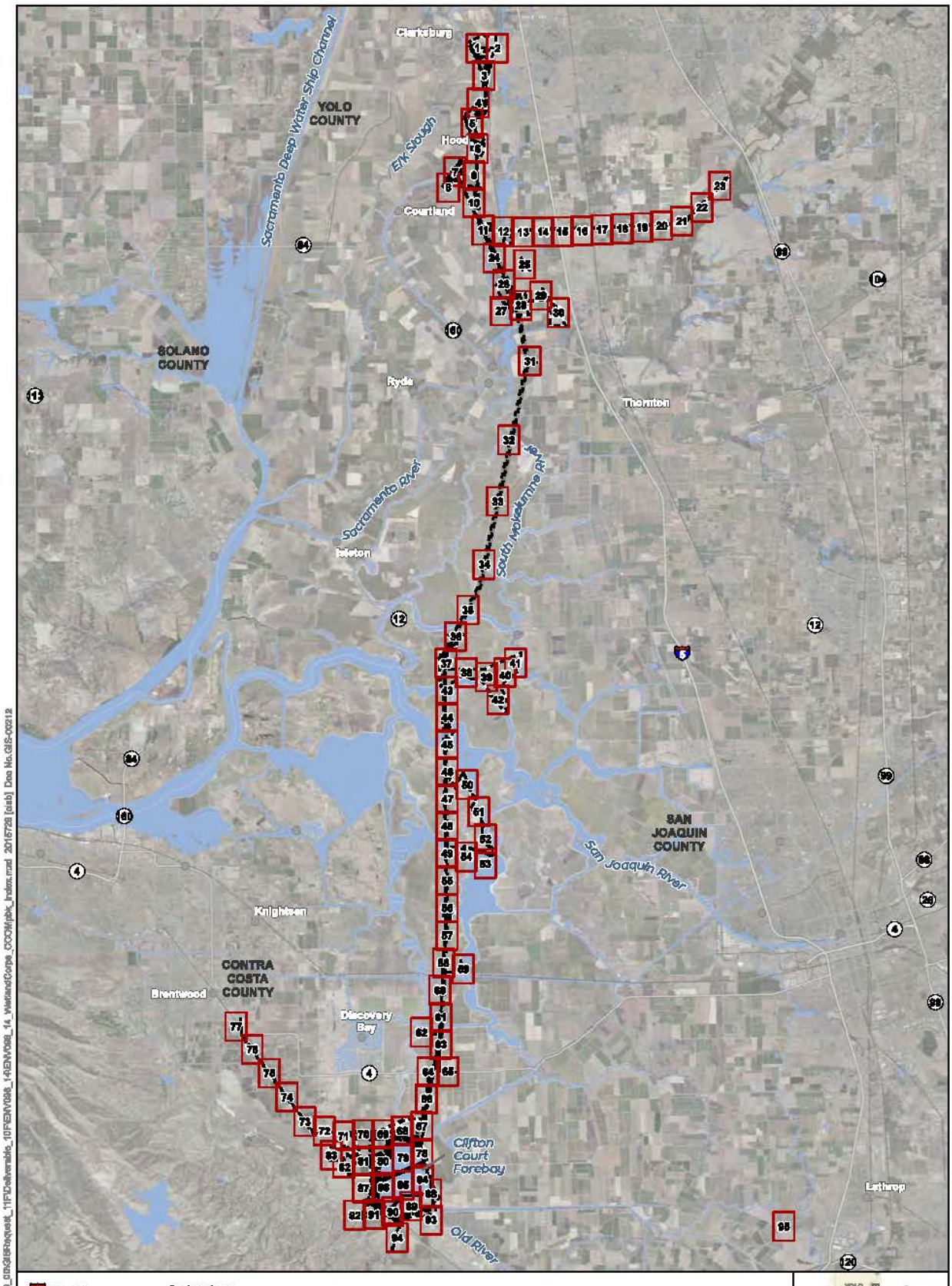
387	EM-46	Emergent Wetland	PEM	0.198	on instream island	H	Transmission Line	38.00563	-121.544
74	FO-36	Forest	PFO	1.321	on instream island	H	Transmission Line	38.00552	-121.544
655	TC-21	Tidal Channel	R1UB	1.643	Connection Slough	H	Barge Unloading Facility	38.00424	-121.5431
654	TC-22	Tidal Channel	R1UB	0.631	Connection Slough	H	Barge Unloading Facility	38.00396	-121.5445
657	TC-23	Tidal Channel	R1UB	0.693	Connection Slough	H	Barge Unloading Facility	38.00394	-121.544
596	SW-66	Seasonal Wetland	PEM	0.076	in ag field	L	Work Area	38.00295	-121.5442
595	SW-67	Seasonal Wetland	PEM	0.385	in ag field	L	Work Area	38.00289	-121.5445
603	AD-132	Agricultural Ditch	R4	0.017	narrow-some vegetation	L	Transmission Line	37.99962	-121.5441
602	AD-133	Agricultural Ditch	R4	0.017	narrow-some vegetation	L	Transmission Line	37.99245	-121.5441
601	AD-134	Agricultural Ditch	R4	0.017	narrow-some vegetation	L	Transmission Line	37.98589	-121.5442
600	AD-135	Agricultural Ditch	R4	0.011	narrow-some vegetation	L	Transmission Line	37.98324	-121.5443
599	AD-136	Agricultural Ditch	R4	0.017	narrow-little vegetation	L	Transmission Line	37.97936	-121.5442
594	SW-68	Seasonal Wetland	PEM	0.034	in ag field	L	Transmission Line	37.97901	-121.5441
576	EM-47	Emergent Wetland	PEM	0.075	in ag field	L	Shaft Location/Access Road	37.97198	-121.5392
598	AD-137	Agricultural Ditch	R4	0.017	narrow-little vegetation	L	Transmission Line	37.95108	-121.546
597	AD-138	Agricultural Ditch	R4	0.017	narrow-little vegetation	L	Transmission Line	37.94785	-121.5463
575	AD-139	Agricultural Ditch	R4	0.314	medium-little vegetation	L	Transmission Line	37.94578	-121.5464
574	AD-140	Agricultural Ditch	R4	0.467	medium-little vegetation	L	Work Area	37.94305	-121.5455
637	TC-25	Tidal Channel	R1UB	1.972	Italian Slough-probably not impacted	H	Transmission Line	37.94012	-121.5469
72	EM-48	Emergent Wetland	PEM	0.113	narrow band along levee	L	Transmission Line	37.93997	-121.5469
73	EM-49	Emergent Wetland	PEM	0.061	narrow band along levee	L	Transmission Line	37.93982	-121.547
282	AD-141	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	37.93876	-121.547
281	AD-142	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	37.93749	-121.5471
280	AD-143	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	37.93604	-121.5473
279	AD-144	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	37.93419	-121.5474
278	AD-145	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	37.93127	-121.5477
276	AD-146	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	37.92859	-121.5479
526	SW-69	Seasonal Wetland	PEM	0.440	in ag field	L	Transmission Line	37.92785	-121.548
527	SW-70	Seasonal Wetland	PEM	0.179	in ag field	L	Transmission Line	37.92729	-121.5482
275	AD-147	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	37.92618	-121.5481
520	SW-71	Seasonal Wetland	PEM	2.412	in ag field	L	Transmission Line	37.92467	-121.5482
277	AD-148	Agricultural Ditch	R4	0.046	narrow-little vegetation	L	Transmission Line	37.92293	-121.5481
274	AD-149	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	37.92226	-121.5484
521	SW-72	Seasonal Wetland	PEM	1.946	in ag field	L	Transmission Line	37.92134	-121.5485
273	AD-150	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Transmission Line	37.92043	-121.5486
522	SW-73	Seasonal Wetland	PEM	2.832	in ag field	L	Transmission Line	37.91923	-121.5487
484	AD-151	Agricultural Ditch	R4	0.074	narrow-little vegetation	L	Transmission Line	37.91842	-121.6778
272	AD-152	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	37.91804	-121.5488
483	AD-153	Agricultural Ditch	R4	0.056	narrow-little vegetation	L	Transmission Line	37.91798	-121.6777
523	SW-74	Seasonal Wetland	PEM	1.496	in ag field	L	Transmission Line	37.91737	-121.5488
271	AD-154	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	37.91673	-121.5489
524	SW-75	Seasonal Wetland	PEM	1.257	in ag field	L	Transmission Line	37.91618	-121.5489
270	AD-155	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	37.91563	-121.549
525	SW-76	Seasonal Wetland	PEM	1.206	in ag field	L	Transmission Line	37.91506	-121.549
269	AD-156	Agricultural Ditch	R4	0.023	narrow-some vegetation	L	Transmission Line	37.91454	-121.5491
649	TC-26	Tidal Channel	R1UB	1.436	North Victoria Canal	H	Transmission Line	37.91355	-121.5492
268	AD-157	Agricultural Ditch	R4	0.090	medium-little vegetation	L	Transmission Line	37.9125	-121.5493
389	EM-50	Emergent Wetland	PEM	0.049	narrow band along levee	L	Barge Unloading Facility	37.91233	-121.5618
648	TC-27	Tidal Channel	R1UB	5.730	Old River	H	Barge Unloading Facility	37.91106	-121.5623
267	AD-158	Agricultural Ditch	R4	0.468	narrow-little vegetation	L	Work Area	37.91076	-121.5499
264	AD-159	Agricultural Ditch	R4	0.002	narrow-little vegetation	L	Barge Unloading Facility	37.90951	-121.5502
265	AD-160	Agricultural Ditch	R4	0.001	narrow-little vegetation	L	Work Area	37.9095	-121.5502
266	AD-161	Agricultural Ditch	R4	0.657	narrow-little vegetation	L	Transmission Line	37.90639	-121.5499
263	AD-162	Agricultural Ditch	R4	0.022	narrow-little vegetation	L	Work Area	37.89906	-121.5501
262	AD-163	Agricultural Ditch	R4	0.093	narrow-little vegetation	L	Transmission Line	37.89904	-121.5518
261	AD-164	Agricultural Ditch	R4	0.080	narrow-little vegetation	L	Work Area	37.89447	-121.55
260	AD-165	Agricultural Ditch	R4	0.111	narrow-little vegetation	L	Work Area	37.89104	-121.55
259	AD-166	Agricultural Ditch	R4	0.529	wide-some vegetation	L	Work Area	37.89026	-121.5462
255	AD-167	Agricultural Ditch	R4	0.106	wide-little vegetation	L	Road Interchange	37.89024	-121.5405
257	AD-169	Agricultural Ditch	R4	0.118	wide-little vegetation	L	Road Interchange	37.89023	-121.5412
258	AD-168	Agricultural Ditch	R4	0.147	wide-little vegetation	L	Transmission Line	37.89023	-121.5543
58	EM-51	Emergent Wetland	PEM	0.076	narrow band along levee	L	Transmission Line	37.89015	-121.5543
60	EM-52	Emergent Wetland	PEM	0.120	narrow band along levee	L	Transmission Line	37.88995	-121.5544
59	EM-53	Emergent Wetland	PEM	0.014	narrow band along levee	L	Work Area	37.88994	-121.5575
256	AD-170	Agricultural Ditch	R4	0.127	wide-little vegetation	L	Road Interchange	37.8899	-121.5405
252	AD-171	Agricultural Ditch	R4	0.045	wide-little vegetation	L	Road Interchange	37.8899	-121.5413
254	AD-172	Agricultural Ditch	R4	0.105	wide-little vegetation	L	Transmission Line	37.88987	-121.5544
253	AD-173	Agricultural Ditch	R4	0.017	wide-little vegetation	L	Work Area	37.88986	-121.5575
482	AD-174	Agricultural Ditch	R4	0.069	narrow-little vegetation	L	Transmission Line	37.88959	-121.659
251	AD-175	Agricultural Ditch	R4	0.430	narrow-little vegetation	L	Transmission Line	37.88806	-121.5549
250	AD-176	Agricultural Ditch	R4	0.058	narrow-little vegetation	L	Transmission Line	37.8827	-121.5562
249	AD-177	Agricultural Ditch	R4	0.009	narrow-little vegetation	L	Work Area	37.88267	-121.5574
248	AD-178	Agricultural Ditch	R4	0.007	narrow-little vegetation	L	Transmission Line	37.88255	-121.556
247	AD-179	Agricultural Ditch	R4	0.016	narrow-little vegetation	L	Work Area	37.88255	-121.5563
246	AD-180	Agricultural Ditch	R4	0.083	narrow-little vegetation	L	Work Area	37.88253	-121.5574
481	AD-181	Agricultural Ditch	R4	0.099	narrow-riparian vegetation	M	Transmission Line	37.88192	-121.6521
245	AD-182	Agricultural Ditch	R4	0.035	narrow-little vegetation	L	Transmission Line	37.87902	-121.557
480	AD-183	Agricultural Ditch	R4	0.098	narrow-little vegetation	L	Transmission Line	37.87592	-121.6464
244	AD-184	Agricultural Ditch	R4	0.104	medium-little vegetation	L	Transmission Line	37.8753	-121.5579
479	AD-185	Agricultural Ditch	R4	0.024	narrow-little vegetation	L	Transmission Line	37.87469	-121.6457
242	AD-186	Agricultural Ditch	R4	0.058	narrow-little vegetation	L	Transmission Line	37.86917	-121.5592
478	AD-187	Agricultural Ditch	R4	0.019	narrow-riparian vegetation	M	Transmission Line	37.86658	-121.6384

241	AD-188	Agricultural Ditch	R4	0.057	narrow-little vegetation	L	Transmission Line	37.86634	-121.5668
240	AD-189	Agricultural Ditch	R4	0.069	narrow-little vegetation	L	Transmission Line	37.86625	-121.5724
643	TC-28	Tidal Channel	R1UB	1.310	Old River	H	Transmission Line	37.86589	-121.5735
57	SS-17	Scrub-Shrub	PSS	0.143	along ag ditch	L	Transmission Line	37.86543	-121.5748
235	AD-190	Agricultural Ditch	R4	0.173	narrow-some vegetation	L	Transmission Line	37.86471	-121.5769
234	AD-191	Agricultural Ditch	R4	0.049	narrow-little vegetation	L	Transmission Line	37.86375	-121.5797
230	AD-193	Agricultural Ditch	R4	0.069	narrow-little vegetation	L	Transmission Line	37.86363	-121.5605
233	AD-192	Agricultural Ditch	R4	0.088	narrow-little vegetation	L	Transmission Line	37.86321	-121.5813
228	AD-194	Agricultural Ditch	R4	0.116	narrow-little vegetation	L	Transmission Line	37.86208	-121.5846
243	AD-195	Agricultural Ditch	R4	0.196	medium-some vegetation	L	Transmission Line	37.8614	-121.5865
477	AD-196	Agricultural Ditch	R4	0.078	narrow-little vegetation	L	Transmission Line	37.86134	-121.6335
476	AD-197	Agricultural Ditch	R4	0.058	narrow-little vegetation	L	Transmission Line	37.8606	-121.6329
383	SS-18	Scrub-Shrub	PSS	0.318	narrow band along levee	L	Shaft Location/Access Road	37.86022	-121.5815
238	AD-198	Agricultural Ditch	R4	0.006	narrow-little vegetation	L	Transmission Line	37.8602	-121.5906
237	AD-199	Agricultural Ditch	R4	0.028	narrow-little vegetation	L	Transmission Line	37.86017	-121.5905
236	AD-200	Agricultural Ditch	R4	0.025	narrow-little vegetation	L	Transmission Line	37.86	-121.6101
475	AD-201	Agricultural Ditch	R4	0.033	narrow-little vegetation	L	Transmission Line	37.85999	-121.6323
217	AD-203	Agricultural Ditch	R4	0.315	narrow-little vegetation	L	Reusable Tunnel Material	37.85995	-121.5934
215	AD-204	Agricultural Ditch	R4	0.122	narrow-little vegetation	L	Concrete Batch Plant	37.85992	-121.5909
216	AD-208	Agricultural Ditch	R4	0.047	narrow-little vegetation	L	Reusable Tunnel Material	37.85991	-121.5867
218	AD-205	Agricultural Ditch	R4	0.275	narrow-little vegetation	L	Concrete Batch Plant	37.85991	-121.5886
231	AD-207	Agricultural Ditch	R4	0.045	narrow-little vegetation	L	Transmission Line	37.85991	-121.6133
401	AW-1	Alkaline Wetland	PSS	0.242	degraded	L	Transmission Line	37.85991	-121.6135
239	AD-206	Agricultural Ditch	R4	0.045	narrow-little vegetation	L	Transmission Line	37.85991	-121.614
225	AD-202	Agricultural Ditch	R4	0.025	narrow-little vegetation	L	Transmission Line	37.8599	-121.6097
232	AD-209	Agricultural Ditch	R4	0.101	medium-little vegetation	L	Transmission Line	37.8599	-121.6099
395	AW-2	Alkaline Wetland	PSS	8.680	some grazing	M	Transmission Line	37.8599	-121.6187
224	AD-211	Agricultural Ditch	R4	0.023	narrow-little vegetation	L	Reusable Tunnel Material	37.85988	-121.6051
227	AD-210	Agricultural Ditch	R4	0.034	narrow-little vegetation	L	Reusable Tunnel Material	37.85988	-121.6053
222	AD-213	Agricultural Ditch	R4	0.091	medium-some vegetation	L	Reusable Tunnel Material	37.85987	-121.6011
220	AD-212	Agricultural Ditch	R4	0.045	narrow-little vegetation	L	Reusable Tunnel Material	37.85987	-121.6012
214	AD-214	Agricultural Ditch	R4	0.052	narrow-little vegetation	L	Reusable Tunnel Material	37.8598	-121.5955
204	AD-215	Agricultural Ditch	R4	0.005	narrow-little vegetation	L	Concrete Batch Plant	37.8597	-121.5909
209	AD-216	Agricultural Ditch	R4	0.018	narrow-little vegetation	L	Concrete Batch Plant	37.8597	-121.591
208	AD-217	Agricultural Ditch	R4	0.003	narrow-little vegetation	L	Reusable Tunnel Material	37.85968	-121.5953
226	AD-218	Agricultural Ditch	R4	0.014	narrow-little vegetation	L	Reusable Tunnel Material	37.85958	-121.6053
200	AD-219	Agricultural Ditch	R4	0.172	narrow-little vegetation	L	Reusable Tunnel Material	37.85942	-121.6072
384	SS-19	Scrub-Shrub	PSS	0.073	narrow band along levee	L	Shaft Location/Access Road	37.85866	-121.5828
229	AD-220	Agricultural Ditch	R4	0.182	narrow-little vegetation	L	Transmission Line	37.85851	-121.5616
199	AD-221	Agricultural Ditch	R4	0.217	narrow-little vegetation	L	Reusable Tunnel Material	37.85808	-121.6053
206	AD-222	Agricultural Ditch	R4	0.177	narrow-little vegetation	L	Concrete Batch Plant	37.85804	-121.5909
223	AD-223	Agricultural Ditch	R4	0.179	narrow-little vegetation	L	Reusable Tunnel Material	37.85804	-121.6051
211	AD-224	Agricultural Ditch	R4	0.440	narrow-little vegetation	L	Concrete Batch Plant	37.85803	-121.591
202	AD-225	Agricultural Ditch	R4	0.472	narrow-little vegetation	L	Concrete Batch Plant	37.85784	-121.5873
528	SS-20	Scrub-Shrub	PSS	0.300	along intermittent ditch	L	Tunnel Conveyor	37.85775	-121.5801
212	AD-227	Agricultural Ditch	R4	0.646	narrow-little vegetation	L	Reusable Tunnel Material	37.85766	-121.5956
198	AD-226	Agricultural Ditch	R4	0.531	narrow-little vegetation	L	Tunnel Conveyor	37.8576	-121.5809
219	AD-228	Agricultural Ditch	R4	0.476	narrow-little vegetation	L	Reusable Tunnel Material	37.85751	-121.6015
207	AD-229	Agricultural Ditch	R4	0.238	narrow-little vegetation	L	Reusable Tunnel Material	37.85748	-121.5954
85	EM-54	Emergent Wetland	PEM	0.182	narrow band along levee	L	Shaft Location/Access Road	37.85717	-121.5752
368	SS-21	Scrub-Shrub	PSS	0.089	blackberry?	M	Shaft Location/Access Road	37.85712	-121.5745
40	CCF-1	Clifton Court Foreba	R1UB	0.358	rock-lined forebay	L	Tunnel Conveyor	37.85709	-121.5804
86	EM-55	Emergent Wetland	PEM	0.063	degraded	L	Tunnel Conveyor	37.85703	-121.5767
54	FO-37	Forest	PFO	0.078	along Huston Canal	H	Shaft Location/Access Road	37.85688	-121.5675
50	SS-23	Scrub-Shrub	PSS	0.031	blackberry?	M	Shaft Location/Access Road	37.85674	-121.571
371	SS-22	Scrub-Shrub	PSS	0.469	willow/arundo	M	Fuel Station	37.8567	-121.5665
197	AD-230	Agricultural Ditch	R4	0.018	narrow-marsh vegetation	M	Concrete Batch Plant	37.85669	-121.5872
196	AD-231	Agricultural Ditch	R4	0.094	narrow-marsh vegetation	M	Reusable Tunnel Material	37.85668	-121.5859
49	SS-24	Scrub-Shrub	PSS	0.104	blackberry?	M	Shaft Location/Access Road	37.85662	-121.5699
375	EM-56	Emergent Wetland	PEM	0.086	wetland grass/ruderal	M	Fuel Station	37.85658	-121.5669
370	SS-25	Scrub-Shrub	PSS	0.193	sandbar willow	H	Forebay Embankment	37.85651	-121.5679
373	FO-38	Forest	PFO	0.354	mixed willows	H	Fuel Station	37.85647	-121.5666
53	DE-17	Depression	PUB	0.009	constructed channel	L	Fuel Station	37.85643	-121.5668
52	DE-18	Depression	PUB	0.015	constructed channel	L	Forebay Embankment	37.85633	-121.5682
374	EM-57	Emergent Wetland	PEM	0.864	wetland grass/ruderal	M	Shaft Location/Access Road	37.8563	-121.5673
203	AD-233	Agricultural Ditch	R4	0.410	narrow-little vegetation	L	Reusable Tunnel Material	37.8562	-121.585
48	EM-58	Emergent Wetland	PEM	0.632	wide band along Old River	H	Transmission Line	37.85614	-121.562
372	FO-39	Forest	PFO	0.424	mixed willows	H	Shaft Location/Access Road	37.85609	-121.5667
210	AD-234	Agricultural Ditch	R4	0.141	narrow-little vegetation	L	Reusable Tunnel Material	37.85592	-121.591
205	AD-235	Agricultural Ditch	R4	0.057	narrow-little vegetation	L	Reusable Tunnel Material	37.85591	-121.5909
51	DE-19	Depression	PUB	0.483	constructed channel	L	Shaft Location/Access Road	37.85589	-121.5671
369	SS-26	Scrub-Shrub	PSS	6.049	sandbar willow/blackberry/arundo	H	Shaft Location/Access Road	37.85579	-121.5657
376	FO-40	Forest	PFO	1.056	mixed willows	H	Shaft Location/Access Road	37.85567	-121.5661
639	TC-29	Tidal Channel	R1UB	3.786	Old River	H	Transmission Line	37.85551	-121.5623
213	AD-236	Agricultural Ditch	R4	0.137	narrow-little vegetation	L	Reusable Tunnel Material	37.85545	-121.5956
377	FO-41	Forest	PFO	0.252	mixed willows	H	Shaft Location/Access Road	37.8554	-121.5653
191	AD-237	Agricultural Ditch	R4	0.175	narrow-little vegetation	L	Reusable Tunnel Material	37.85529	-121.5932
193	AD-239	Agricultural Ditch	R4	0.055	narrow-little vegetation	L	Reusable Tunnel Material	37.85529	-121.596
192	AD-238	Agricultural Ditch	R4	0.961	narrow-little vegetation	L	Reusable Tunnel Material	37.85529	-121.5989
201	AD-240	Agricultural Ditch	R4	0.666	narrow-little vegetation	L	Reusable Tunnel Material	37.85527	-121.5878
378	FO-42	Forest	PFO	0.162	mixed willows	H	Shaft Location/Access Road	37.85508	-121.565
640	TC-30	Tidal Channel	R1UB	2.491	Old River	H	Barge Unloading Facility	37.85496	-121.5641

47	FO-43	Forest	PFO	1.549	on instream island	H	Transmission Line	37.85479	-121.5625
185	AD-241	Agricultural Ditch	R4	0.126	narrow-little vegetation	L	Reusable Tunnel Material	37.85414	-121.5909
184	AD-242	Agricultural Ditch	R4	0.257	narrow-little vegetation	L	Reusable Tunnel Material	37.85411	-121.591
221	AD-232	Agricultural Ditch	R4	2.584	medium-some vegetation	L	Reusable Tunnel Material	37.85381	-121.6017
38	CCF-2	Clifton Court Foreba	R1UB	3.906	rock-lined forebay	L	Shaft Location/Access Road	37.85312	-121.566
188	AD-246	Agricultural Ditch	R4	1.122	narrow-little vegetation	L	Reusable Tunnel Material	37.85308	-121.5997
33	EM-59	Emergent Wetland	PEM	22.422	Polygonum/Frankenia	H	Shaft Location/Access Road	37.85305	-121.5644
181	AD-243	Agricultural Ditch	R4	0.259	narrow-little vegetation	L	Reusable Tunnel Material	37.85286	-121.5889
194	AD-252	Agricultural Ditch	R4	0.623	narrow-little vegetation	L	Reusable Tunnel Material	37.85234	-121.6048
34	EM-60	Emergent Wetland	PEM	0.544	Polygonum/Frankenia	H	Shaft Location/Access Road	37.8523	-121.5631
32	SS-27	Scrub-Shrub	PSS	0.005	narrow band on levee	L	Shaft Location/Access Road	37.8518	-121.5622
81	EM-61	Emergent Wetland	PEM	3.440	narrow band along ag ditch	M	Reusable Tunnel Material	37.85155	-121.602
190	AD-245	Agricultural Ditch	R4	0.799	narrow-marsh vegetation	M	Reusable Tunnel Material	37.85154	-121.602
189	AD-247	Agricultural Ditch	R4	0.011	narrow-little vegetation	L	Reusable Tunnel Material	37.85152	-121.596
183	AD-244	Agricultural Ditch	R4	0.926	narrow-little vegetation	L	Reusable Tunnel Material	37.85135	-121.5957
178	AD-248	Agricultural Ditch	R4	0.333	narrow-little vegetation	L	Reusable Tunnel Material	37.85095	-121.5982
180	AD-249	Agricultural Ditch	R4	0.556	narrow-little vegetation	L	Reusable Tunnel Material	37.85082	-121.591
195	AD-250	Agricultural Ditch	R4	0.384	narrow-little vegetation	L	Reusable Tunnel Material	37.85056	-121.6059
186	AD-253	Agricultural Ditch	R4	0.748	narrow-little vegetation	L	Reusable Tunnel Material	37.8504	-121.594
35	DE-20	Depression	PUB	0.170	pond with some vegetation	M	Shaft Location/Access Road	37.85014	-121.562
179	AD-254	Agricultural Ditch	R4	0.396	narrow-little vegetation	L	Reusable Tunnel Material	37.85008	-121.5874
182	AD-251	Agricultural Ditch	R4	0.381	narrow-little vegetation	L	Reusable Tunnel Material	37.84934	-121.6141
187	AD-255	Agricultural Ditch	R4	0.162	narrow-little vegetation	L	Reusable Tunnel Material	37.84916	-121.5956
632	TC-31	Tidal Channel	R1UB	0.103	Italian Slough-probably not impacted	H	Reusable Tunnel Material	37.84872	-121.5869
177	AD-256	Agricultural Ditch	R4	0.026	narrow-little vegetation	L	Reusable Tunnel Material	37.84865	-121.596
174	AD-257	Agricultural Ditch	R4	0.143	narrow-little vegetation	L	Reusable Tunnel Material	37.84823	-121.6074
173	AD-258	Agricultural Ditch	R4	0.213	narrow-little vegetation	L	Reusable Tunnel Material	37.84817	-121.6074
382	EM-62	Emergent Wetland	PEM	0.063	narrow band along levee	L	Shaft Location/Access Road	37.84814	-121.5891
381	SS-29	Scrub-Shrub	PSS	0.024	narrow band along levee	L	Shaft Location/Access Road	37.84793	-121.5899
176	AD-262	Agricultural Ditch	R4	0.277	narrow-little vegetation	L	Reusable Tunnel Material	37.84791	-121.5984
170	AD-260	Agricultural Ditch	R4	0.040	narrow-little vegetation	L	Reusable Tunnel Material	37.8479	-121.6036
175	AD-261	Agricultural Ditch	R4	0.078	narrow-little vegetation	L	Reusable Tunnel Material	37.84789	-121.6205
379	SS-28	Scrub-Shrub	PSS	0.277	blackberry?	M	Shaft Location/Access Road	37.84785	-121.5862
434	EM-63	Emergent Wetland	PEM	0.330	degraded	L	Shaft Location/Access Road	37.84784	-121.5879
167	AD-263	Agricultural Ditch	R4	0.370	narrow-little vegetation	L	Reusable Tunnel Material	37.84774	-121.5988
161	AD-264	Agricultural Ditch	R4	0.181	narrow-little vegetation	L	Reusable Tunnel Material	37.84763	-121.5944
162	AD-265	Agricultural Ditch	R4	0.018	narrow-little vegetation	L	Reusable Tunnel Material	37.84763	-121.5956
61	EM-64	Emergent Wetland	PEM	0.041	degraded	L	Reusable Tunnel Material	37.84742	-121.6135
380	FO-44	Forest	PFO	0.168	narrow band along levee	L	Shaft Location/Access Road	37.84741	-121.5911
171	AD-266	Agricultural Ditch	R4	0.262	narrow-little vegetation	L	Reusable Tunnel Material	37.84712	-121.6077
634	TC-34	Tidal Channel	R1UB	2.260	Italian Slough-probably not impacted	H	Shaft Location/Access Road	37.84708	-121.588
172	AD-259	Agricultural Ditch	R4	0.588	narrow-little vegetation	L	Reusable Tunnel Material	37.84686	-121.6052
160	AD-267	Agricultural Ditch	R4	0.094	narrow-little vegetation	L	Reusable Tunnel Material	37.84649	-121.6192
46	CCF-3	Clifton Court Foreba	R1UB	821.682	rock-lined forebay	L	Forebay Dredging Area	37.84621	-121.5762
165	AD-268	Agricultural Ditch	R4	0.184	narrow-little vegetation	L	Reusable Tunnel Material	37.84615	-121.601
168	AD-272	Agricultural Ditch	R4	0.211	narrow-little vegetation	L	Reusable Tunnel Material	37.84592	-121.6038
166	AD-269	Agricultural Ditch	R4	0.420	narrow-little vegetation	L	Reusable Tunnel Material	37.84591	-121.6039
641	TC-33	Tidal Channel	R1UB	1.397	West Canal	H	Forebay Overflow Structure	37.84588	-121.5594
638	TC-32	Tidal Channel	R1UB	0.597	Italian Slough-probably not impacted	H	Forebay Overflow Structure	37.84583	-121.5596
163	AD-271	Agricultural Ditch	R4	0.604	medium-little vegetation	L	Reusable Tunnel Material	37.84583	-121.5958
169	AD-270	Agricultural Ditch	R4	1.084	medium-little vegetation	L	Reusable Tunnel Material	37.84583	-121.601
37	CCF-4	Clifton Court Foreba	R1UB	0.145	rock-lined forebay	L	Forebay Overflow Structure	37.84558	-121.5606
39	CCF-5	Clifton Court Foreba	R1UB	0.120	rock-lined forebay	L	Forebay Overflow Structure	37.84558	-121.5606
159	AD-273	Agricultural Ditch	R4	0.330	narrow-little vegetation	L	Reusable Tunnel Material	37.84461	-121.5979
158	AD-274	Agricultural Ditch	R4	0.027	narrow-little vegetation	L	Reusable Tunnel Material	37.84425	-121.5995
41	CCF-6	Clifton Court Foreba	R1UB	214.962	rock-lined forebay	L	Forebay Embankment	37.84354	-121.5758
157	AD-275	Agricultural Ditch	R4	0.039	narrow-little vegetation	L	Transmission Line	37.84314	-121.5956
156	AD-276	Agricultural Ditch	R4	0.007	narrow-little vegetation	L	Transmission Line	37.84298	-121.5956
164	AD-277	Agricultural Ditch	R4	0.818	medium-little vegetation	L	Transmission Line	37.84152	-121.5958
154	AD-278	Agricultural Ditch	R4	0.029	narrow-little vegetation	L	Transmission Line	37.84144	-121.5956
155	AD-279	Agricultural Ditch	R4	0.024	narrow-little vegetation	L	Transmission Line	37.83901	-121.5955
636	TC-35	Tidal Channel	R1UB	0.887	Italian Slough-probably not impacted	H	Transmission Line	37.83825	-121.5956
26	EM-65	Emergent Wetland	PEM	0.013	along road	L	Shaft Location/Access Road	37.838	-121.6025
633	TC-36	Tidal Channel	R1UB	0.107	Italian Slough-probably not impacted	H	Shaft Location/Access Road	37.83796	-121.6024
635	TC-37	Tidal Channel	R1UB	0.020	Italian Slough-probably not impacted	H	Shaft Location/Access Road	37.83789	-121.5956
27	DE-21	Depression	PUB	0.003	Allenrolfea	H	Transmission Line	37.83755	-121.5953
399	AW-3	Alkaline Wetland	PSS	3.074	Allenrolfea	H	Transmission Line	37.83634	-121.5956
66	AW-4	Alkaline Wetland	PSS	1.041	Allenrolfea	H	Transmission Line	37.83434	-121.5955
42	CCF-7	Clifton Court Foreba	R1UB	7.996	rock-lined forebay	L	Forebay/Spillway	37.83256	-121.5922
45	CCF-8	Clifton Court Foreba	R1UB	1107.996	rock-lined forebay	L	Forebay Dredging Area	37.8321	-121.5742
153	AD-280	Agricultural Ditch	R4	0.083	narrow-shrubs	M	Transmission Line	37.83014	-121.5955
25	AW-5	Alkaline Wetland	PEM	0.938	degraded	L	Transmission Line	37.82951	-121.5956
148	CO-1	Conveyance Channe	NA	3.846	large constructed channel	L	Control Structure	37.82945	-121.5939
152	CO-2	Conveyance Channe	NA	1.184	large constructed channel	L	Work Area	37.82944	-121.5939
145	AD-281	Agricultural Ditch	R4	0.088	narrow-little vegetation	L	Transmission Line	37.82898	-121.5543
43	CCF-9	Clifton Court Foreba	R1UB	17.897	rock-lined forebay	L	Forebay Embankment	37.82873	-121.5913
144	AD-282	Agricultural Ditch	R4	0.517	narrow-little vegetation	L	Forebay Embankment	37.82872	-121.556
400	AW-6	Alkaline Wetland	PSS	1.101	somewhat degraded	L	Transmission Line	37.82871	-121.5957
30	SS-30	Scrub-Shrub	PSS	1.516	blackberry?	M	Transmission Line	37.8284	-121.5535
36	CCF-10	Clifton Court Foreba	R1UB	11.950	rock-lined forebay	L	Canal	37.82777	-121.5923
31	SS-31	Scrub-Shrub	PSS	0.242	Arundo	L	Transmission Line	37.82755	-121.5527
364	VP-1	Vernal Pool	PEM2	0.069	degraded	L	Transmission Line	37.82753	-121.5964

79	SS-32	Scrub-Shrub	PSS	0.385	degraded	L	Transmission Line	37.82747	-121.553
433	EM-66	Emergent Wetland	PEM	0.059	in ag field	L	New Forebay	37.8274	-121.5584
392	AW-7	Alkaline Wetland	PSS	0.034	Allenrolfea	H	Work Area	37.82725	-121.5933
146	AD-283	Agricultural Ditch	R4	0.995	narrow-little vegetation	L	New Forebay	37.827	-121.5593
393	AW-8	Alkaline Wetland	PSS	0.116	narrow band along road	L	Canal	37.82686	-121.5931
62	EM-67	Emergent Wetland	PEM	0.152	pond with some vegetation	M	New Forebay	37.82654	-121.5727
87	SS-33	Scrub-Shrub	PSS	0.309	narrow band along ag ditch	M	New Forebay	37.82634	-121.5624
394	AW-9	Alkaline Wetland	PSS	0.029	narrow band along road	L	Work Area	37.82622	-121.5932
141	AD-286	Agricultural Ditch	R4	0.231	narrow-little vegetation	L	Work Area	37.82602	-121.5936
138	AD-284	Agricultural Ditch	R4	1.077	narrow-shrubs	M	New Forebay	37.8257	-121.5727
139	AD-285	Agricultural Ditch	R4	0.143	narrow-little vegetation	L	New Forebay	37.82558	-121.558
28	EM-68	Emergent Wetland	PEM	0.169	degraded	L	New Forebay	37.82552	-121.5684
29	EM-69	Emergent Wetland	PEM	0.093	degraded	L	New Forebay	37.82549	-121.5691
80	SS-34	Scrub-Shrub	PSS	0.066	degraded	L	Transmission Line	37.82505	-121.5526
140	AD-287	Agricultural Ditch	R4	0.148	narrow-little vegetation	L	Canal	37.825	-121.5924
149	CO-3	Conveyance Channe	NA	0.913	large constructed channel	L	Transmission Line	37.82435	-121.5968
142	AD-288	Agricultural Ditch	R4	0.102	narrow-little vegetation	L	Forebay Embankment	37.82425	-121.5913
88	SS-35	Scrub-Shrub	PSS	0.168	narrow band along levee	L	Transmission Line	37.82388	-121.5531
137	AD-290	Agricultural Ditch	R4	0.809	narrow-little vegetation	L	New Forebay	37.82384	-121.5661
135	AD-289	Agricultural Ditch	R4	0.780	narrow-little vegetation	L	New Forebay	37.82383	-121.5728
44	CCF-11	Clifton Court Foreba	R1UB	1.014	rock-lined forebay	L	New Forebay	37.82365	-121.5845
24	SS-36	Scrub-Shrub	PSS	0.173	degraded	L	New Forebay	37.8236	-121.5775
78	EM-70	Emergent Wetland	PEM	0.647	in ag field	L	Transmission Line	37.82347	-121.5546
23	SS-37	Scrub-Shrub	PSS	0.324	ruderal	L	New Forebay	37.82344	-121.5784
136	AD-292	Agricultural Ditch	R4	0.402	narrow-little vegetation	L	New Forebay	37.82335	-121.5596
390	SS-38	Scrub-Shrub	PSS	0.228	narrow band between levees	L	New Forebay	37.82327	-121.5789
134	AD-291	Agricultural Ditch	R4	0.071	narrow-little vegetation	L	Forebay Embankment	37.82325	-121.5908
125	AD-293	Agricultural Ditch	R4	0.019	narrow-little vegetation	L	Work Area	37.82268	-121.5957
126	AD-294	Agricultural Ditch	R4	0.243	narrow-little vegetation	L	Work Area	37.82252	-121.5942
131	AD-295	Agricultural Ditch	R4	0.135	narrow-little vegetation	L	Canal	37.82251	-121.5915
474	FO-45	Forest	PFO	0.625	narrow band along ag ditch	M	Transmission Line	37.82209	-121.5547
117	AD-296	Agricultural Ditch	R4	0.053	narrow-riparian vegetation	M	Transmission Line	37.82208	-121.5547
65	EM-71	Emergent Wetland	PEM	0.041	in ag field	L	Work Area	37.82191	-121.5959
133	AD-297	Agricultural Ditch	R4	0.035	narrow-little vegetation	L	Work Area	37.8219	-121.5921
132	AD-298	Agricultural Ditch	R4	0.020	narrow-little vegetation	L	Work Area	37.8217	-121.5923
127	AD-299	Agricultural Ditch	R4	0.052	narrow-little vegetation	L	Work Area	37.82169	-121.5928
124	AD-300	Agricultural Ditch	R4	0.327	narrow-little vegetation	L	New Forebay	37.82167	-121.5666
397	AD-301	Agricultural Ditch	R4	0.048	narrow-little vegetation	L	New Forebay	37.82149	-121.5814
123	AD-302	Agricultural Ditch	R4	0.648	narrow-little vegetation	L	New Forebay	37.82132	-121.5609
398	EM-72	Emergent Wetland	PEM	0.184	somewhat degraded	L	New Forebay	37.82125	-121.5812
114	AD-303	Agricultural Ditch	R4	0.053	narrow-little vegetation	L	Work Area	37.82124	-121.5918
111	AD-304	Agricultural Ditch	R4	0.131	narrow-little vegetation	L	Work Area	37.8211	-121.5919
128	AD-305	Agricultural Ditch	R4	0.605	narrow-little vegetation	L	New Forebay	37.82097	-121.571
396	AD-306	Agricultural Ditch	R4	0.020	narrow-little vegetation	L	New Forebay	37.82094	-121.5828
109	AD-307	Agricultural Ditch	R4	0.055	narrow-little vegetation	L	New Forebay	37.82081	-121.5583
130	AD-308	Agricultural Ditch	R4	0.752	narrow-little vegetation	L	New Forebay	37.82061	-121.576
110	AD-309	Agricultural Ditch	R4	0.054	narrow-little vegetation	L	Work Area	37.82058	-121.5911
120	AD-310	Agricultural Ditch	R4	0.256	narrow-little vegetation	L	Work Area	37.82057	-121.5957
391	AW-10	Alkaline Wetland	PSS	5.145	Allenrolfea	H	New Forebay	37.82056	-121.5839
143	AD-311	Agricultural Ditch	R4	1.415	narrow-little vegetation	L	New Forebay	37.82009	-121.5845
402	VP-2	Vernal Pool	PEM2	0.033	mostly undisturbed	H	New Forebay	37.81993	-121.5825
107	AD-312	Agricultural Ditch	R4	0.048	narrow-little vegetation	L	Forebay Embankment	37.81987	-121.5582
406	VP-3	Vernal Pool	PEM2	0.015	mostly undisturbed	H	New Forebay	37.81985	-121.5822
113	AD-313	Agricultural Ditch	R4	0.197	narrow-little vegetation	L	Work Area	37.81985	-121.5895
121	AD-314	Agricultural Ditch	R4	0.143	narrow-little vegetation	L	Forebay Embankment	37.81983	-121.5599
408	VP-4	Vernal Pool	PEM2	0.041	mostly undisturbed	H	New Forebay	37.81974	-121.5826
405	VP-5	Vernal Pool	PEM2	0.030	mostly undisturbed	H	New Forebay	37.81968	-121.5822
407	VP-6	Vernal Pool	PEM2	0.018	mostly undisturbed	H	New Forebay	37.81949	-121.5827
403	VP-7	Vernal Pool	PEM2	0.061	mostly undisturbed	H	New Forebay	37.81948	-121.5824
404	VP-8	Vernal Pool	PEM2	0.041	mostly undisturbed	H	New Forebay	37.8194	-121.5821
116	AD-315	Agricultural Ditch	R4	0.001	narrow-little vegetation	L	Work Area	37.81892	-121.5877
106	AD-316	Agricultural Ditch	R4	0.307	narrow-little vegetation	L	Work Area	37.81878	-121.588
151	CO-4	Conveyance Channe	NA	0.400	large constructed channel	L	Work Area	37.81873	-121.601
108	AD-317	Agricultural Ditch	R4	0.102	narrow-little vegetation	L	Transmission Line	37.8185	-121.5582
122	AD-320	Agricultural Ditch	R4	0.166	narrow-little vegetation	L	Transmission Line	37.81816	-121.5613
118	AD-319	Agricultural Ditch	R4	0.146	narrow-little vegetation	L	Canal	37.81813	-121.5957
112	AD-318	Agricultural Ditch	R4	0.232	narrow-little vegetation	L	Canal	37.8177	-121.5851
129	AD-321	Agricultural Ditch	R4	0.074	narrow-little vegetation	L	Forebay Embankment	37.81742	-121.5736
115	AD-322	Agricultural Ditch	R4	0.045	narrow-little vegetation	L	Work Area	37.81718	-121.5847
105	AD-323	Agricultural Ditch	R4	0.038	narrow-little vegetation	L	Work Area	37.81695	-121.5847
63	EM-73	Emergent Wetland	PEM	0.469	in depression between levees	M	Forebay Embankment	37.81674	-121.5752
64	EM-74	Emergent Wetland	PEM	0.114	in depression between levees	M	Transmission Line	37.81672	-121.5746
104	AD-325	Agricultural Ditch	R4	0.059	narrow-little vegetation	L	Work Area	37.81668	-121.5978
103	AD-324	Agricultural Ditch	R4	0.047	narrow-little vegetation	L	Canal	37.81668	-121.599
119	AD-326	Agricultural Ditch	R4	0.096	narrow-little vegetation	L	Work Area	37.81667	-121.5977
147	CO-5	Conveyance Channe	NA	0.673	large constructed channel	L	Canal	37.81661	-121.6028
99	AD-327	Agricultural Ditch	R4	0.014	narrow-little vegetation	L	New Forebay	37.81632	-121.5772
100	CO-6	Conveyance Channe	NA	2.203	large constructed channel	L	Control Structure	37.81607	-121.5728
102	CO-7	Conveyance Channe	NA	1.135	large constructed channel	L	Work Area	37.81607	-121.5728
21	EM-75	Emergent Wetland	PEM	2.368	emergent wetland in swale	M	Forebay Embankment	37.81604	-121.5765
22	EM-76	Emergent Wetland	PEM	0.755	emergent wetland in swale	M	Transmission Line	37.81595	-121.576
98	AD-328	Agricultural Ditch	R4	0.288	narrow-little vegetation	L	Forebay Embankment	37.81546	-121.5774

150	CO-8	Conveyance Channe	NA	0.133	large constructed channel	L	Work Area	37.81544	-121.6038
95	AD-329	Agricultural Ditch	R4	0.170	narrow-little vegetation	L	Canal	37.81437	-121.5784
97	AD-330	Agricultural Ditch	R4	0.074	narrow-little vegetation	L	Work Area	37.8138	-121.579
96	AD-331	Agricultural Ditch	R4	0.161	narrow-little vegetation	L	Work Area	37.81367	-121.5797
101	CO-9	Conveyance Channe	NA	0.349	large constructed channel	L	Transmission Line	37.81273	-121.5781
94	AD-332	Agricultural Ditch	R4	0.049	narrow-little vegetation	L	Transmission Line	37.8119	-121.5772
93	AD-333	Agricultural Ditch	R4	0.009	narrow-little vegetation	L	Transmission Line	37.81175	-121.5768
92	AD-334	Agricultural Ditch	R4	0.043	narrow -little vegetation	L	Transmission Line	37.81089	-121.5776
642	TC-38	Tidal Channel	R1UB	2.730	Old River	H	Operable Barrier	37.80804	-121.3293

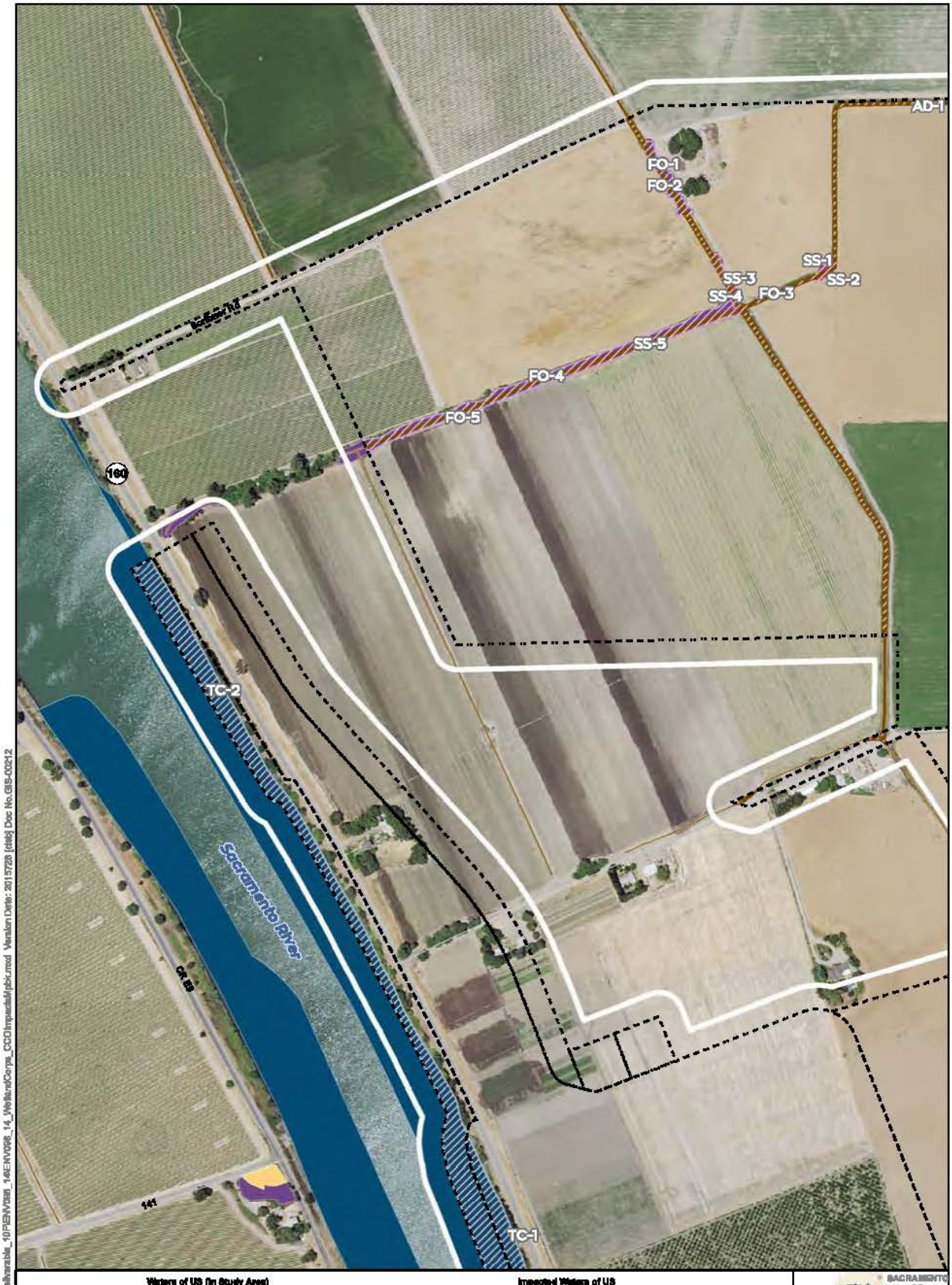


Sources: Conveyance Planning Area reds (DWR 2016); Wetlands (DWR 20150821); NAIP 2014

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Sources: CM1 Wetland Study Area (DWR 2015), Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
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SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
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		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
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SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,091 acres

Project Area
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Subsurface Impact

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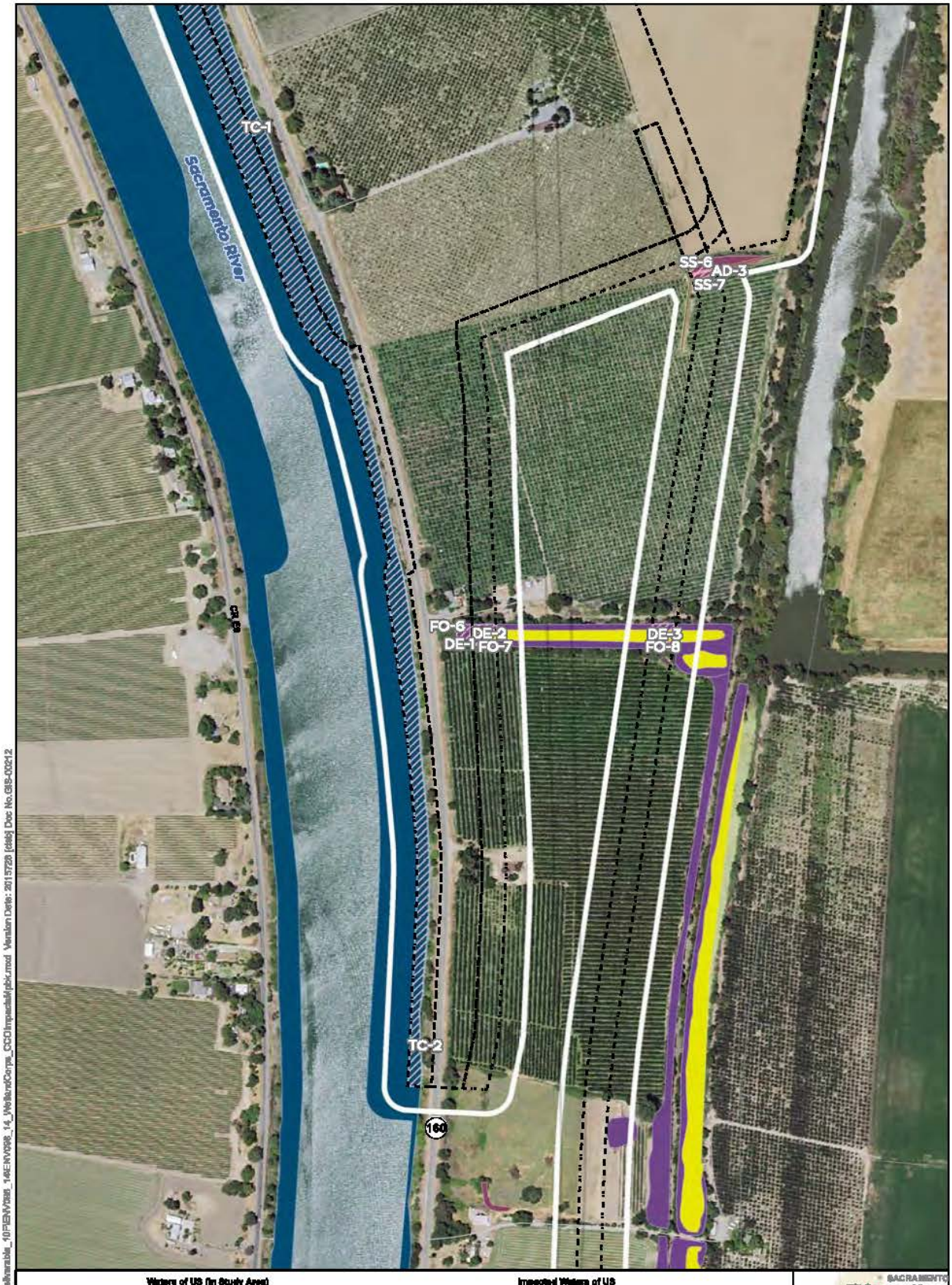
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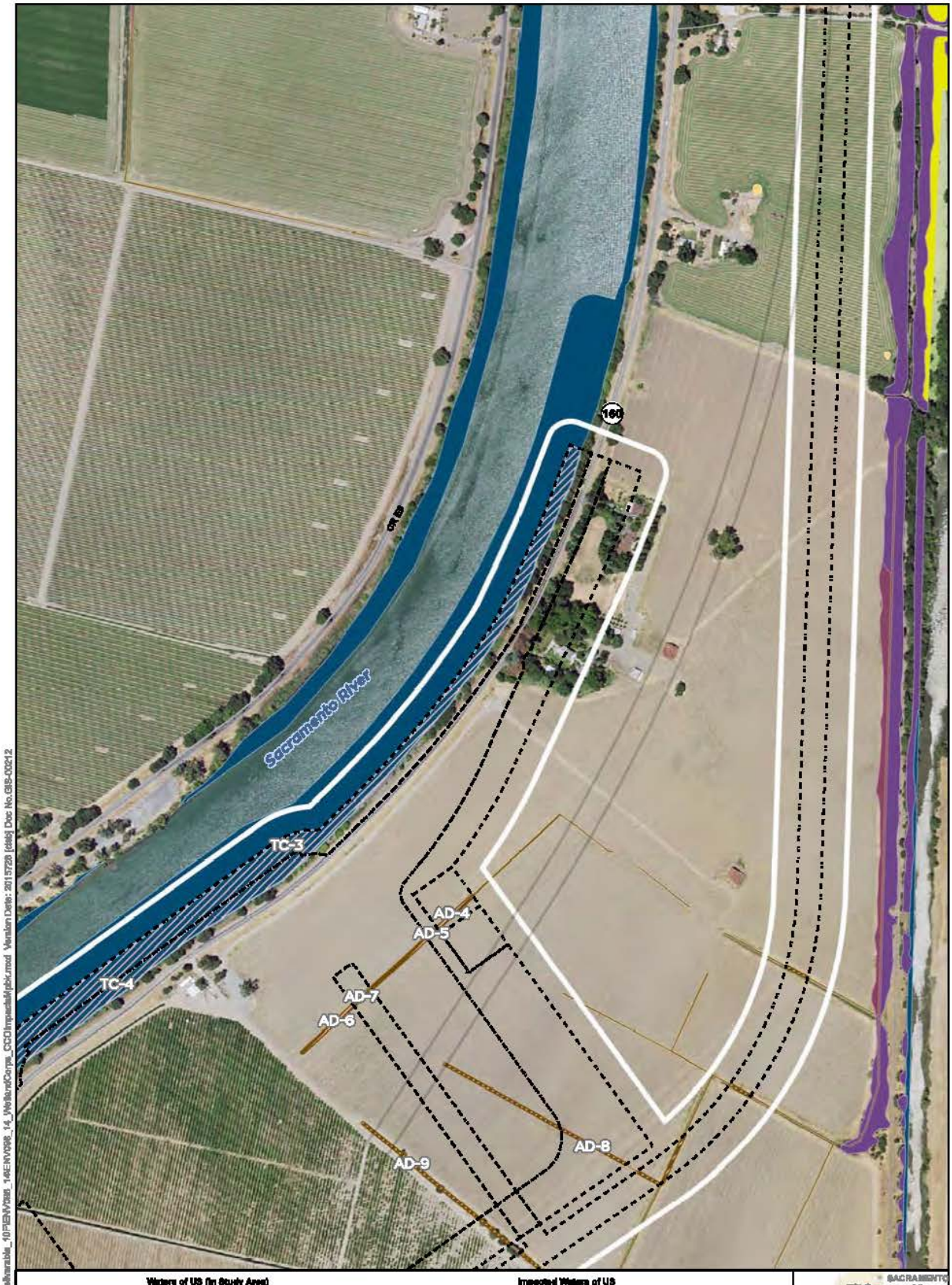
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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Waters of US (in Study Area)

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		temporary	1,031 acres

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Subsurface Impact

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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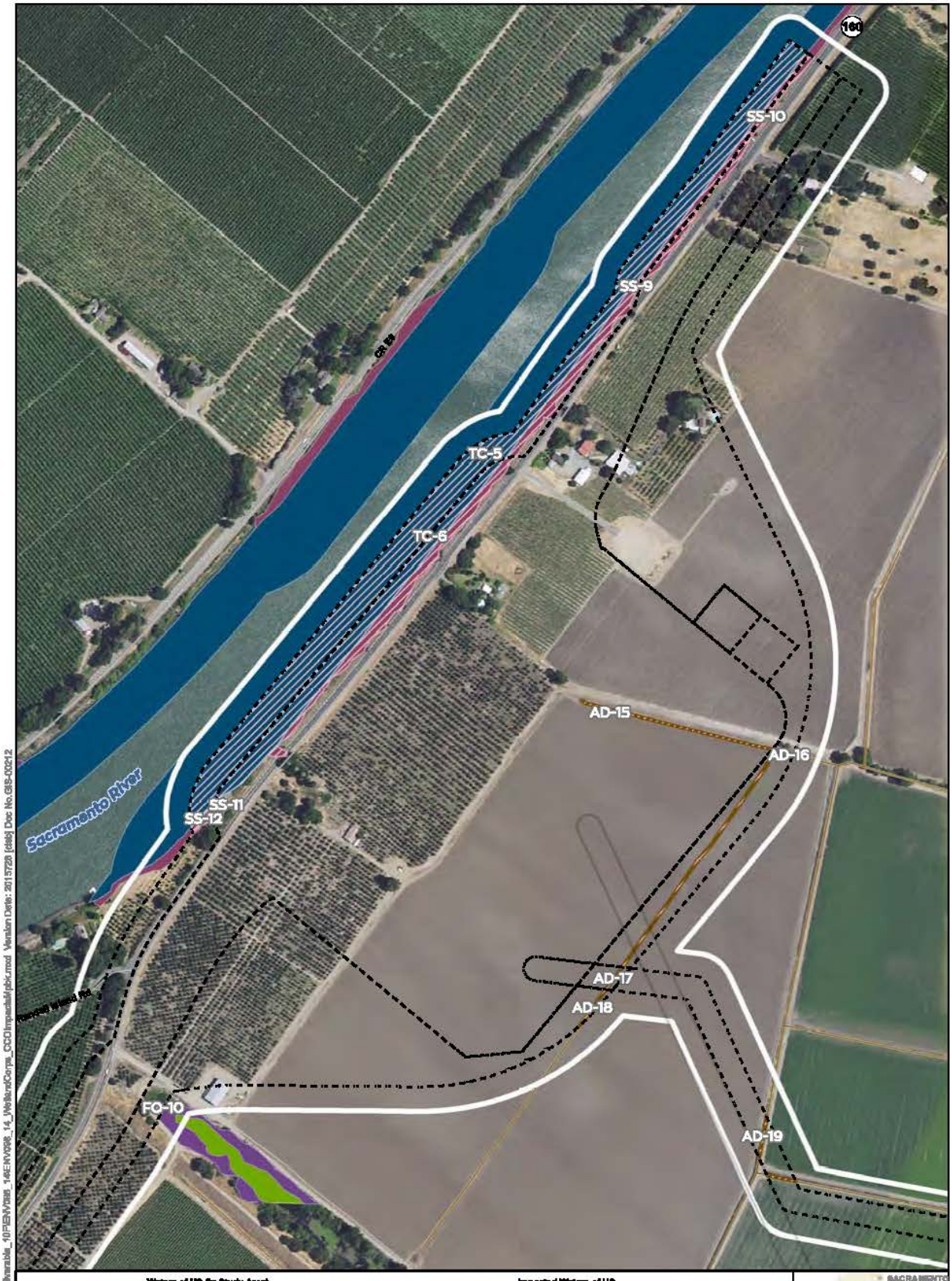
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Waters of US (in Study Area)

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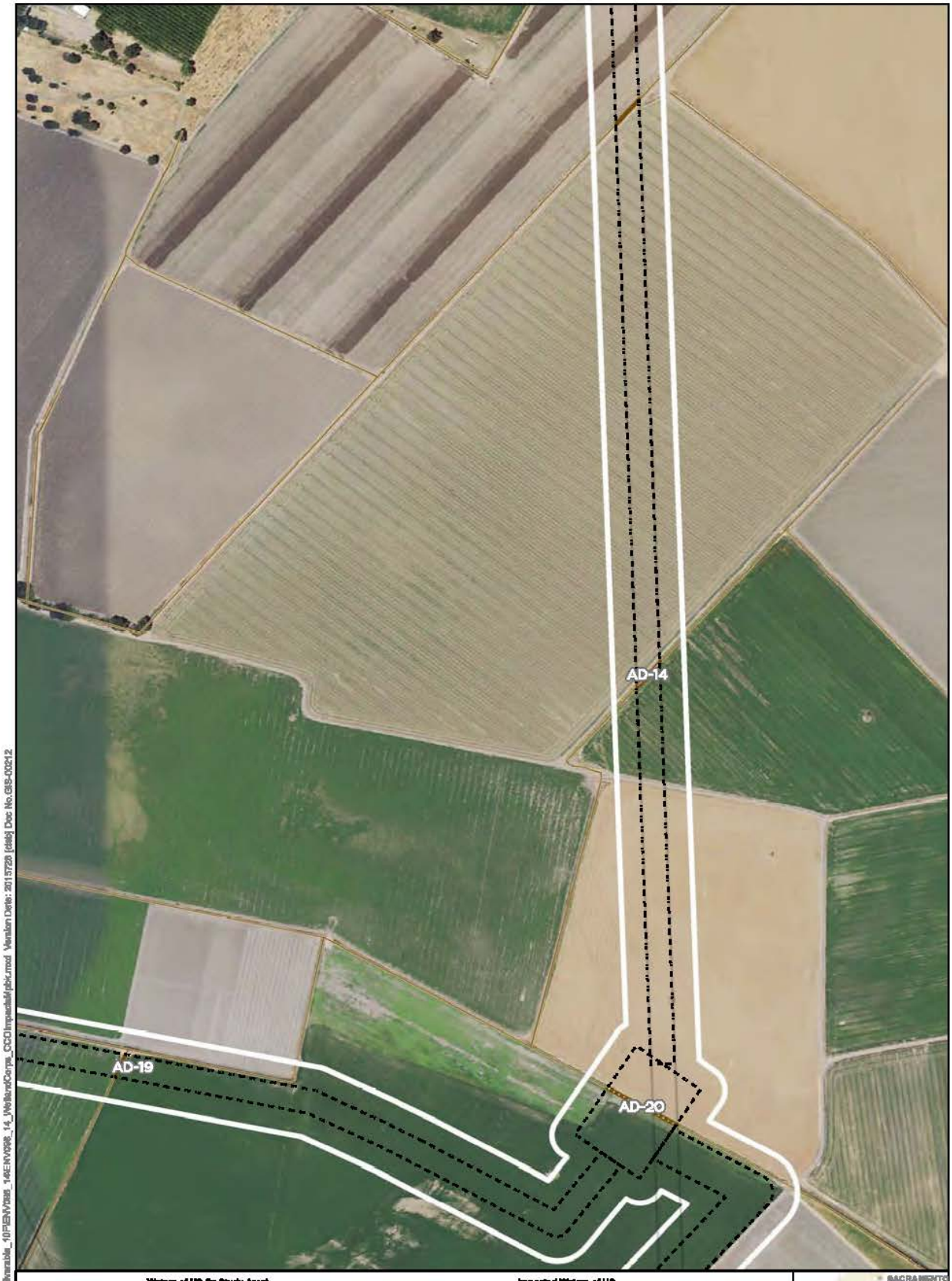
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Waters of US (in Study Area)

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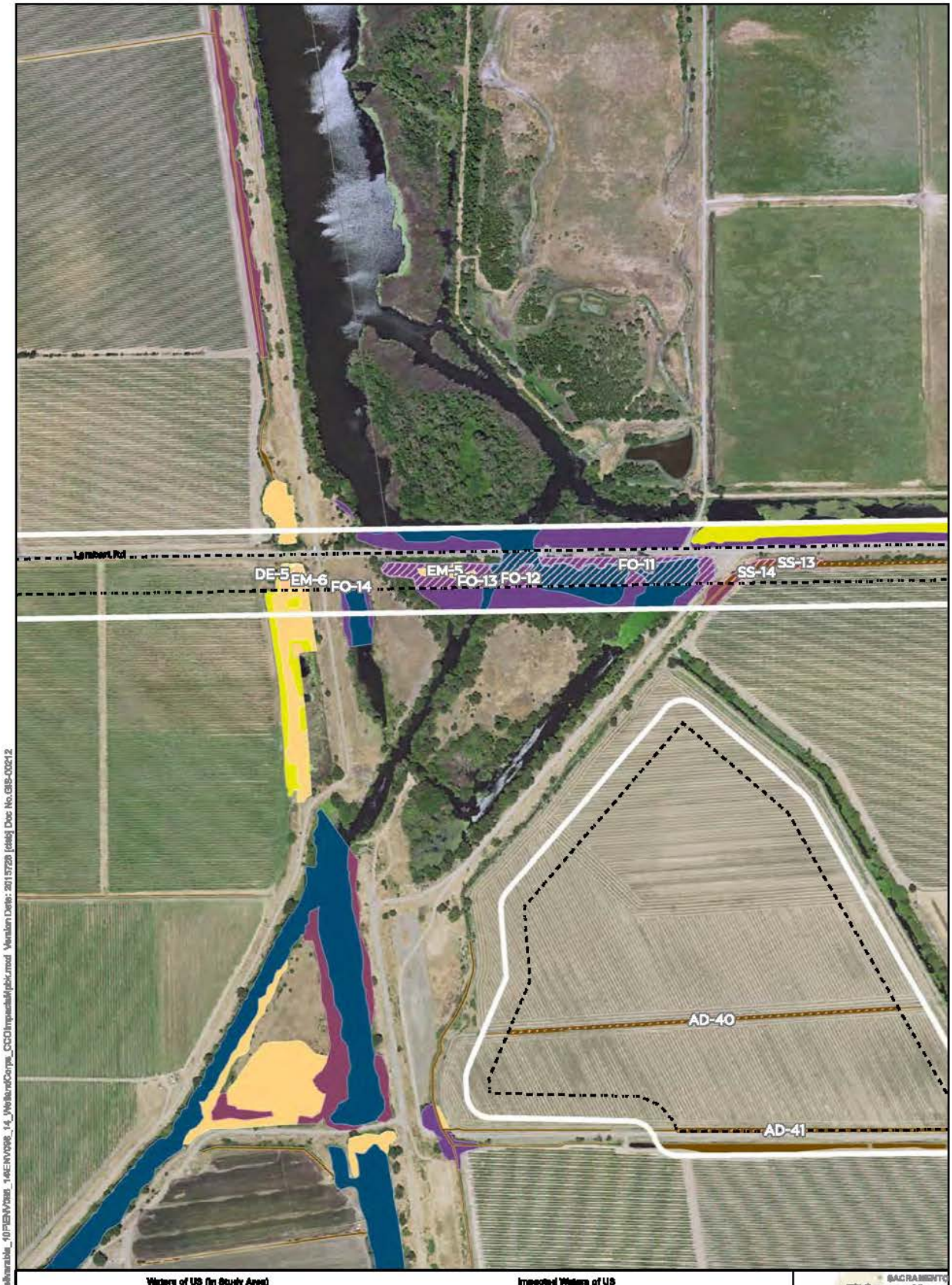
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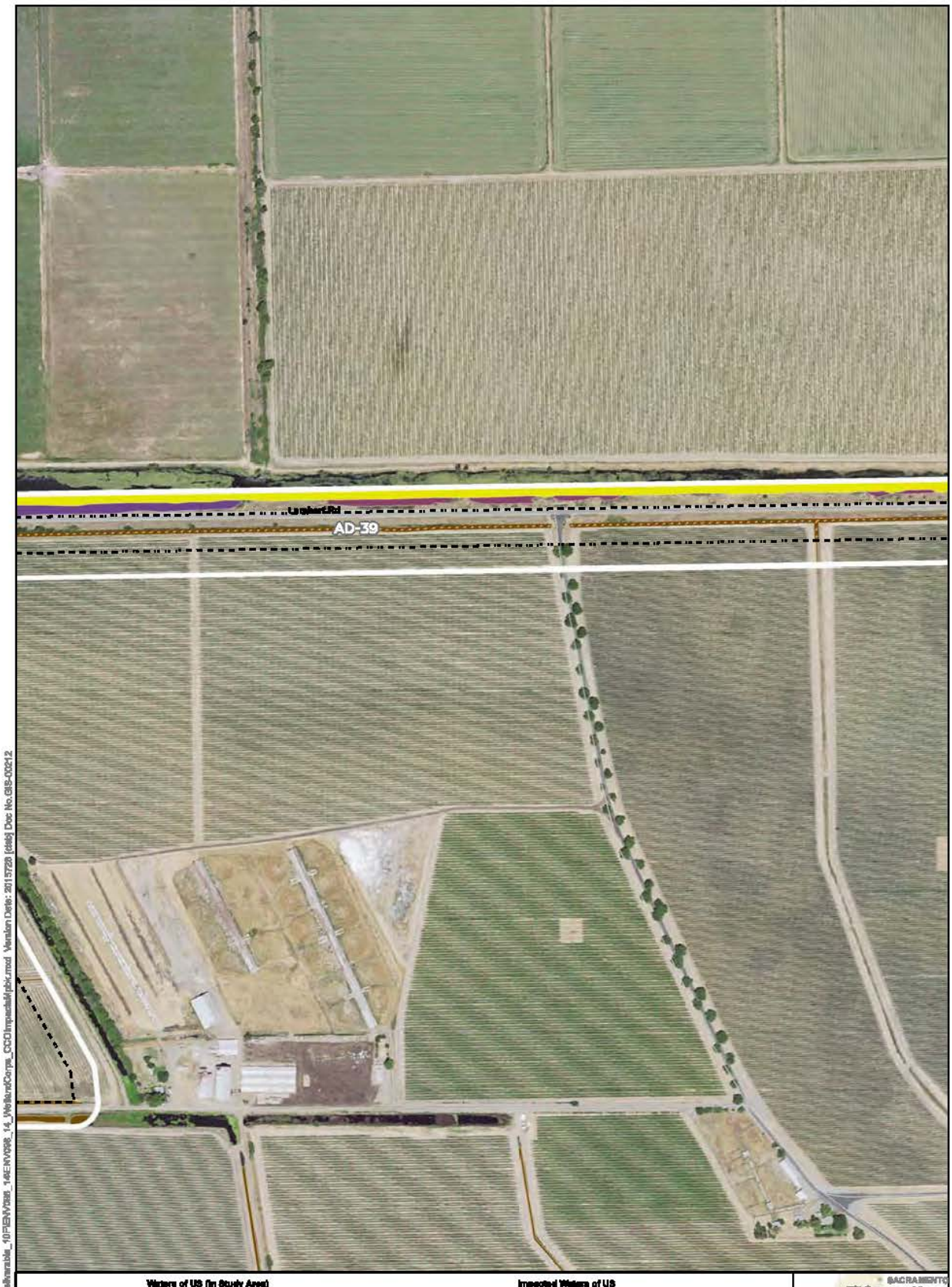
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 13 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area

Conveyance Footprint
Surface Impact
Subsurface Impact

N
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Feet
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 14 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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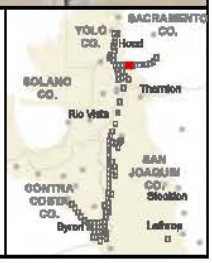
Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres



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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

Prepared by:
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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area

Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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Feet
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 16 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 17 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

0 200 400 Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres



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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER.

Sheet 19 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	163 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 21 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	156 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	54 acres
SS (Scrub Shrub)	25 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.5 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area

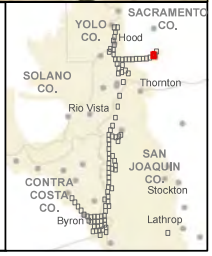
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
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Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	18 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	100 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,931 acres



Sources: CM1 Wetland Study Area (DWR 2015), Wetlands and Other Waters of US Impacts (DWR 20150601); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE CLEAN WATER

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Sources: CM1 Wetland Study Area (DWR 2015), Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 24 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,091 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
1:4,800



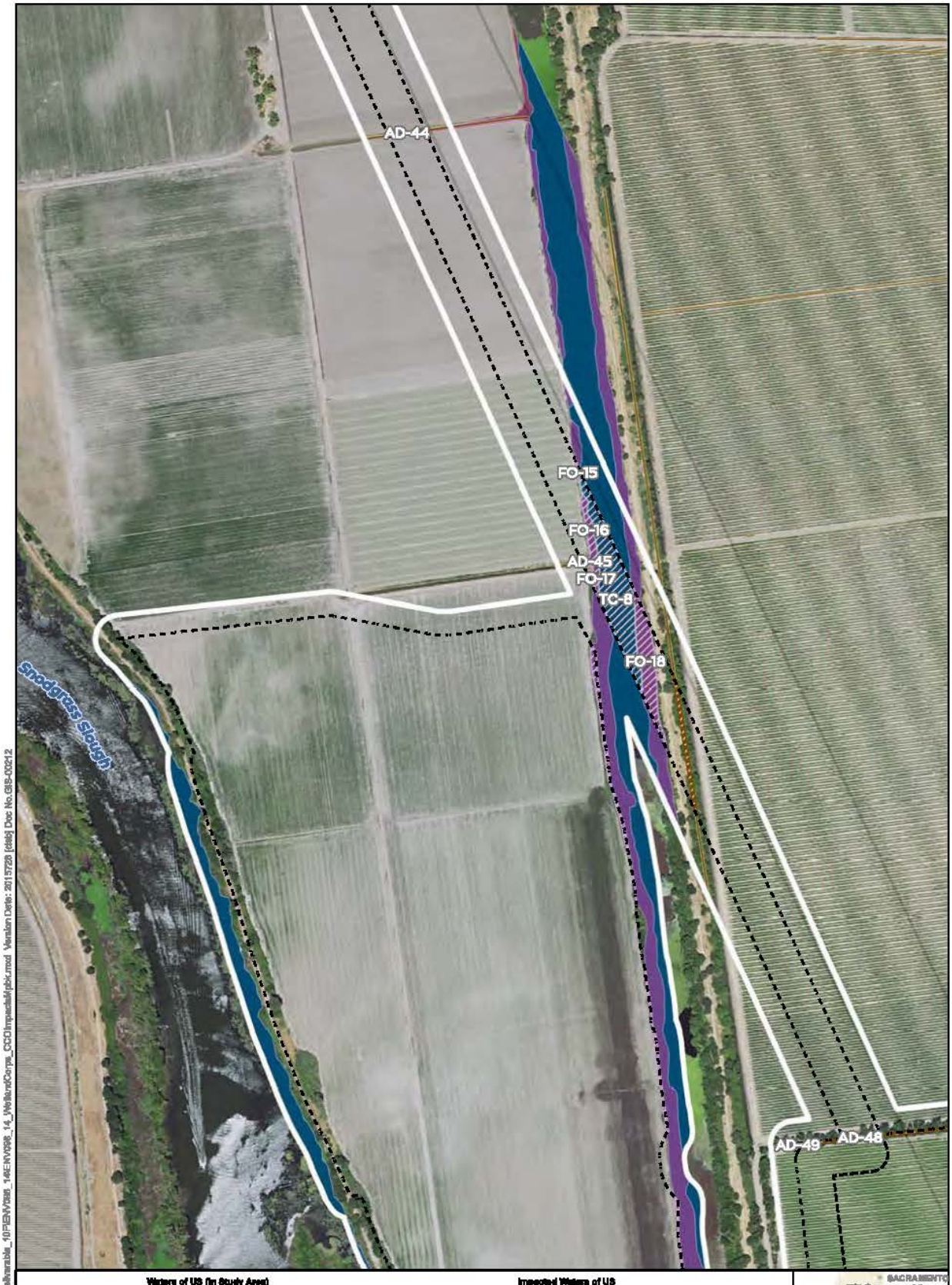
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 25 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	166 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 200 400
Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 26 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

N
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Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015), Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 27 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 250 500
Feet
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

Prepared by:
Division of Environmental Services
Department of Water Resources
3500 Industrial Blvd.
West Sacramento, CA 95691

CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area

Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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Feet
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 29 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
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Impacted Waters of US

Wetlands		Other Waters of US	
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		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
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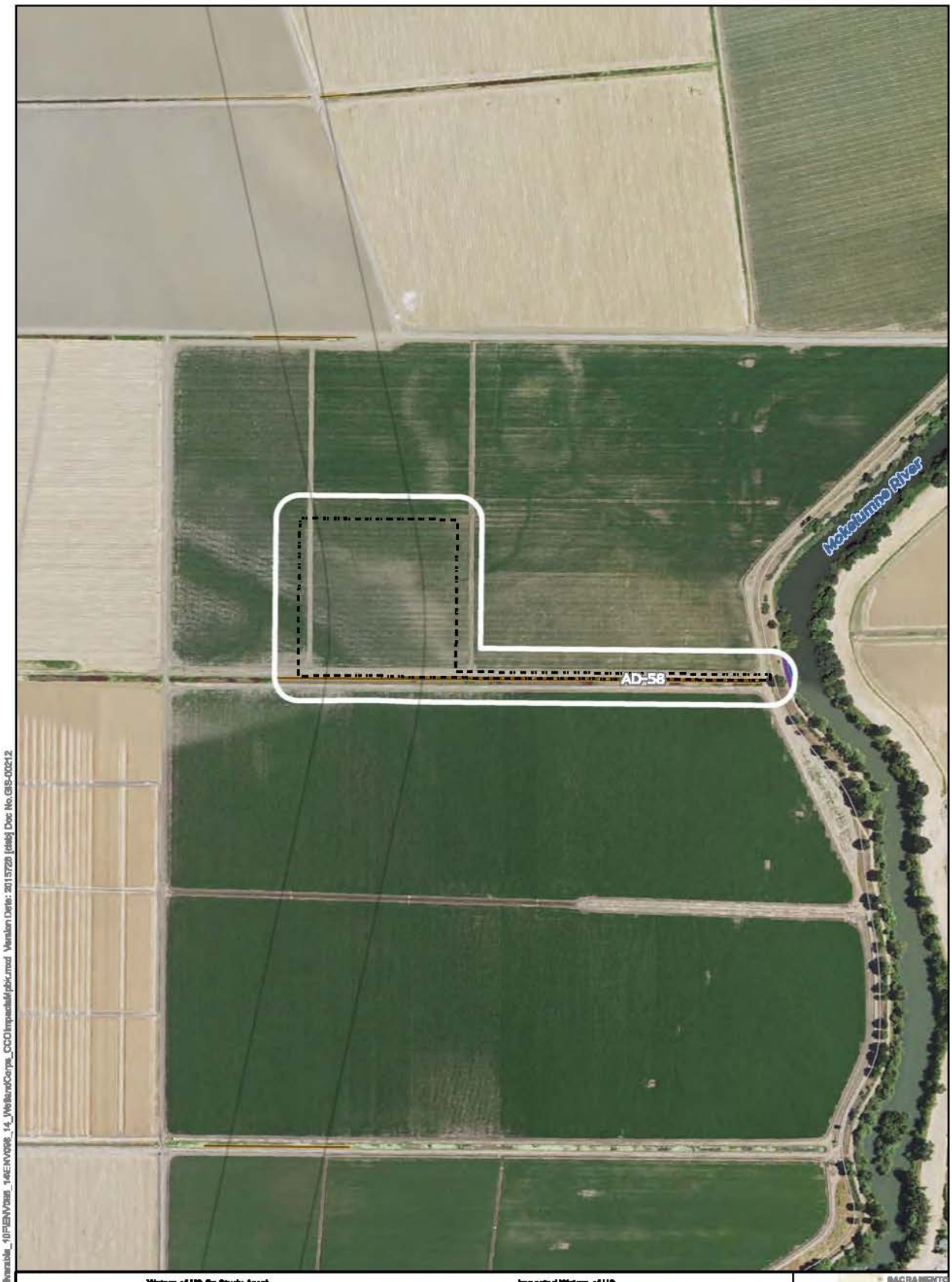


Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 30 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
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SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	163 acres	CO (Conveyance)	32 acres
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Impacted Waters of US

Wetlands		Other Waters of US	
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		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 31 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
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Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
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VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres



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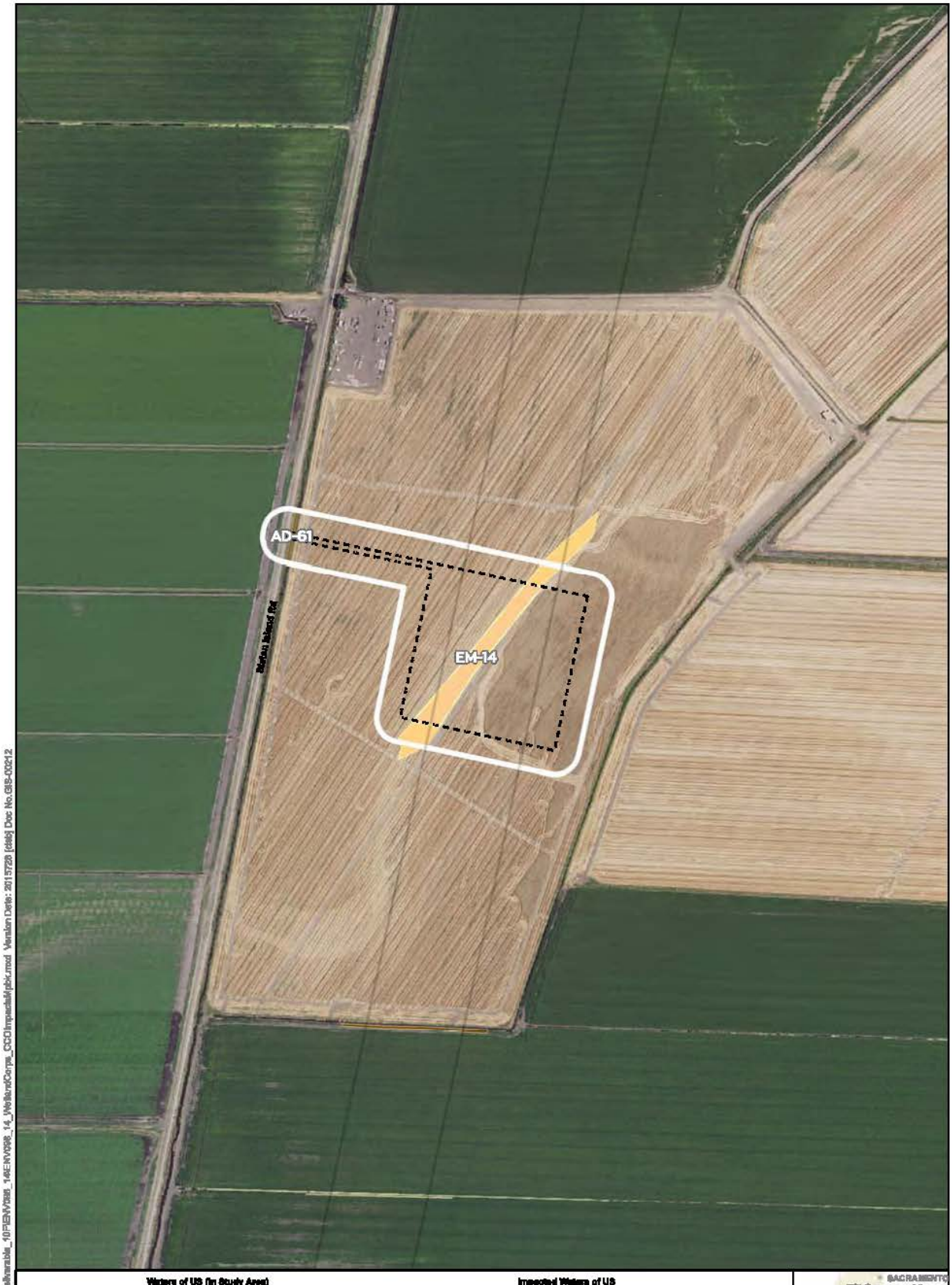
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
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SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
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VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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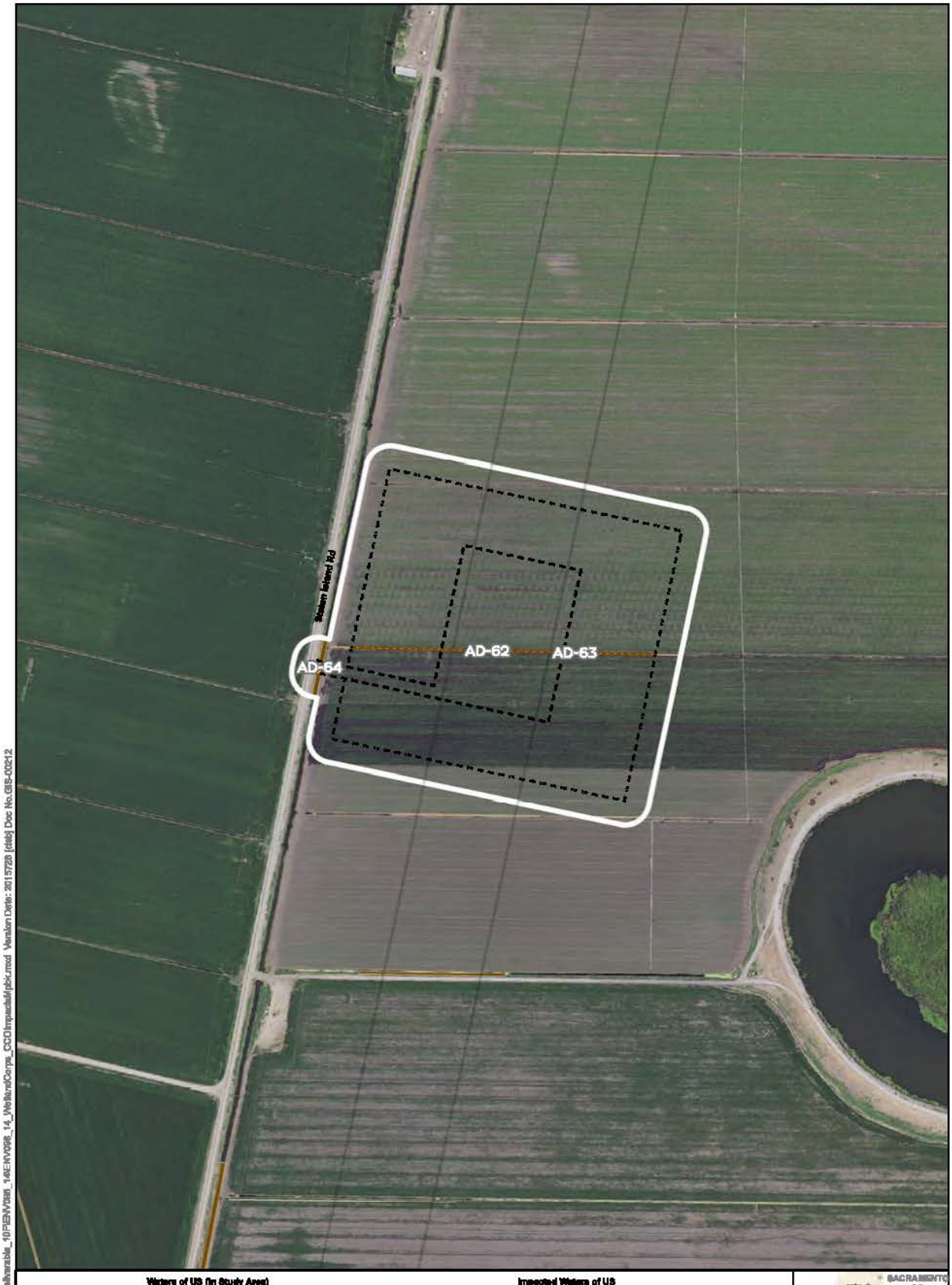
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 33 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
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Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
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		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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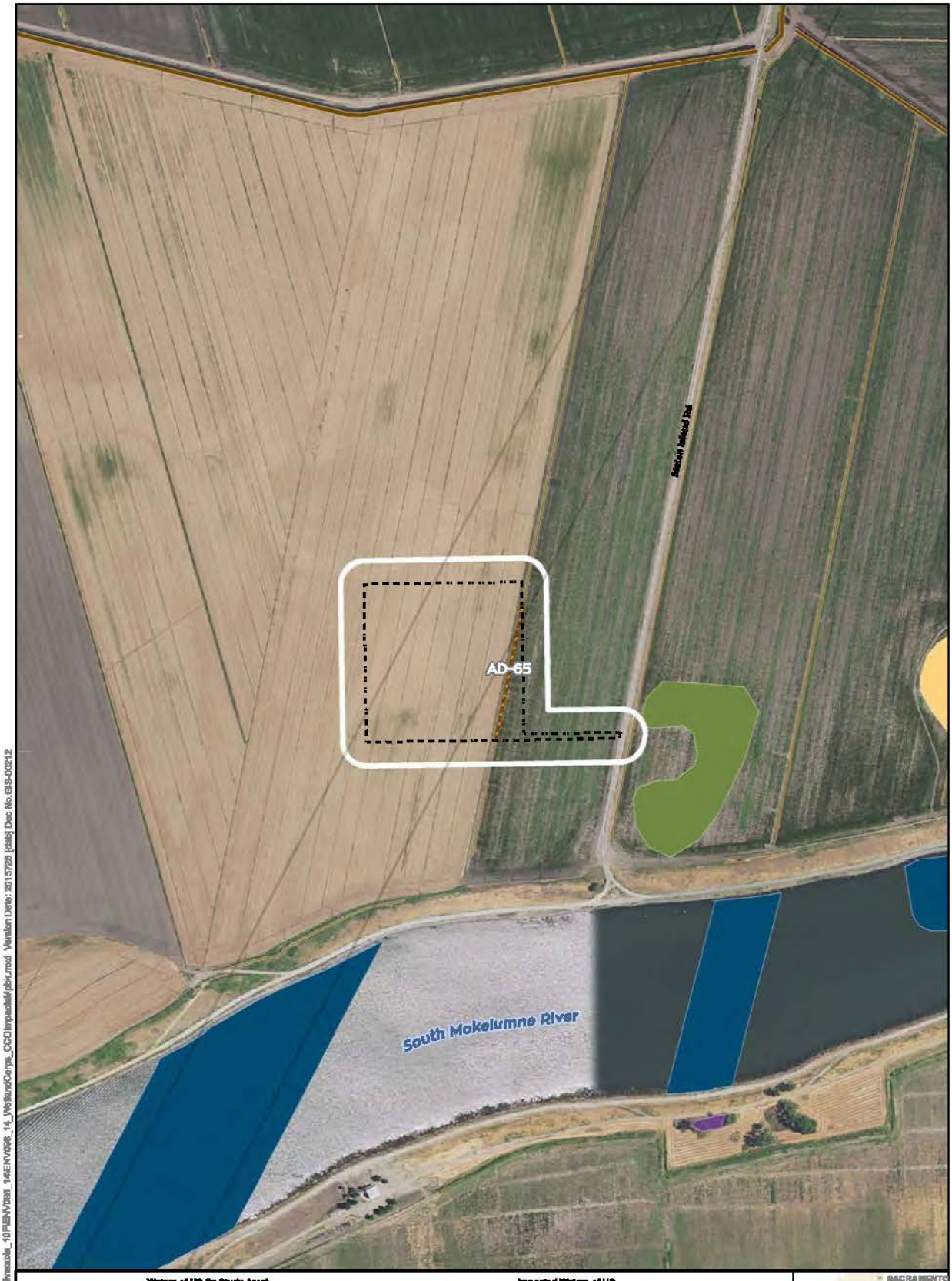
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 34 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,091 acres



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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 35 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	166 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area

Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
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SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 36 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	166 acres	CH (Natural Channel)	0 acres
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Project Area
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Conveyance Footprint
Surface Impact
Subsurface Impact

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 37 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
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Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

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		CCF (Clifton Court Forebay)	
		permanent	258 acres
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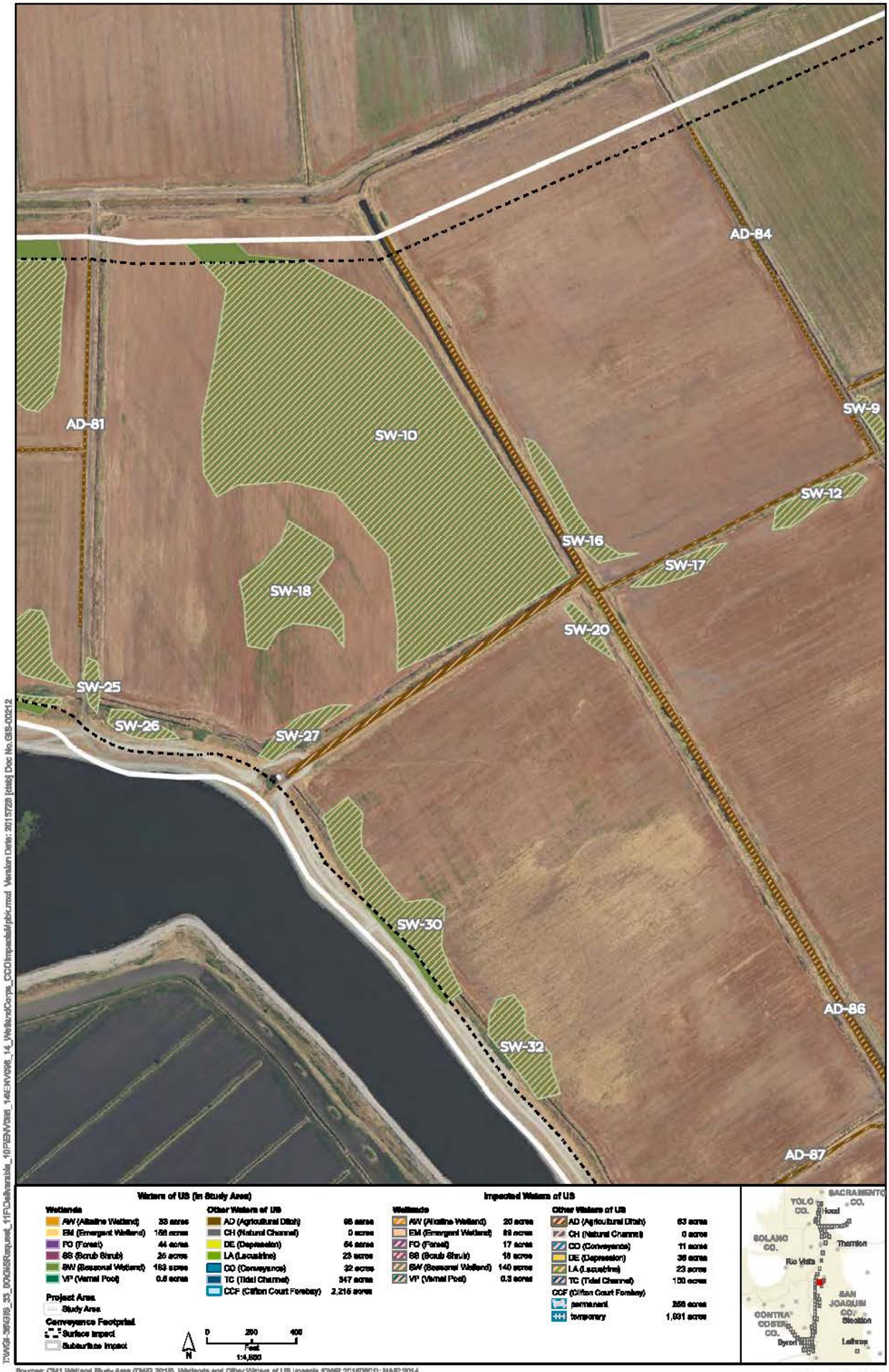
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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 38 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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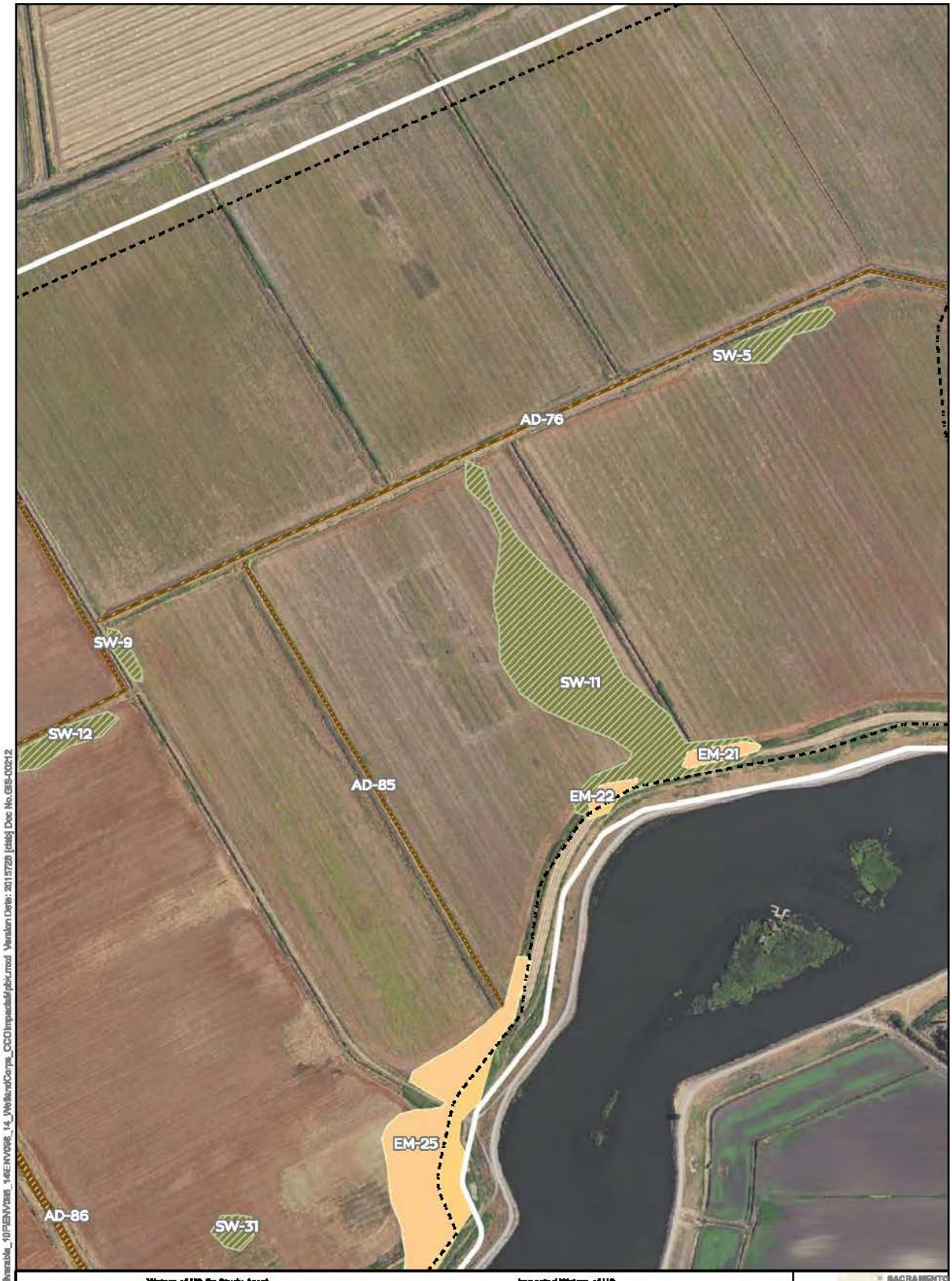


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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 39 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (In Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
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Impacted Waters of US

Wetlands		Other Waters of US	
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VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,091 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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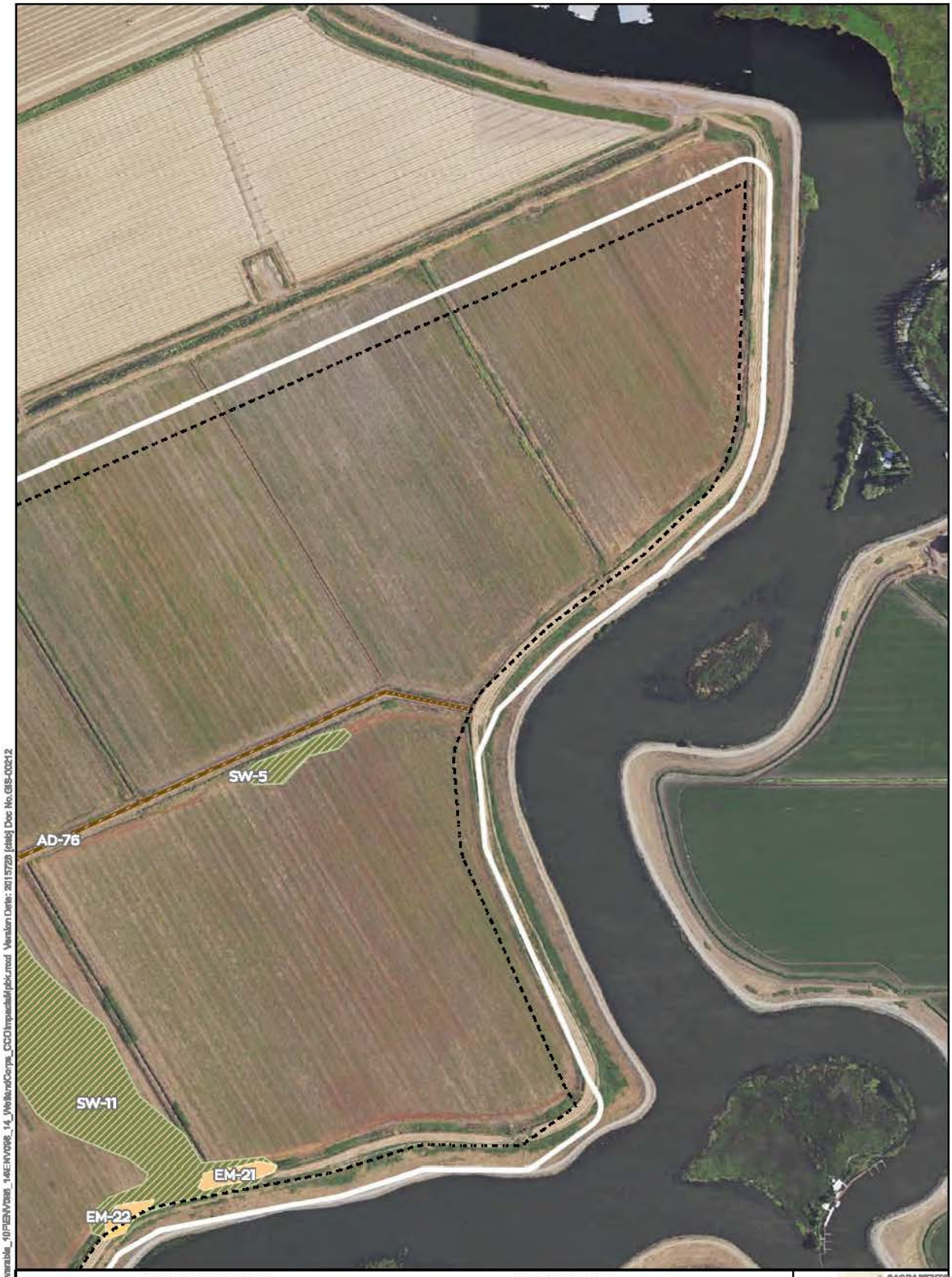
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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 40 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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Sources: CM1 Wetland Study Area (DWR 2015), Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

Prepared by:
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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

Prepared by:
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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 42 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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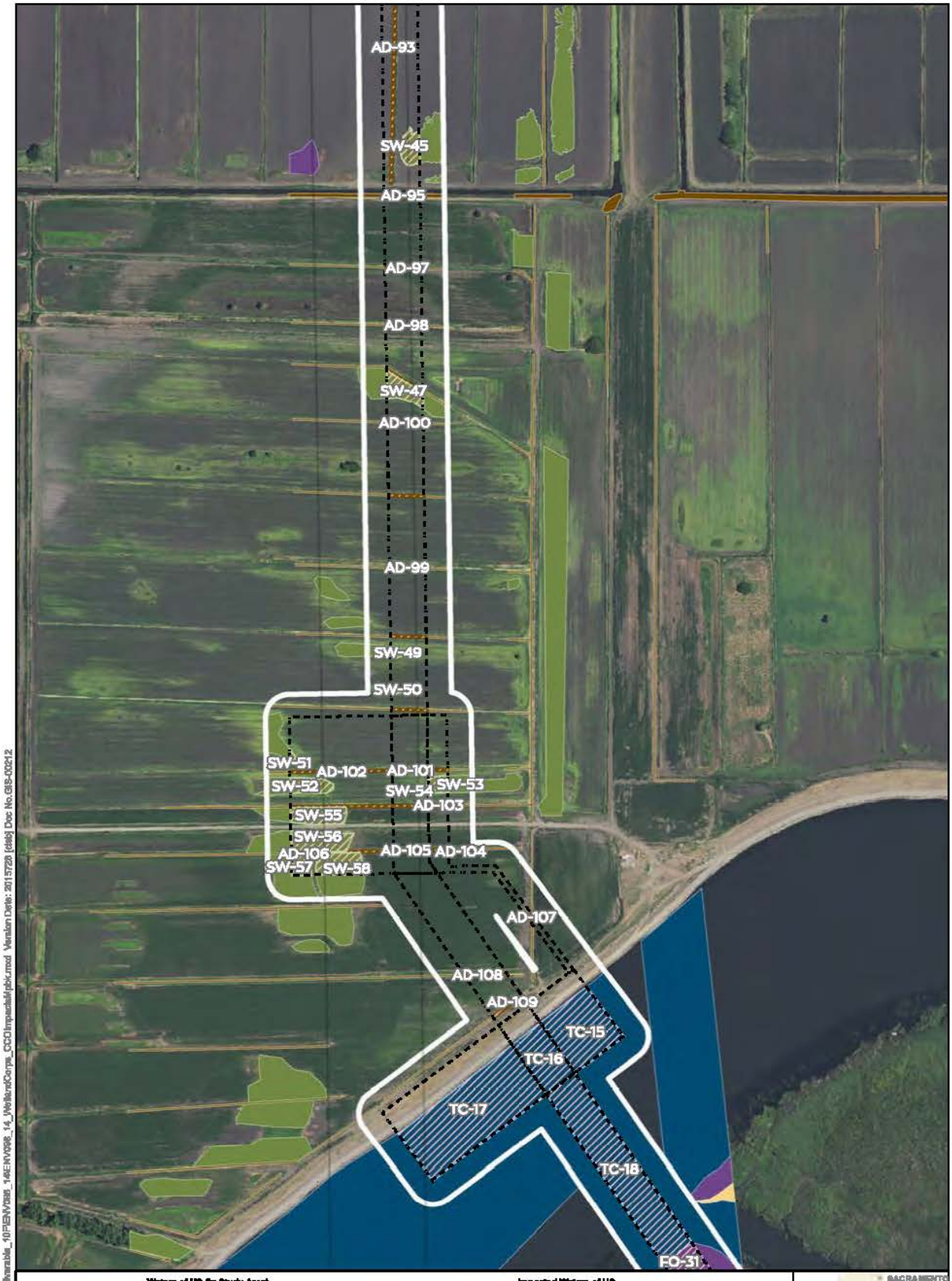
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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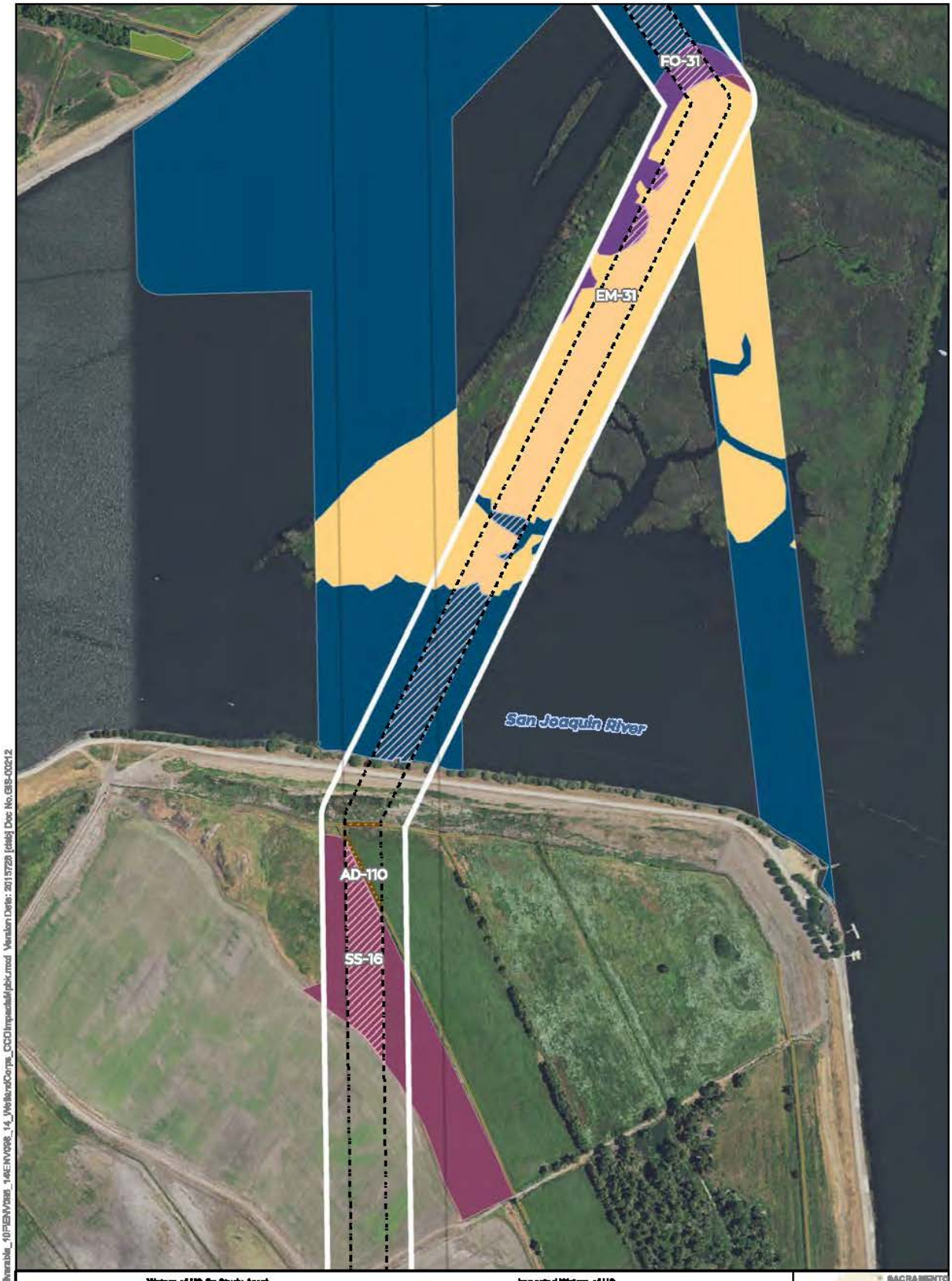


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CALIFORNIA WATER FIX
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Sheet 44 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	163 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
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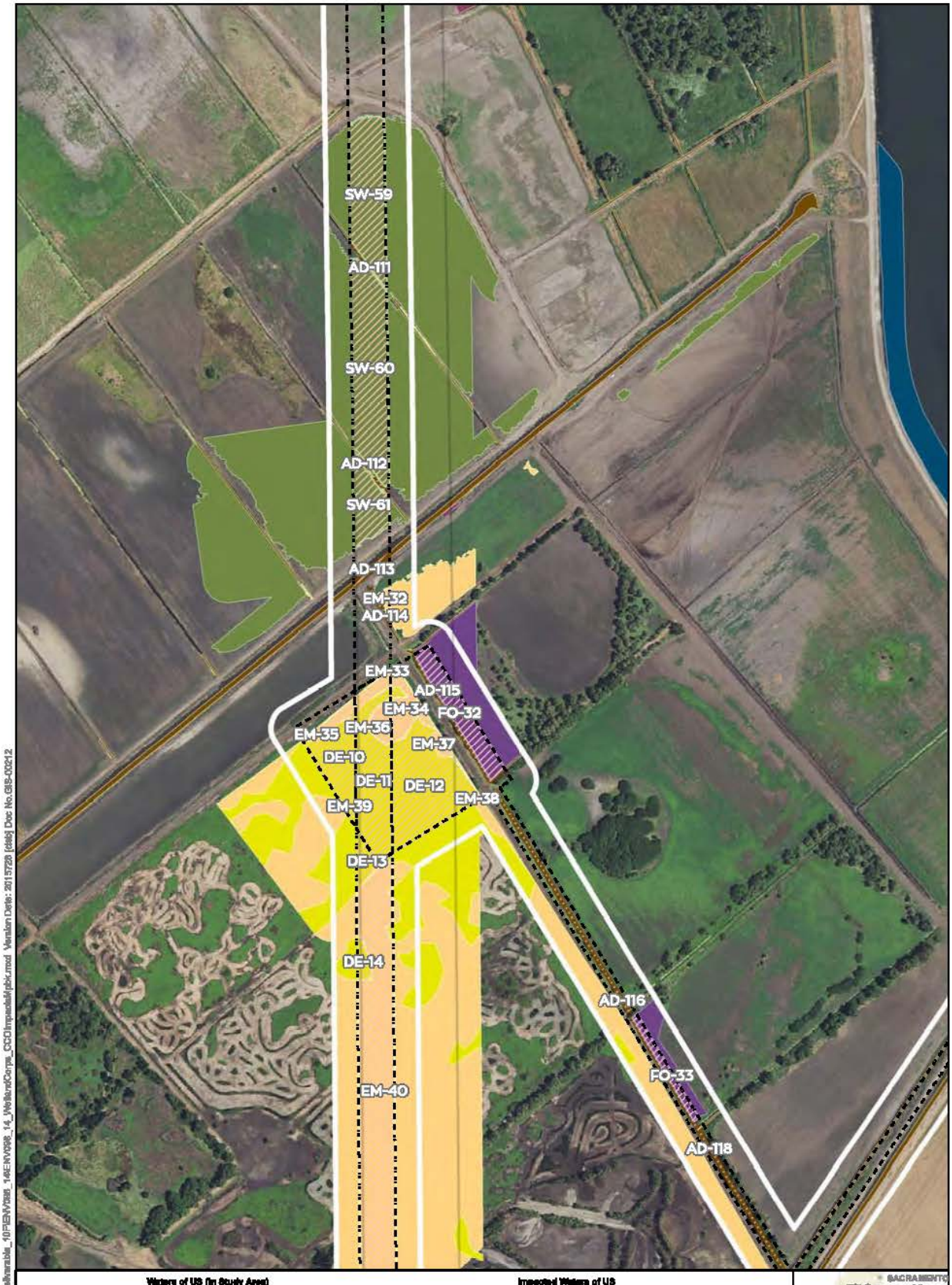


Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 45 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,091 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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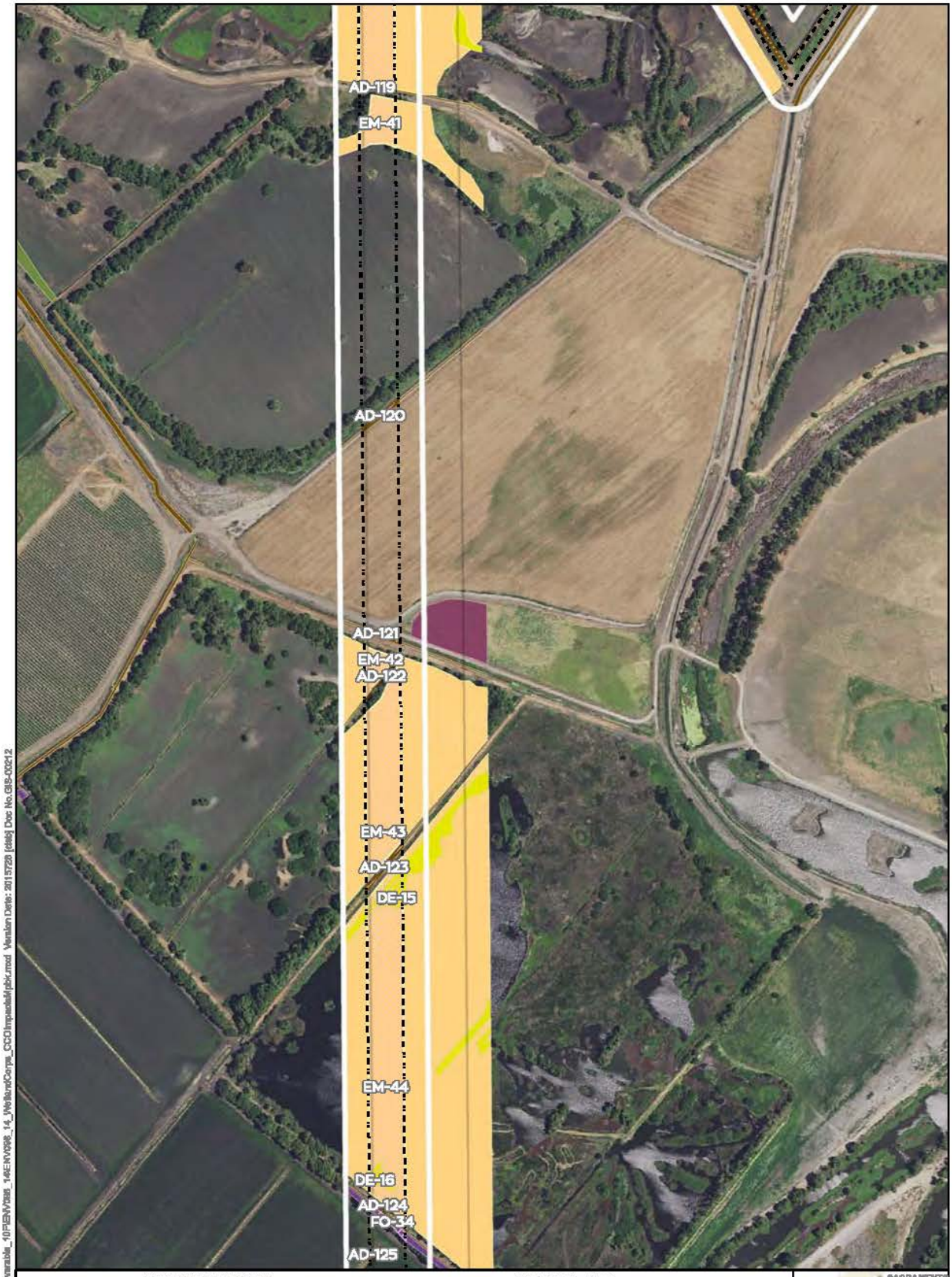


Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,216 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres



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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER.

Sheet 47 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	166 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area

Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,091 acres



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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	166 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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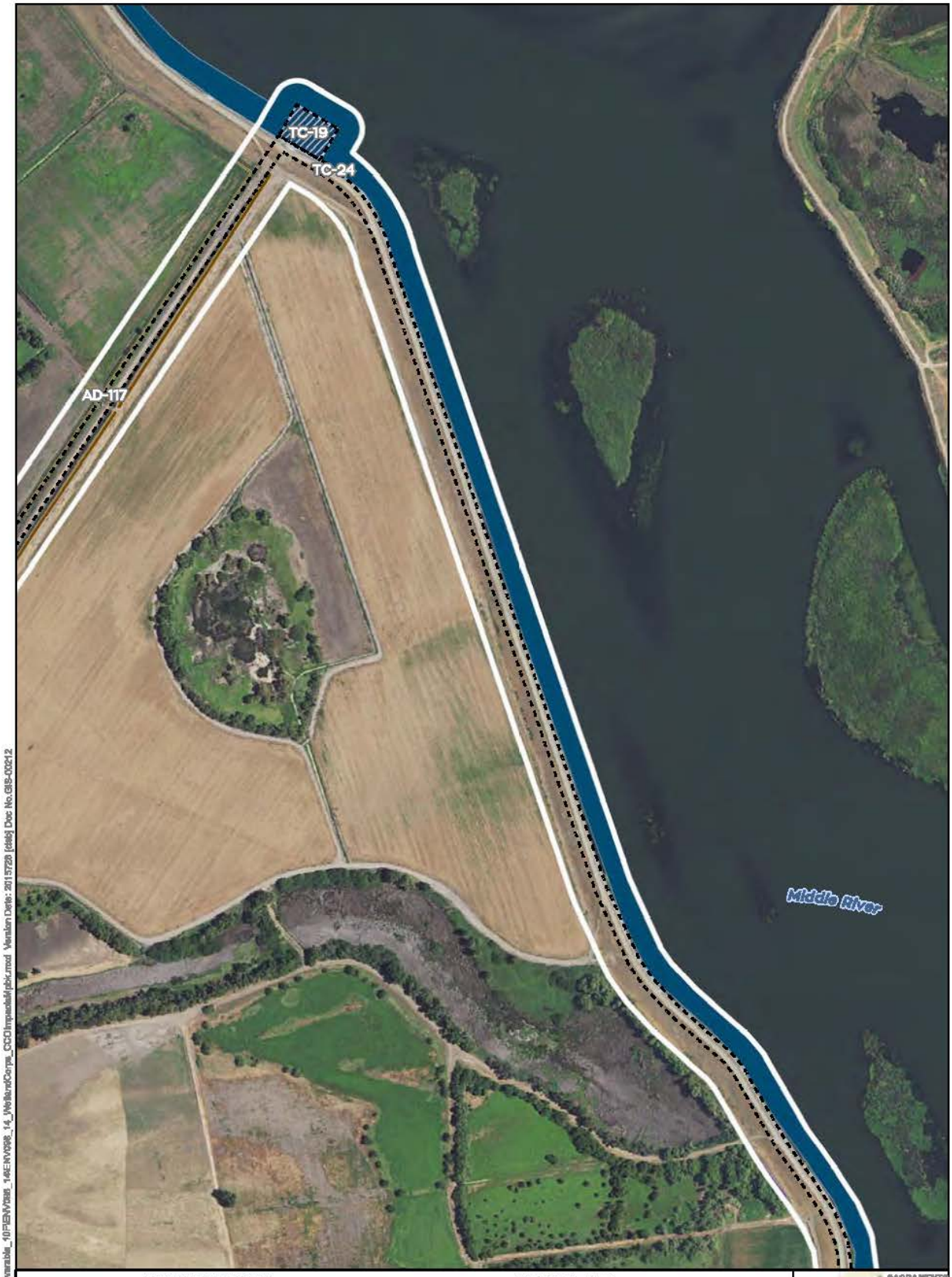
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 49 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 50 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	166 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	163 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
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VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 51 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (In Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
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VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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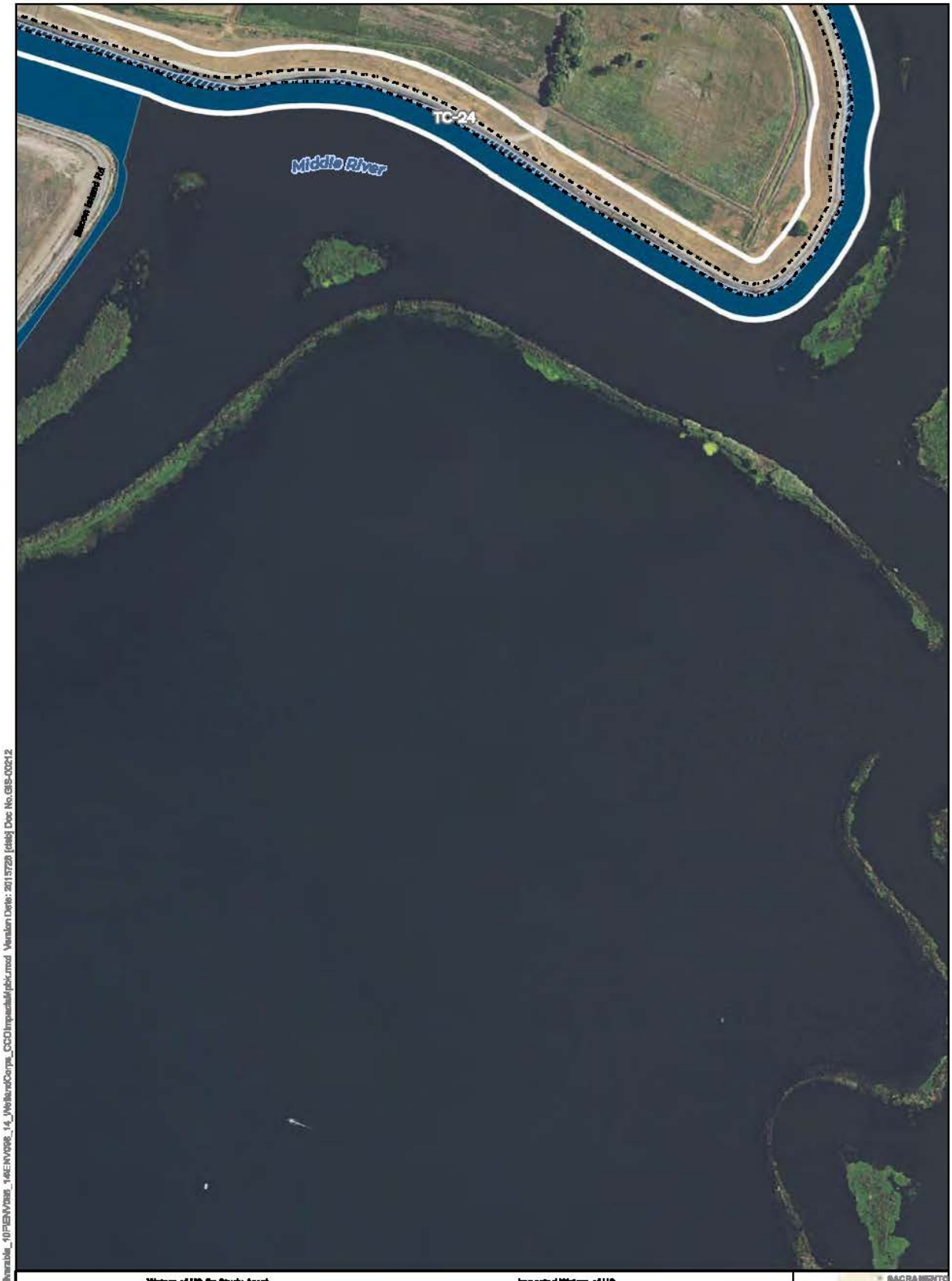
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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 52 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 53 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
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Sheet 54 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
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VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area

Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
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SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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Department of Water Resources
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West Sacramento, CA 95691

CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 55 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 200 400
Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
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Sheet 56 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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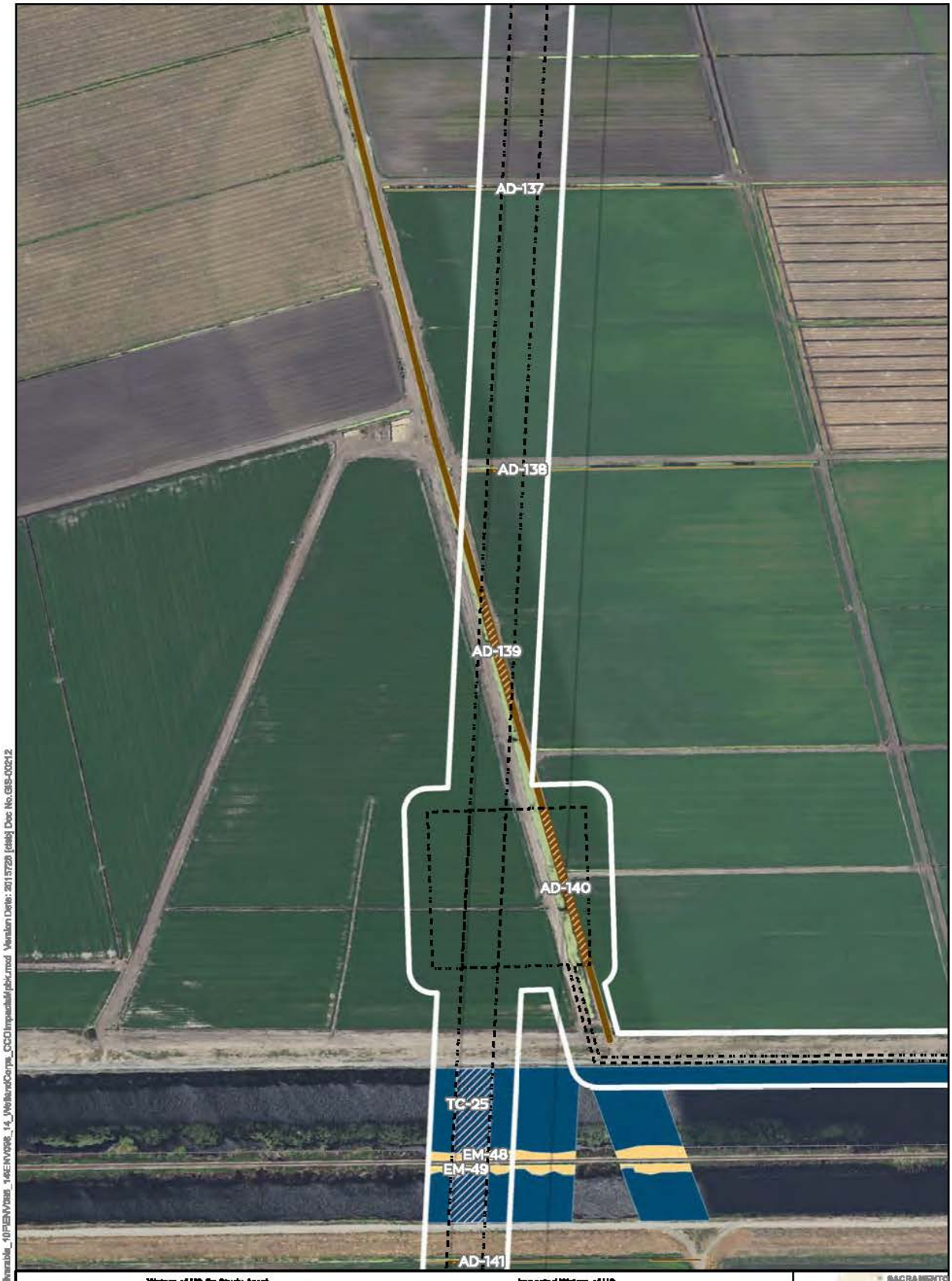


Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 57 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 200 400
Feet
1:4,800



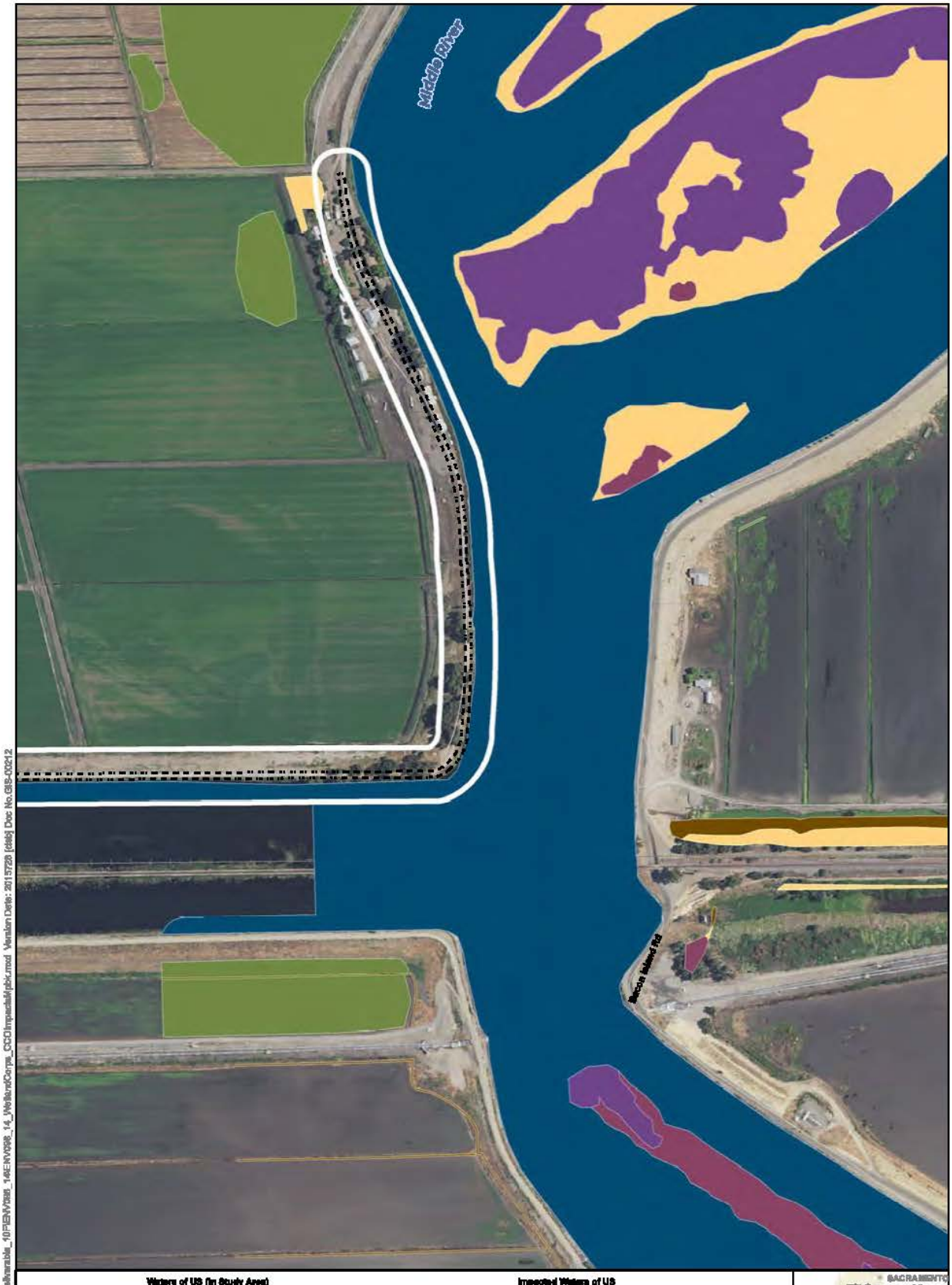
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 58 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 59 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (In Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 200 400
Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 60 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 250 500
Feet
1:4,800



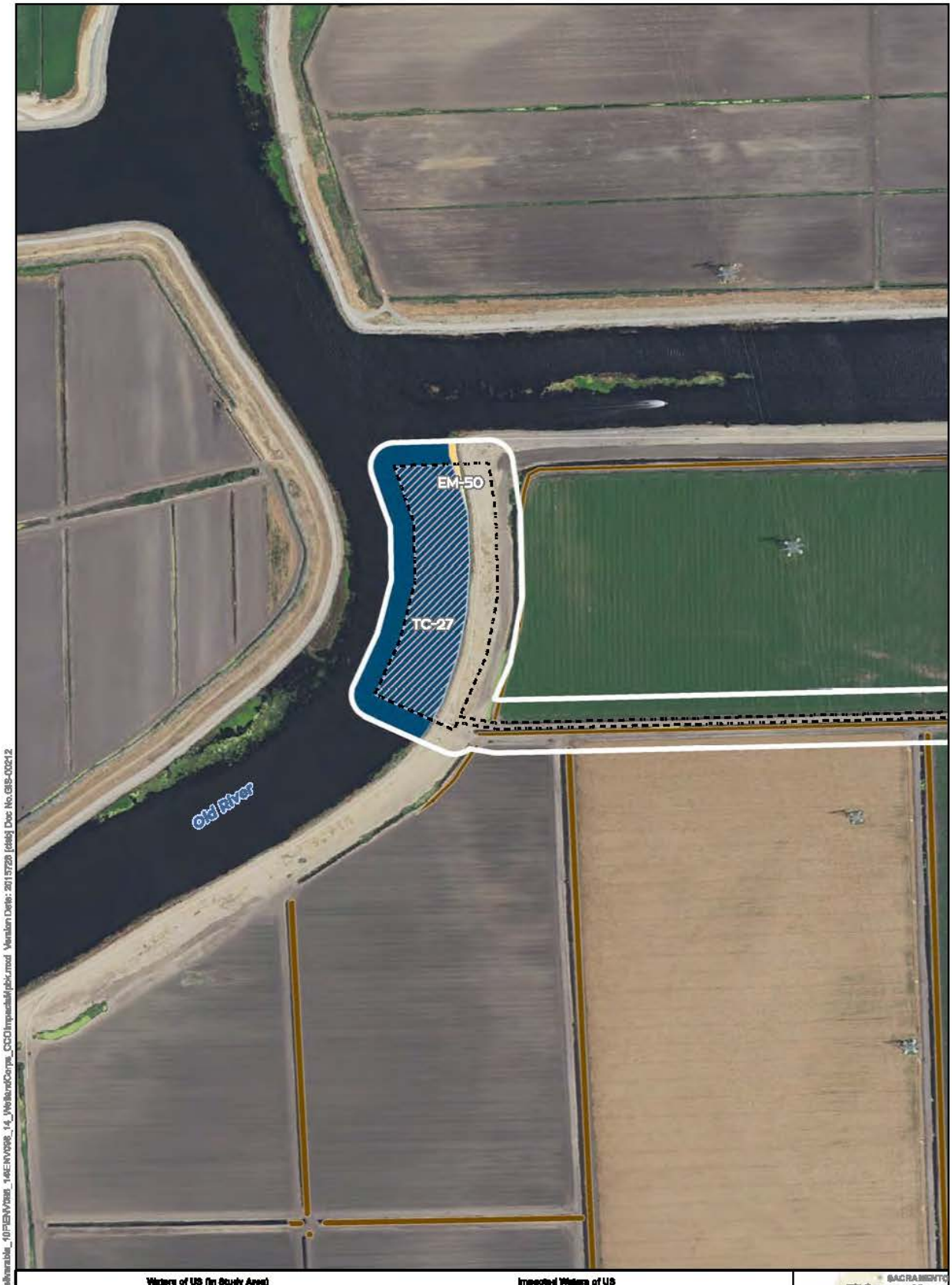
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 61 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	163 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,091 acres



N
0 250 500
Feet
1:4,800

Sources: CM1 Wetland Study Area (DWR 2015), Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

N
0 200 400
Feet
1:4,800



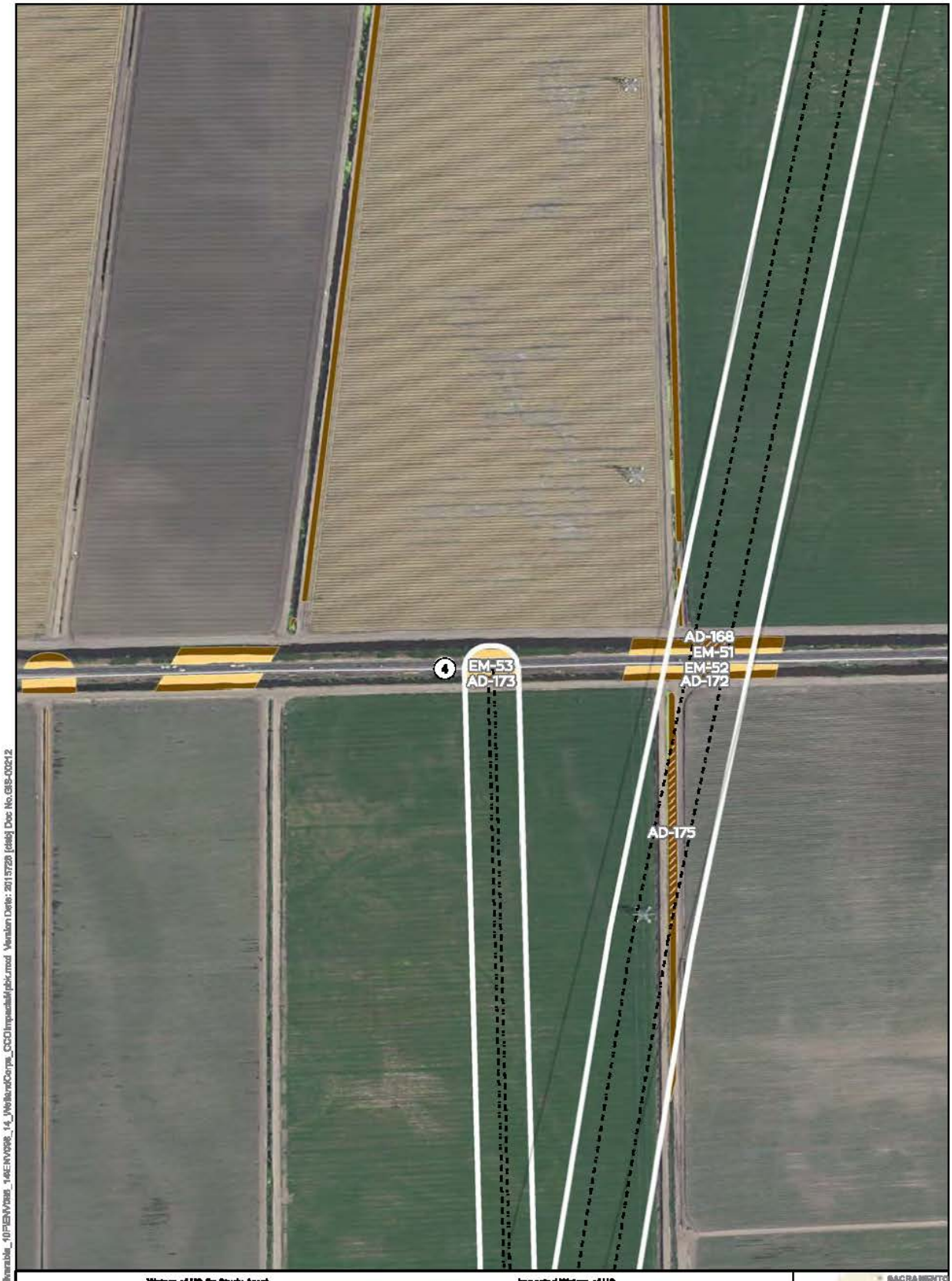
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 63 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (In Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,691 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 200 400
Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER.

Sheet 64 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres



N
0 250 500 Feet
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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RELIABLE. RESILIENT. WATER.

Sheet 65 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (In Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
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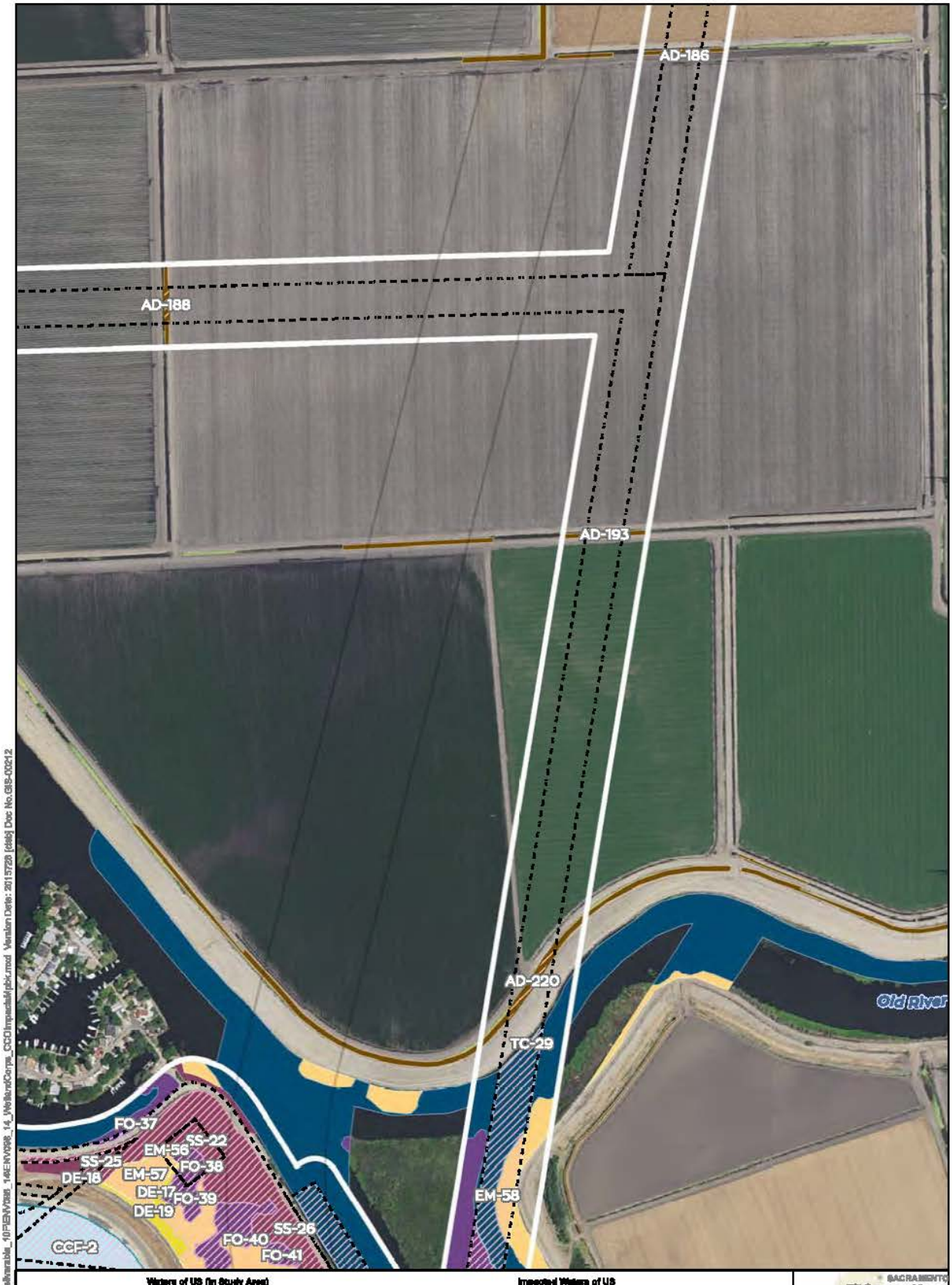
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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER.

Sheet 66 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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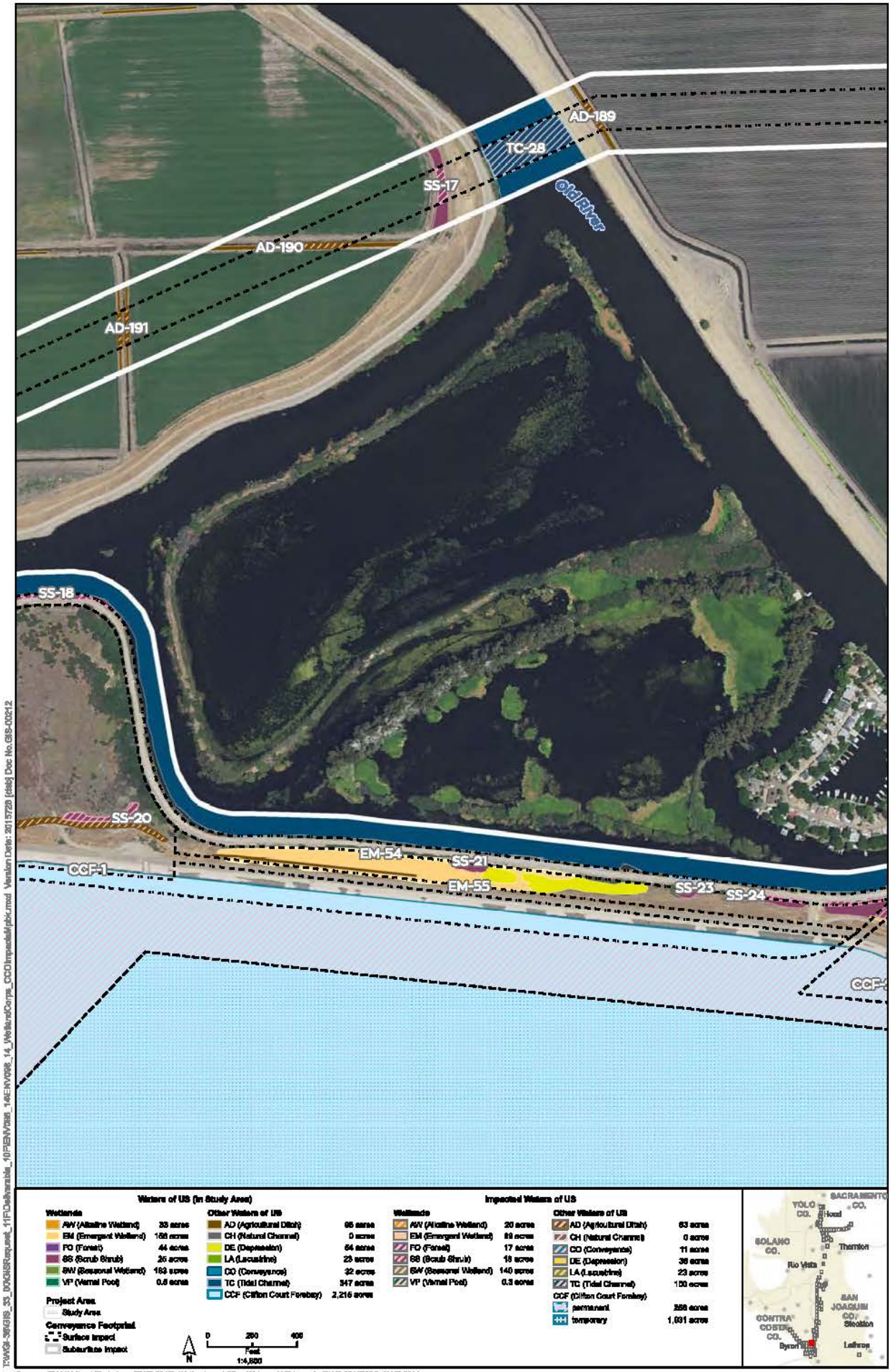


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Sources: CM1 Wetland Study Area (DWR 2015), Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 69 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 70 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (In Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 200 400
Feet
1:4,800



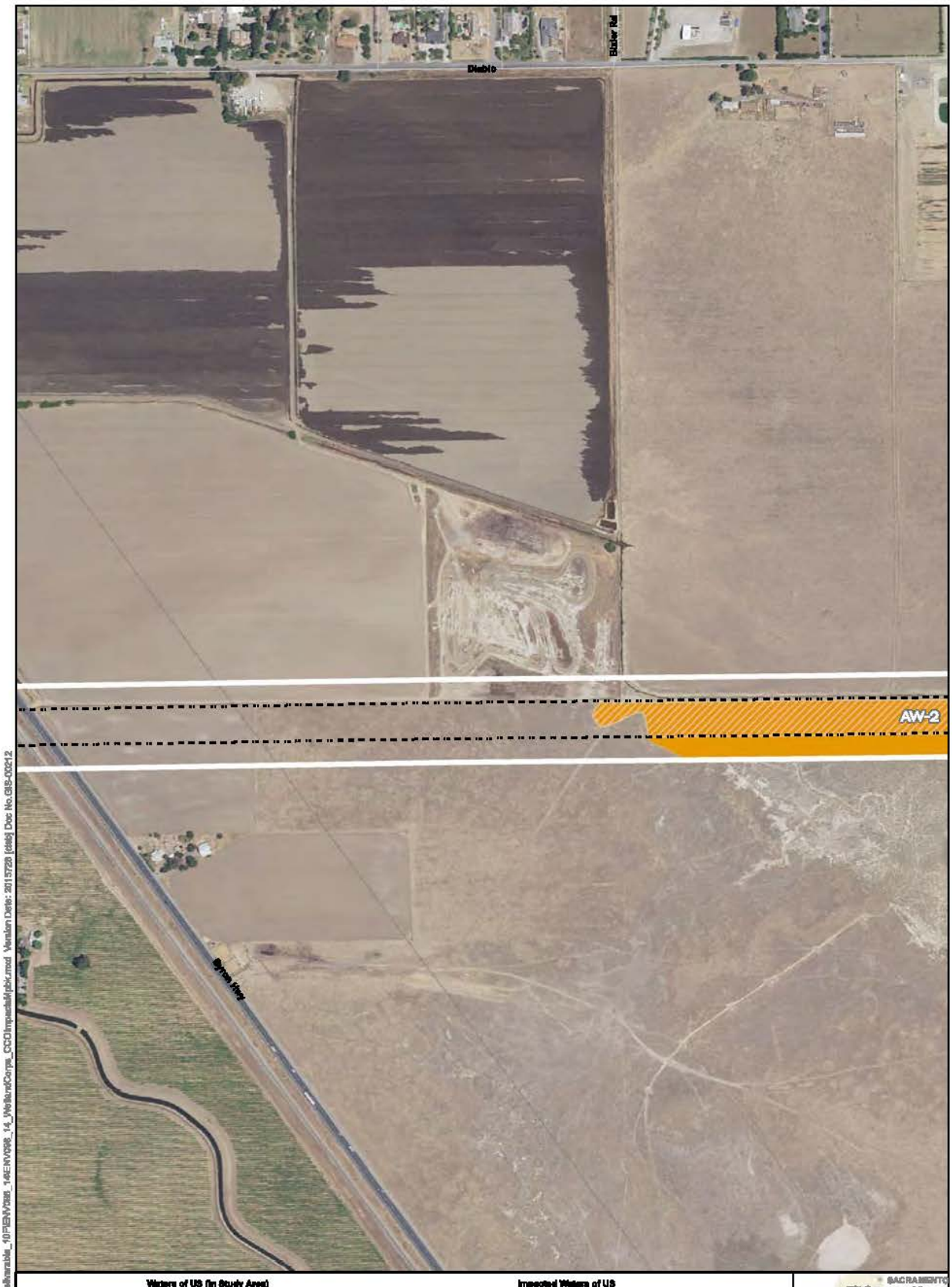
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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 71 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 200 400
Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

Prepared by:
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West Sacramento, CA 95691

CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (In Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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0 200 400
Feet
1:4,800



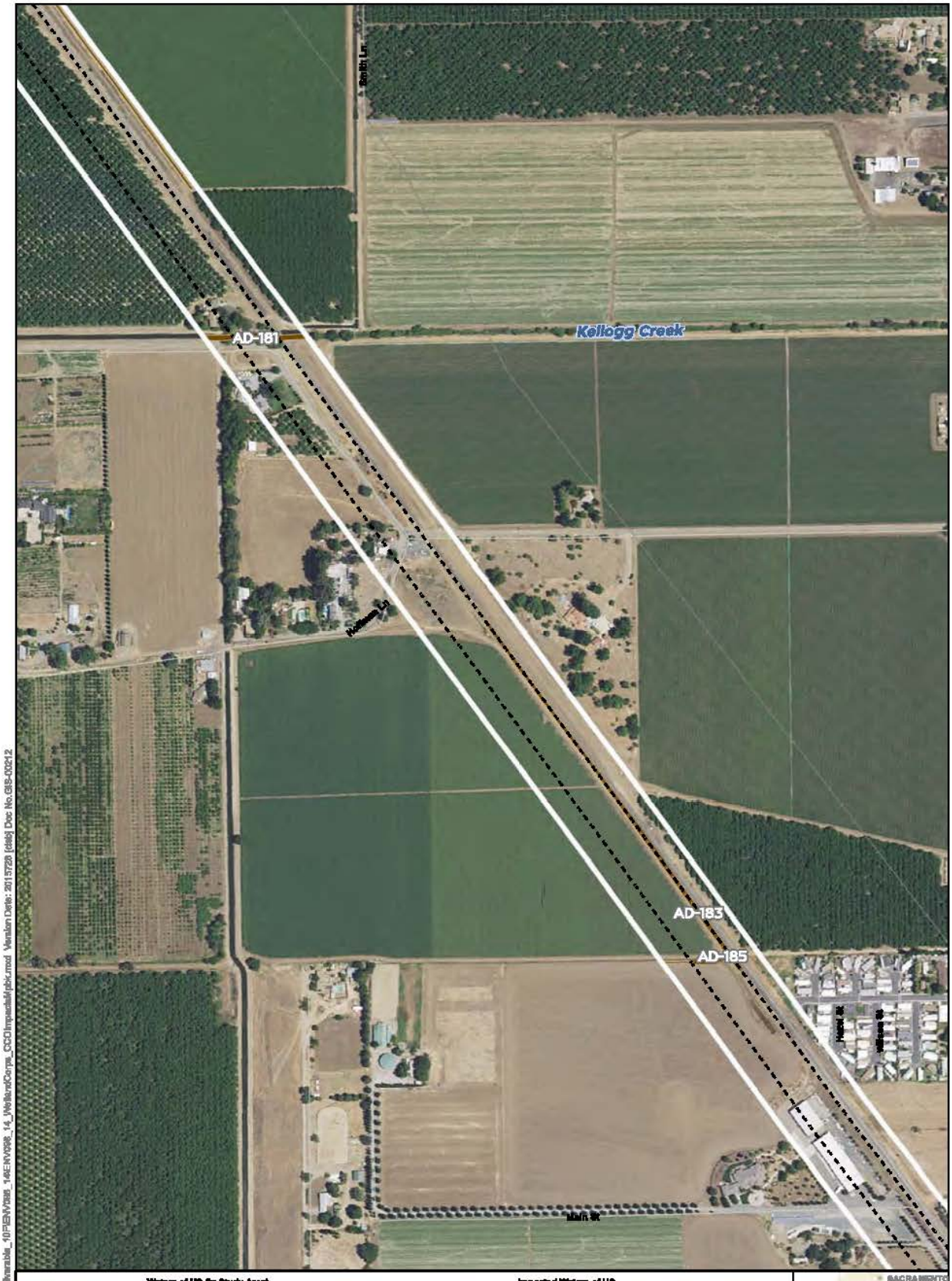
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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Sheet 73 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

Sheet 74 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	166 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres



N

0 200 400
Feet
1:4,800

Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area

Conveyance Footprint
Surface Impact
Subsurface Impact

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0 200 400
Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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Sheet 76 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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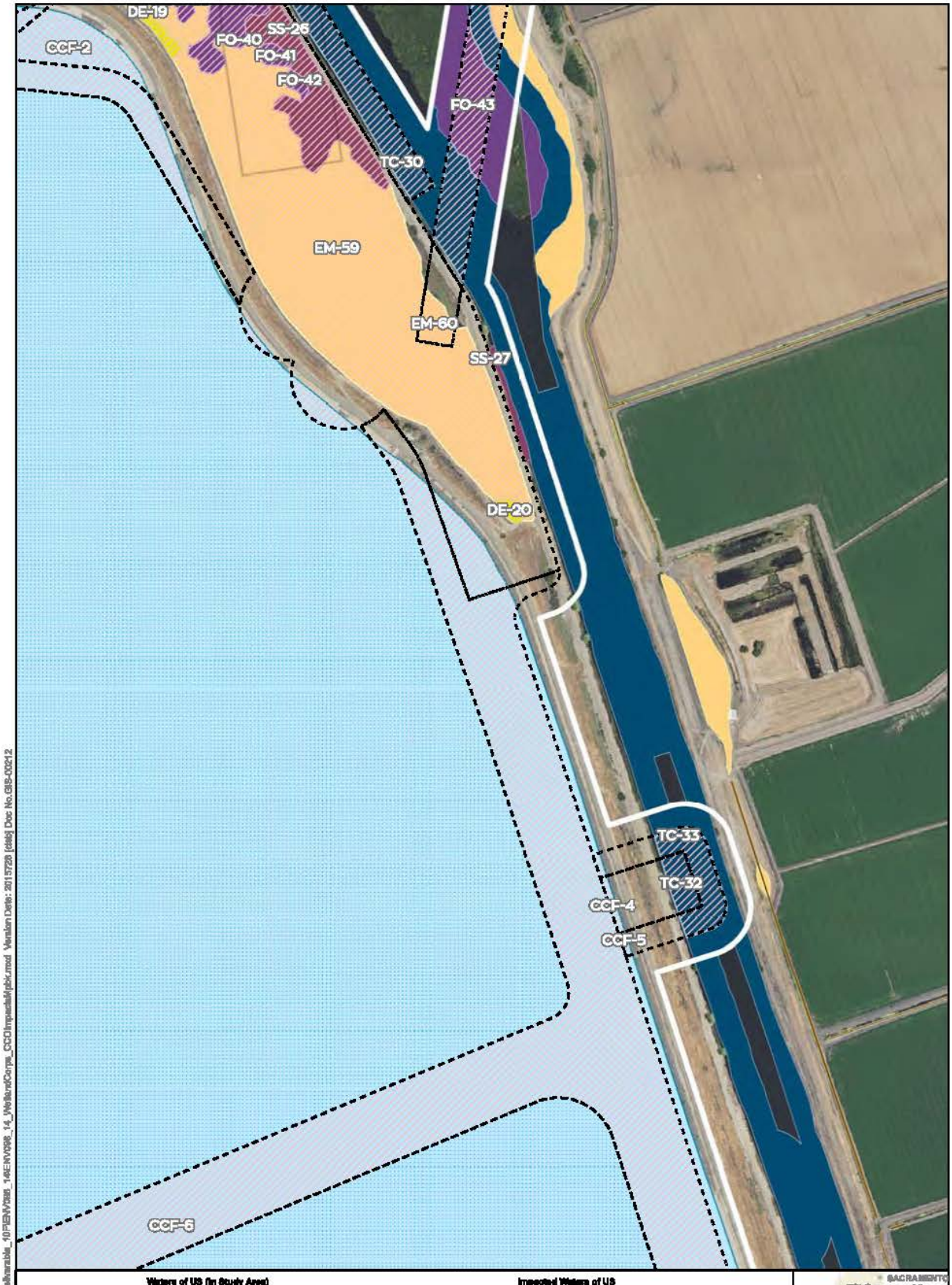
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

Sheet 77 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



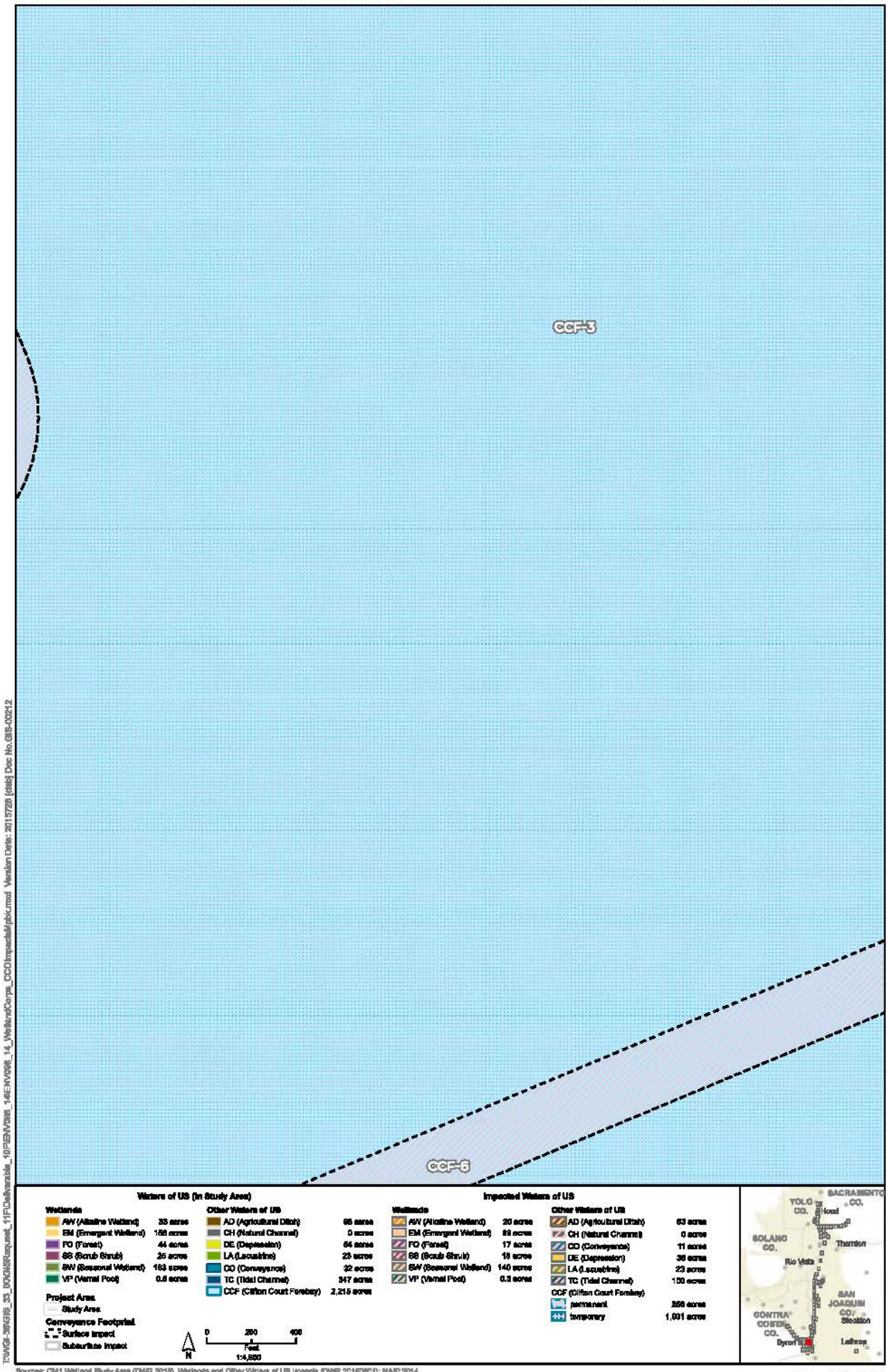
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20162601); NAIP 2014

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

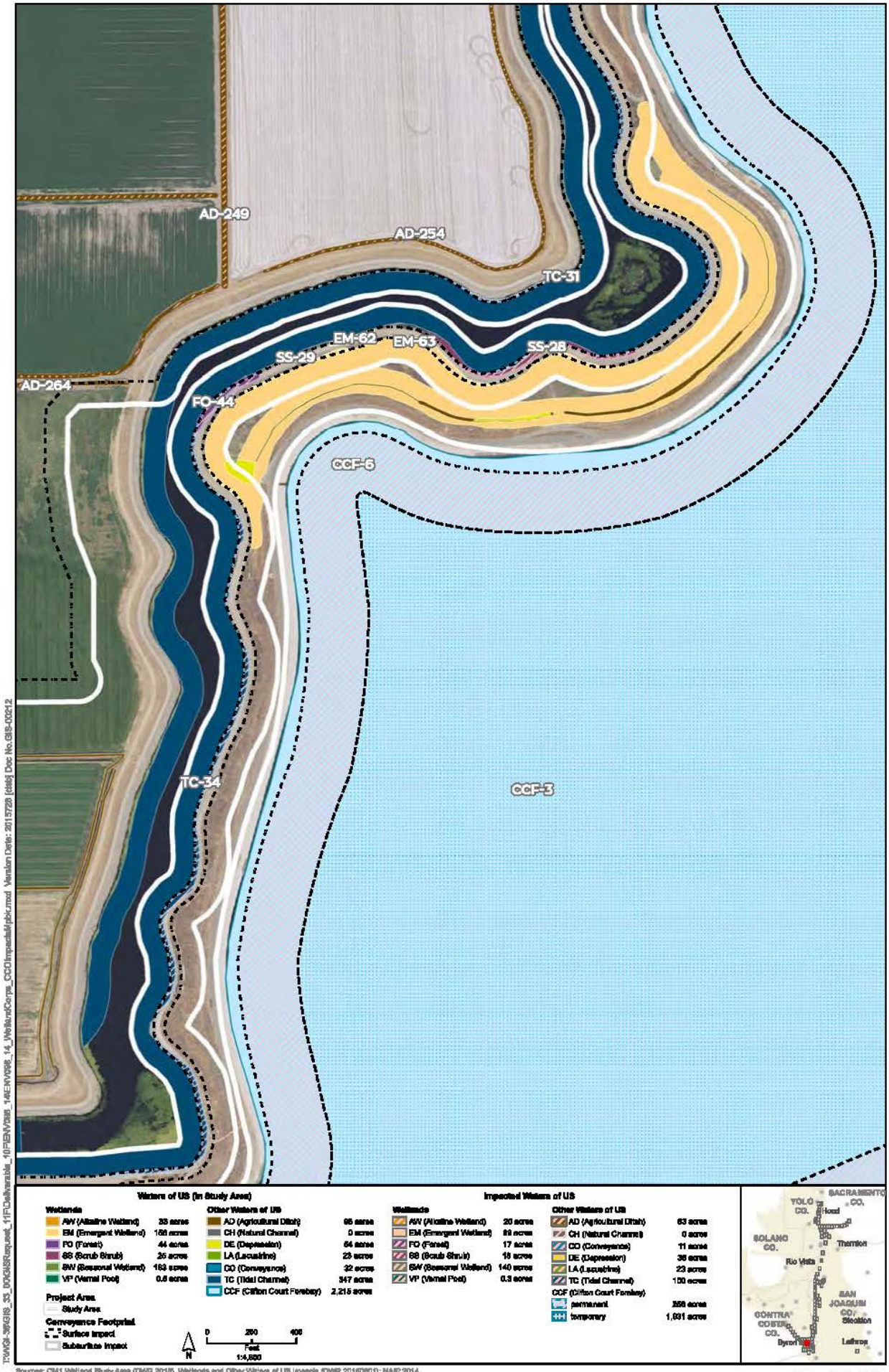


Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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RELIABLE. CLEAN. WATER

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (In Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

0 200 400 Feet
1:4,800



Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER.

Sheet 82 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (In Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
EM (Emergent Wetland)	89 acres	CH (Natural Channel)	0 acres
FO (Forest)	17 acres	CO (Conveyance)	11 acres
SS (Scrub Shrub)	19 acres	DE (Depression)	36 acres
SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,091 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

N
0 250 500
Feet
1:6,000

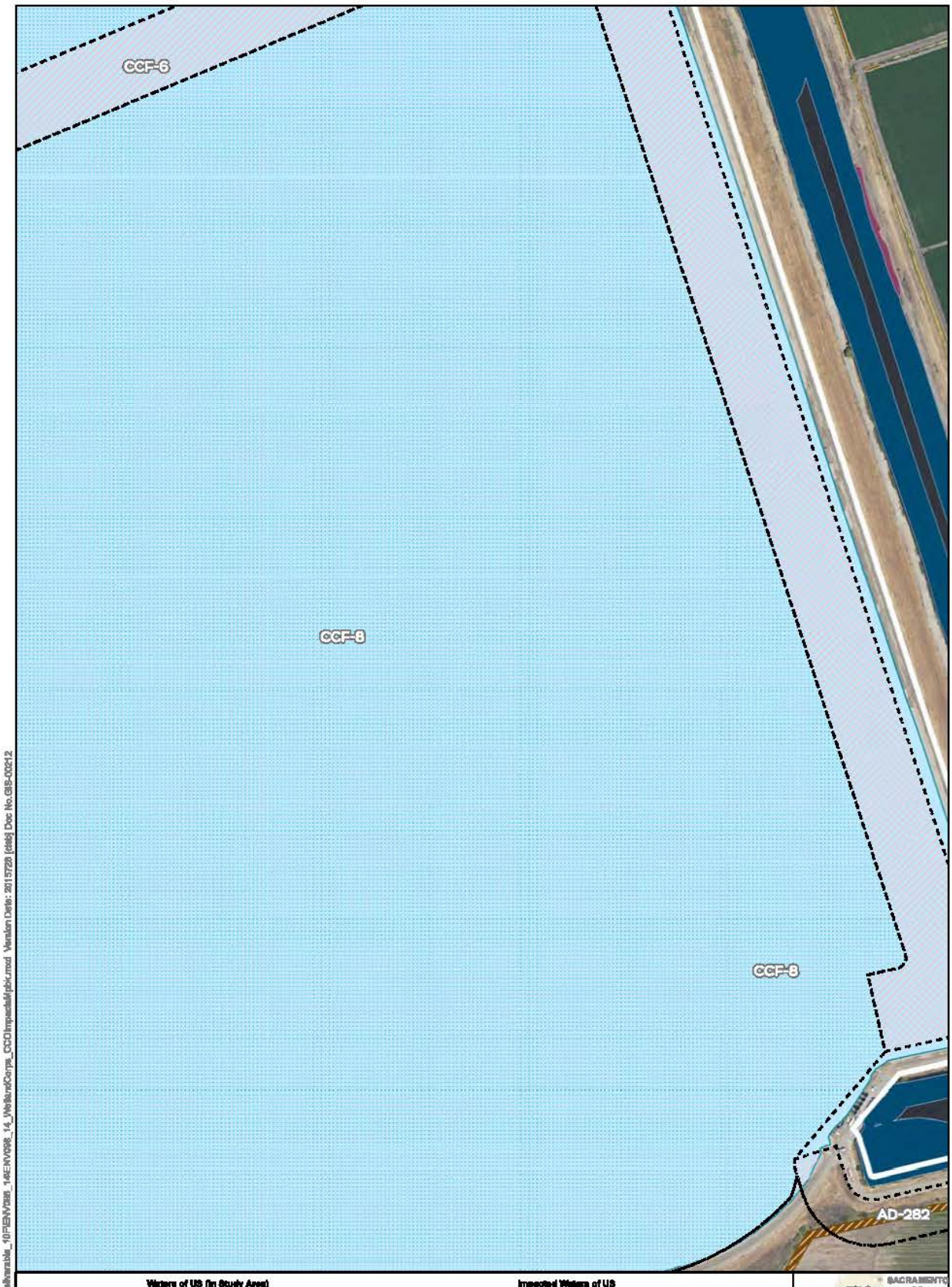


Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. RESILIENT. WATER.

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
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Impacted Waters of US

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VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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Feet
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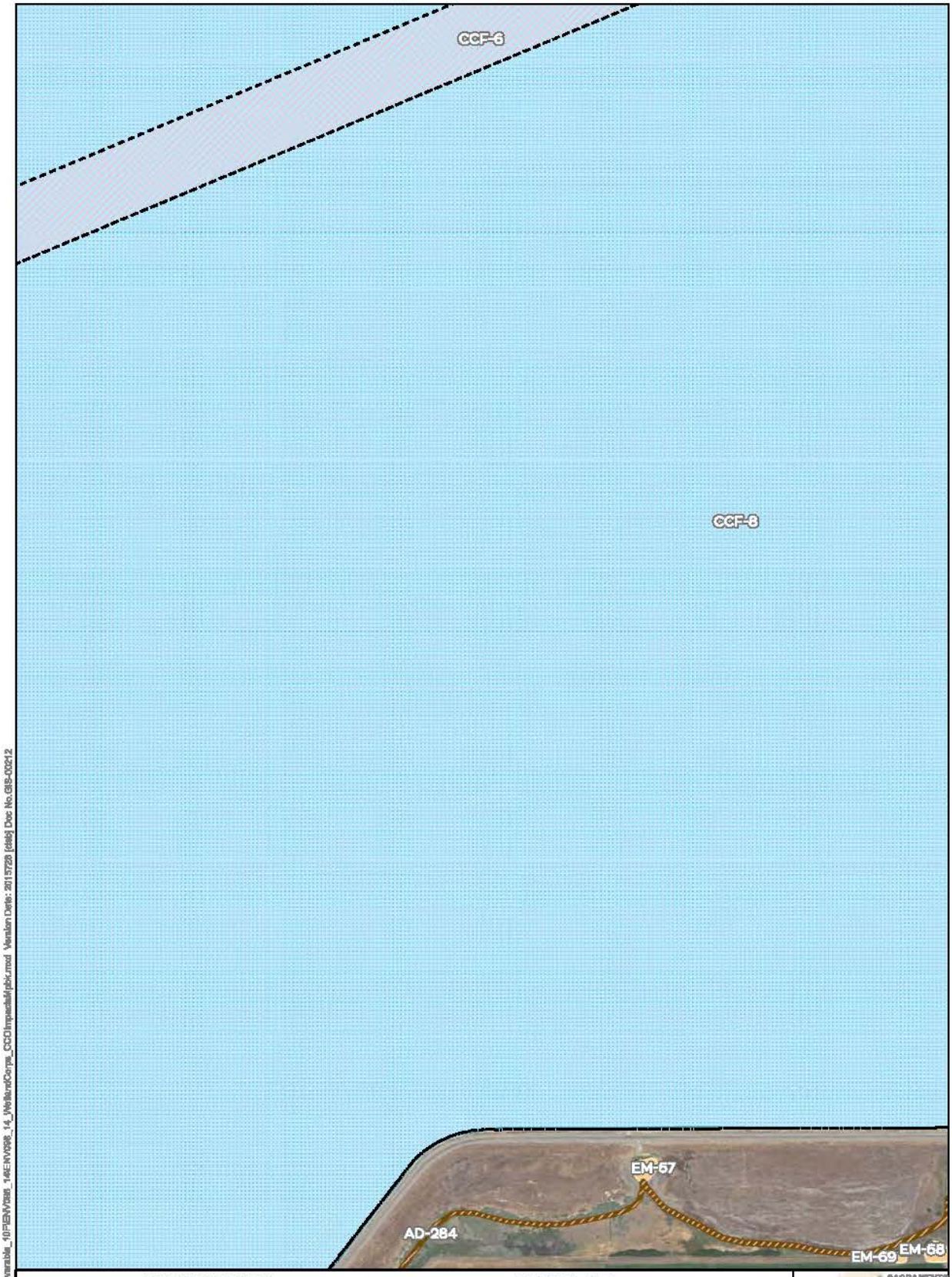
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER.

Sheet 84 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	183 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
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SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,091 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

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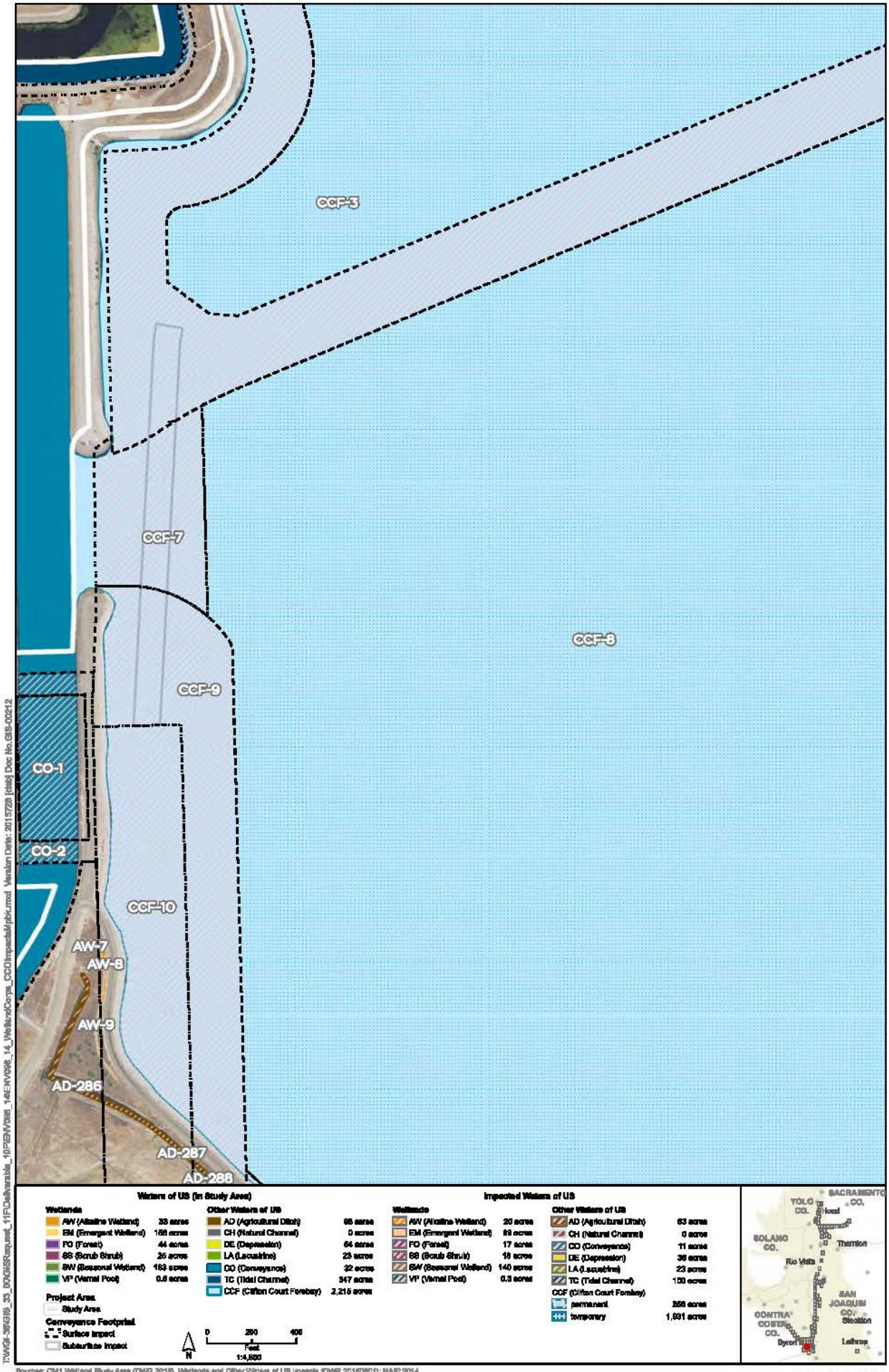
Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER.

Sheet 85 of 95
California Water Fix
Impacts to Waters of US
Wetland Delineation v.2

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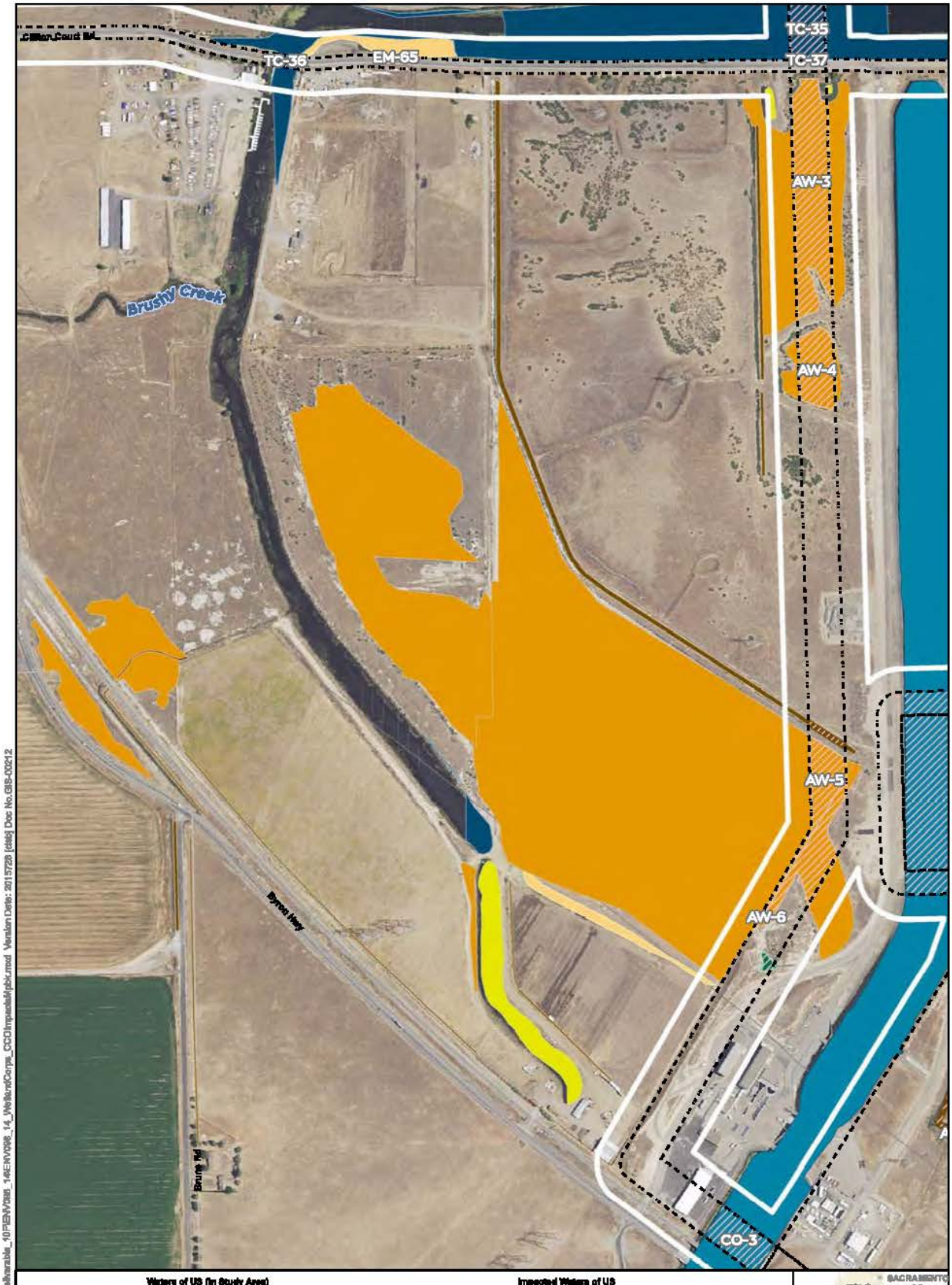
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Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
RELIABLE. CLEAN. WATER

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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
EM (Emergent Wetland)	168 acres	CH (Natural Channel)	0 acres
FO (Forest)	44 acres	DE (Depression)	64 acres
SS (Scrub Shrub)	26 acres	LA (Lacustrine)	23 acres
SW (Seasonal Wetland)	163 acres	CO (Conveyance)	32 acres
VP (Vernal Pool)	0.8 acres	TC (Tidal Channel)	347 acres
		CCF (Clifton Court Forebay)	2,215 acres

Impacted Waters of US

Wetlands		Other Waters of US	
AW (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
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SW (Seasonal Wetland)	140 acres	LA (Lacustrine)	23 acres
VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

0 200 400 Feet
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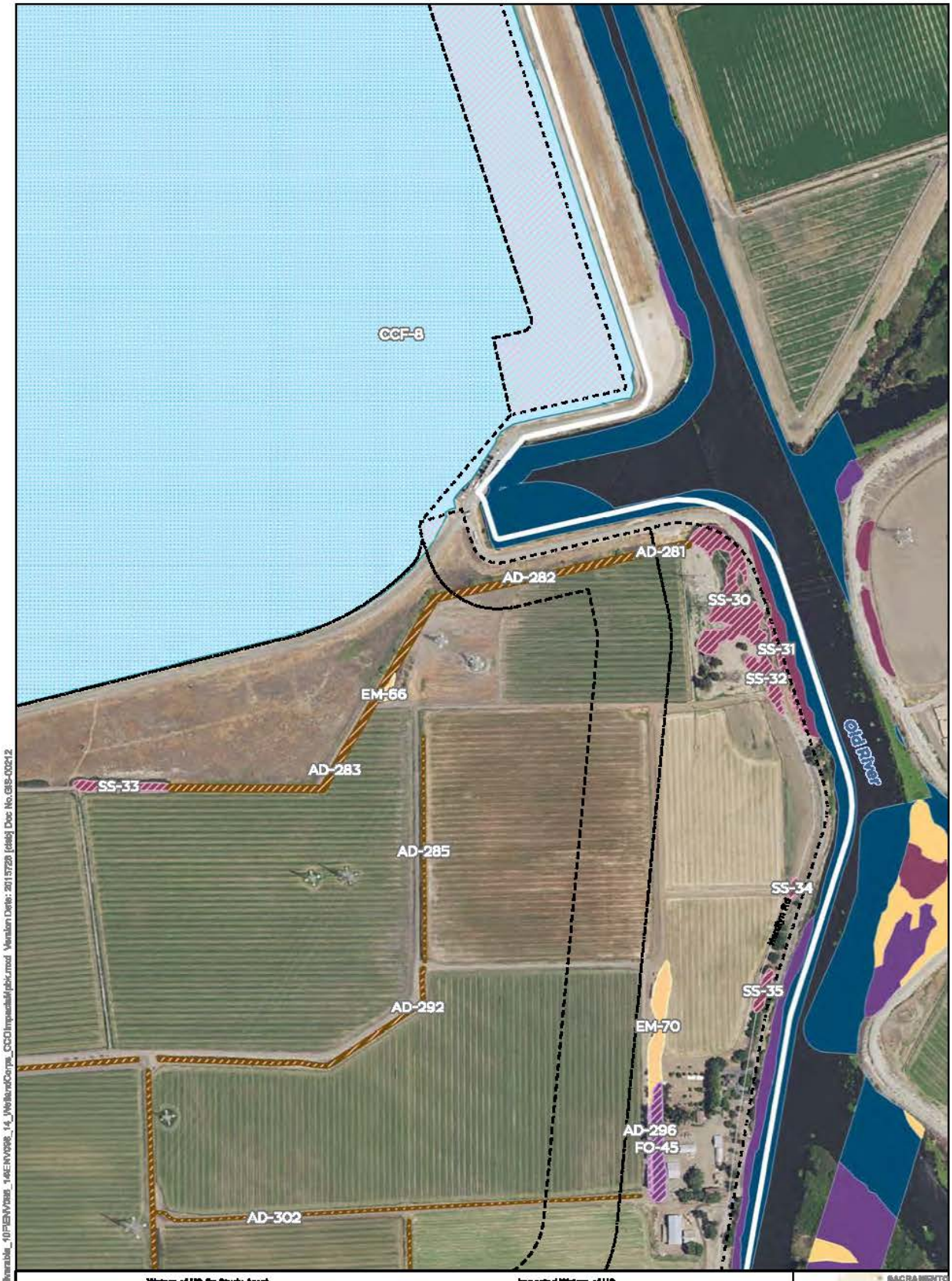


Sources: CM1 Wetland Study Area (DWR 2015); Wetlands and Other Waters of US Impacts (DWR 20160801); NAIP 2014

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CALIFORNIA WATER FIX
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California Water Fix
Impacts to Waters of US
Wetland Delineation v.2



Waters of US (in Study Area)

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	33 acres	AD (Agricultural Ditch)	95 acres
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FO (Forest)	44 acres	DE (Depression)	64 acres
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Project Area
Study Area
Conveyance Footprint
Surface Impact
Subsurface Impact

Impacted Waters of US

Wetlands		Other Waters of US	
AV (Alkaline Wetland)	20 acres	AD (Agricultural Ditch)	63 acres
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VP (Vernal Pool)	0.3 acres	TC (Tidal Channel)	130 acres
		CCF (Clifton Court Forebay)	
		permanent	258 acres
		temporary	1,031 acres

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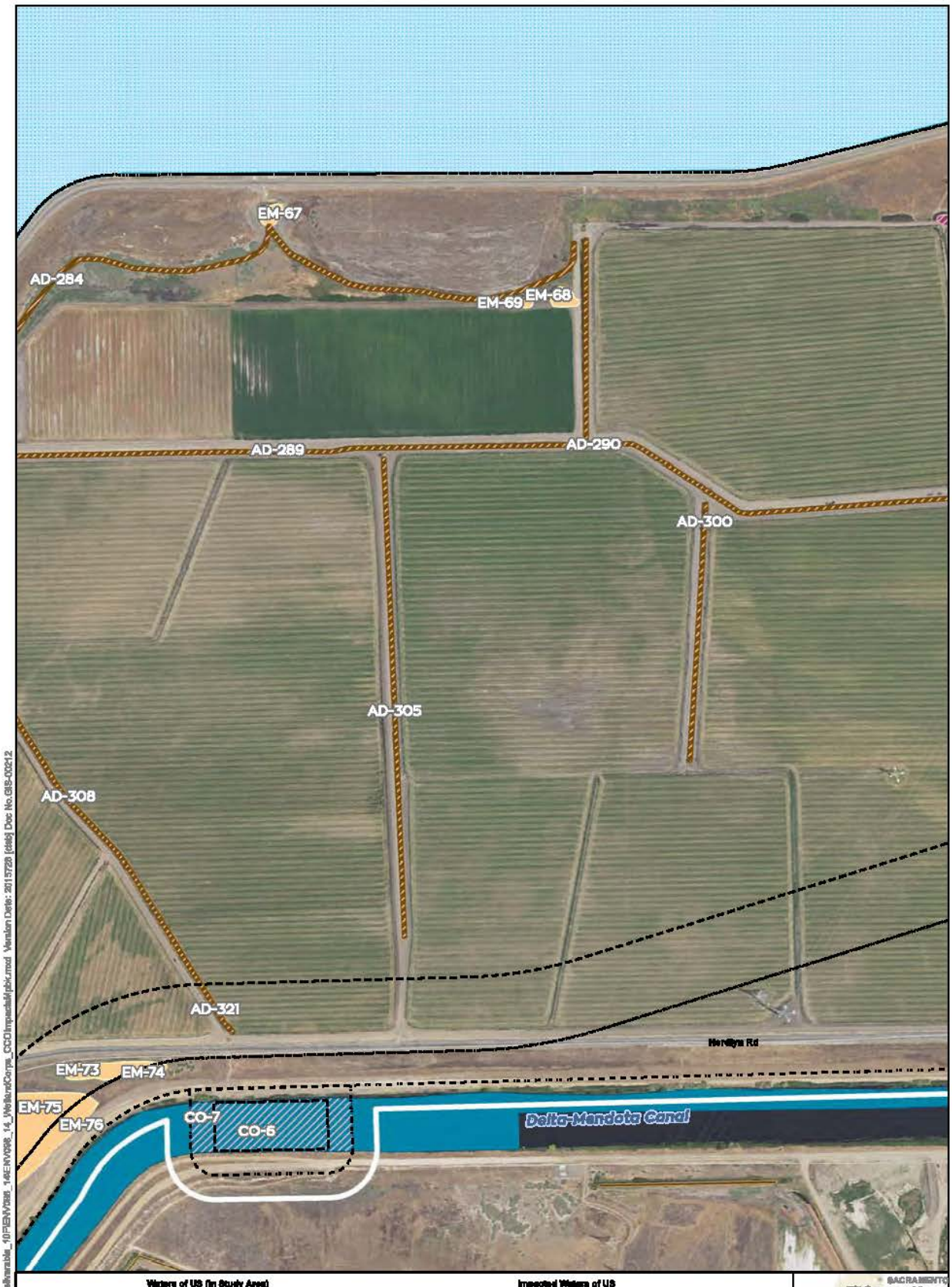
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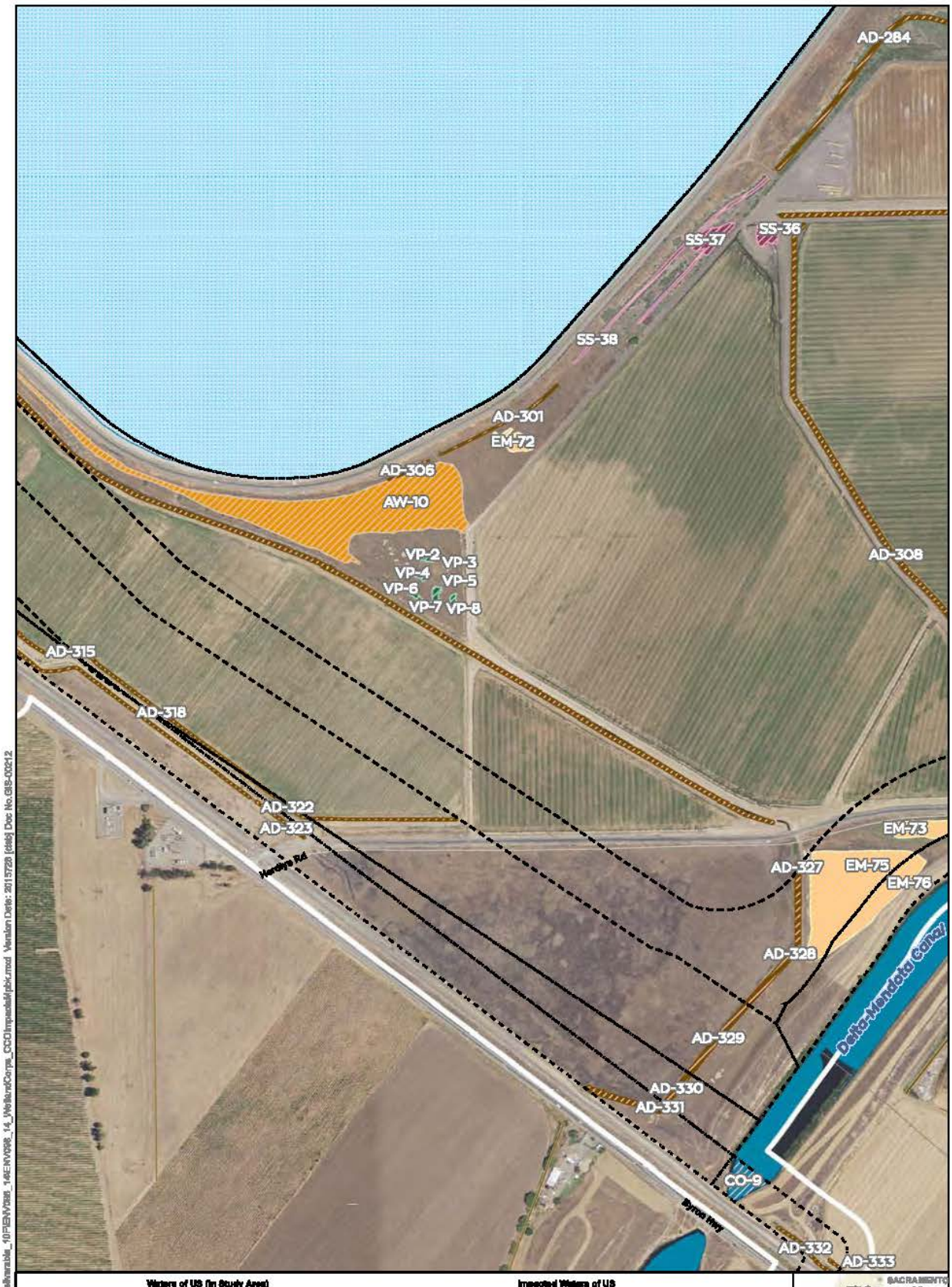
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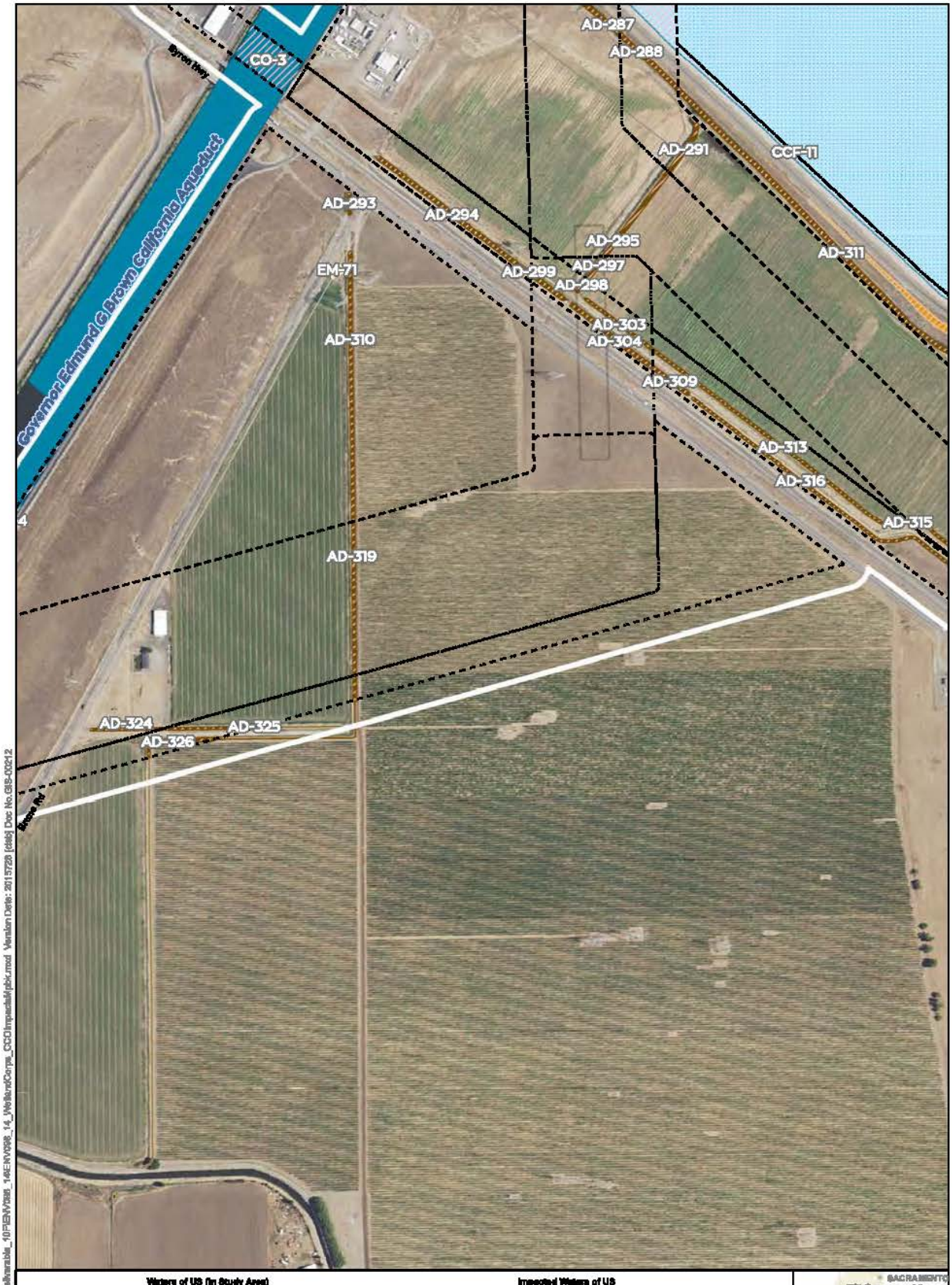


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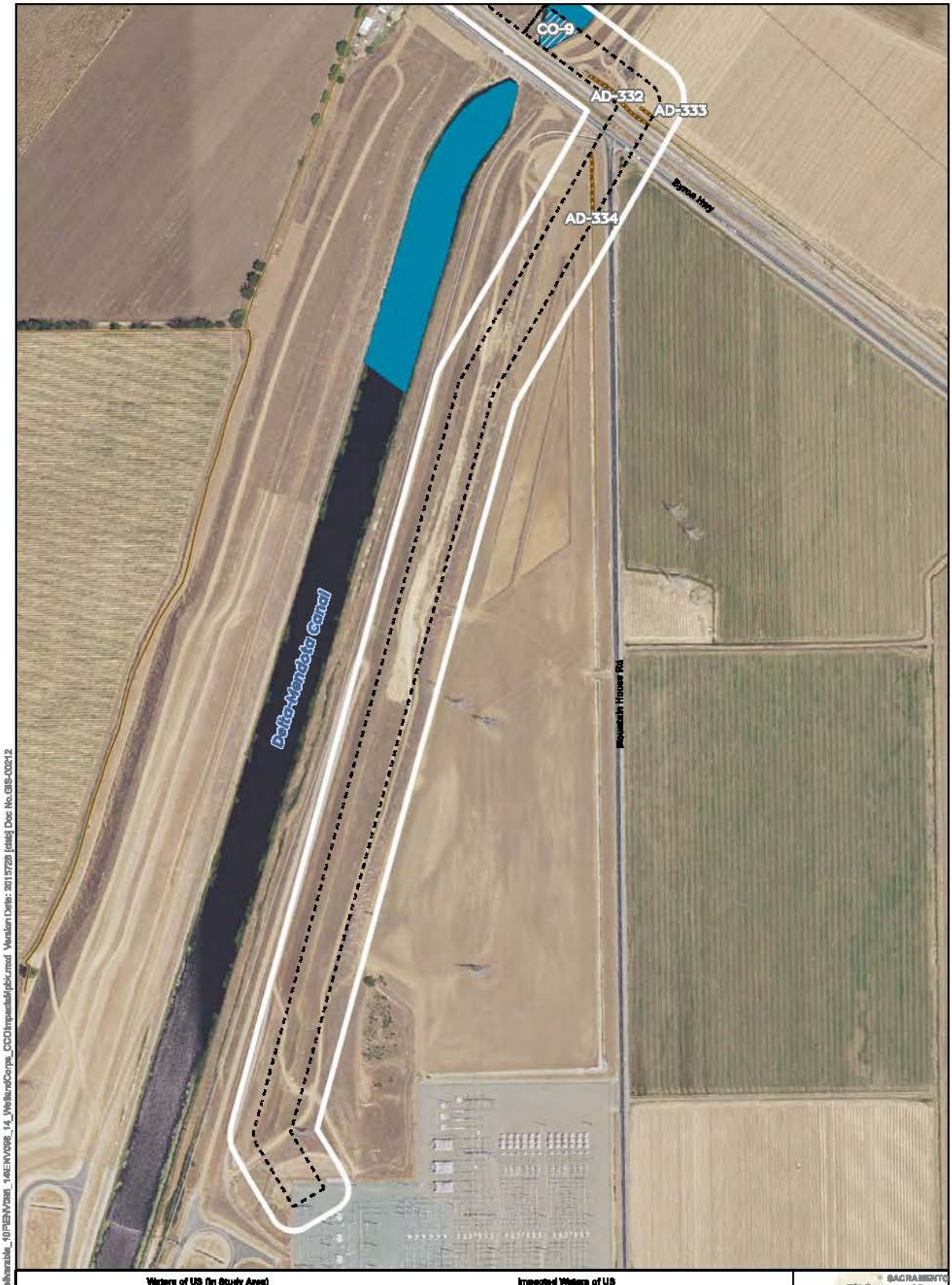
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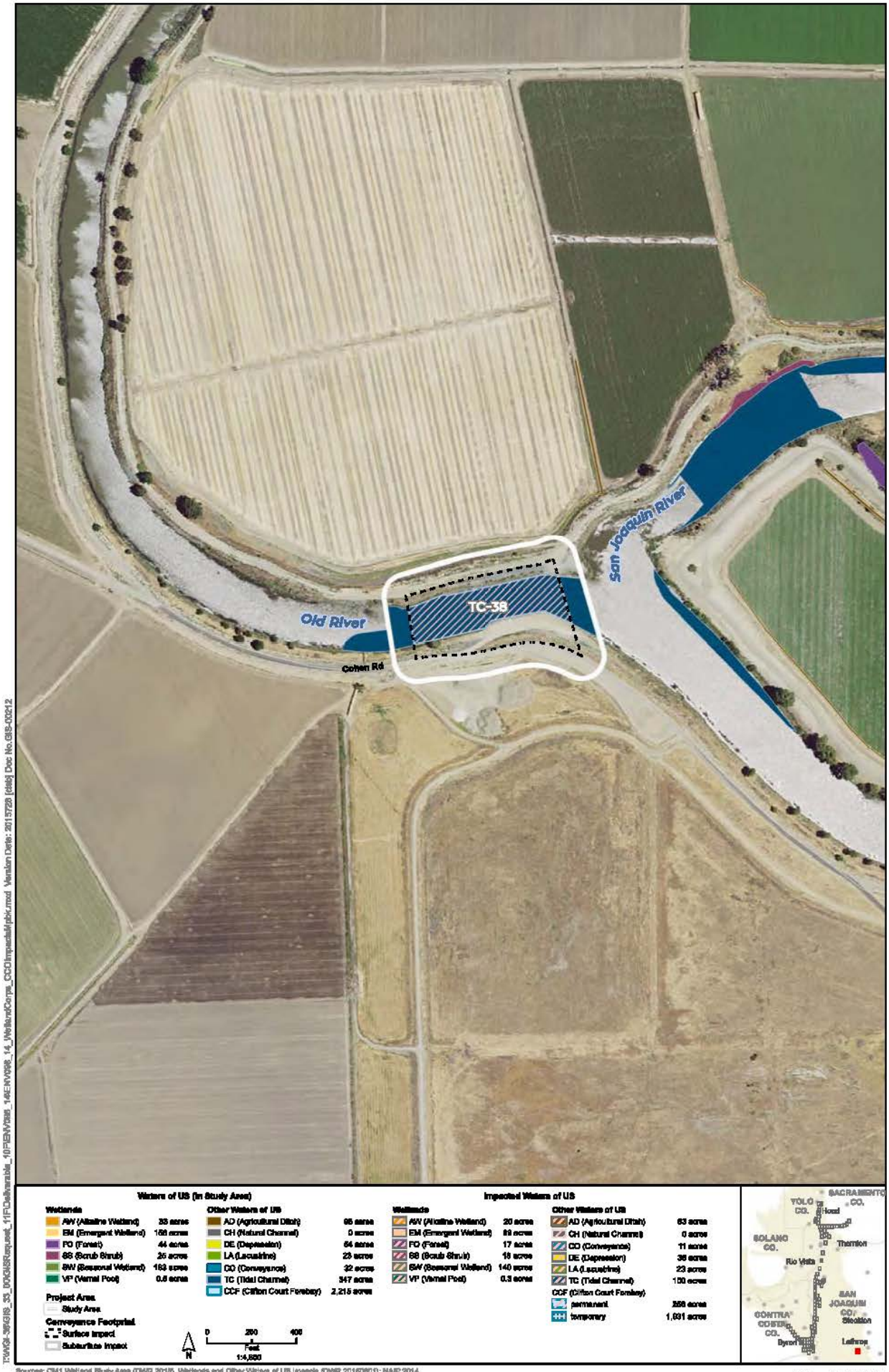
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Delta Habitat Conservation & Conveyance Program (DHCCP)

Conceptual Engineering Report

July 1, 2015

ENVIRONMENTAL WATER CAUCUS COMMENT LETTER
BAY DELTA CONSERVATION PLAN AND EIR/EIS
JUNE 11, 2014





























Foothill Conservancy

epic
wildcalifornia.org

Lower Sherman Island Duck Hunters Association

Butte Environmental Council
Protecting Butte County's Land, Air & Water Since 1975

CA Save Our Streams Council

California Rural Legal Assistance Foundation

earth LAW CENTER

Tuolumne River Trust

sacramento river preservation trust

CLEAN WATER ACTION
CALIFORNIA

Institute for Fisheries Resources
Unite. Protect. Restore.

Santa Clarita Organization for Planning and the Environment (SCOPE)

Desal Response Group

NORTHERN CALIFORNIA COUNCIL
FEDERATION OF FLY FISHERS

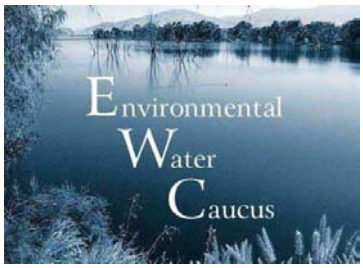
food&waterwatch

citizens water watch of Northern California

KLAMATH RIVERKEEPER

The Fish Sniffer

CALIF. STRIPED BASS ASSOC.



BDCP Comments
Ryan Wulff, NMFS
650 Capitol Mall, Suite 5-100
Sacramento, CA 95814

Via Email to: BDCP.Comments@noaa.gov

June 11, 2014:

Subject: Comments on the Draft BDCP and Draft BDCP EIR/EIS

The Environmental Water Caucus and affiliated organizations throughout the state have consistently opposed the Bay Delta Conservation Plan in concept. After careful review of the actual December 2013 BDCP Plan and EIR/EIS documents, we see no reason to change our position. In fact, our review of the Draft BDCP Plan and its Draft EIR/EIS only heightens our opposition to the project, reinforcing our view that this project must not go forward.

Originally, the BDCP plan was conceived as a collaboration among south of Delta water export agencies. Their object was to increase exports from the Delta, using water supply "reliability" and ecosystem restoration as their stalking horse. Given the political power and influence of these large state, federal, and special district agencies[1], claims by BDCP officials that the Twin Tunnels will not increase water exports must be taken with many grains of salt. Our comments, attached, demonstrate that BDCP's Twin Tunnels project will increase contract-based deliveries in wetter years, *and* will increase Delta exports in dry and drought years as the Tunnels increase water transfer opportunities for California's water market. The Bay Delta "Conservation" Plan has little to do with conservation. Indeed, the very name of the project is disingenuous at best and deeply cynical at worst. Even the planned tunnels – which are essentially a means for draining the Delta of life-sustaining fresh water in the most expeditious way possible – are perversely referred to as "Conservation Measure 1."

The BDCP project objective to export more water from the Delta is a foregone conclusion, essentially predetermined from the start of the project and advocated by major south of Delta water exporters referenced above. In this pursuit, they have been

1 We refer here to the California Department of Water Resources, the US Bureau of Reclamation, Kern County Water Agency, the Metropolitan Water District of Southern California, Westlands Water District, and a handful of other water contractors supporting BDCP.

aided and abetted by the Department of Water Resources whose goal is to procure and sell more water to these same proponents, who are also their main water customers. In order to hide these objectives, they have jointly utilized consultants through the BDCP project who have cherry picked the science and who have developed 40,000 pages of biased analytical findings to support their predetermined objectives, thus obfuscating their real intent in the process. Their representatives in Congress have used the safeguards of the Endangered Species Act as their whipping post, while the main reason for the current lack of adequate water supplies (water supply "reliability") has obviously been a persistent drought, not endangered species restrictions. A chronology of events to support these findings of a predetermined and predecisional project to move more water south is shown as Attachment 3.

BDCP documents total more than 40,000 pages. The size, complexity, and obfuscation it displays are gross and inexcusable abuses of NEPA and CEQA mandates. Their sheer volume subverts NEPA and CEQA objectives, defeats the rights of the public and decision-makers for clarity about the scientific and analytic bases for government actions. The impossibility of analyzing objectives and impacts in these documents makes a mockery of the environmental review process and fails NEPA and CEQA standards for clarity.

The BDCP fundamentally will fail to achieve its core purpose of restoring the Delta's ecosystem. The conservation measures promoted by the Plan would be unlikely to work for the Delta's listed fish species and their costs would be fobbed off on the taxpaying public – the Twin Tunnels beneficiaries would at most pay 10 percent of habitat restoration costs. Thus, the BDCP fails miserably as a "comprehensive conservation strategy" for the Delta. The era of ruinously expensive, environmentally destructive and inefficient infrastructure projects is dying, but rather than continue in that vein, we must embrace bold and innovative strategies that will insure the restoration and stability of the Delta and provide sustainable sources of water to our cities and farms, ideas that the Environmental Water Caucus has laid out in our Responsible Exports Plan for California.[2]

Numerous scientific elements of the plan have been questioned by federal regulatory and fishery agencies, the National Research Council and the Delta Independent Science Board. All these entities emphasize that the outcomes of the BDCP are rife with uncertainties. In short, the plan puts billions of taxpayer dollars at risk, with little if any benefit for listed species. Alternative means to address California's water future and restore the Delta and its species of concern must be examined. The current plan and preferred alternative should be abandoned.

The federal and state habitat conservation plan laws require that a permissible project contain a vetted financing plan – precisely the kind of plan that BDCP lacks. Even after seven years of public debate, BDCP's Implementing Agreement, a required document that spells out the financial and other obligations of BDCP applicants, was absent from the December 2013 draft plan and the draft EIR/EIS. The delayed June 2014 release of

[2] Online at http://ewccalifornia.org/reports/responsibleexportsplanmay2013.pdf.

an Implementing Agreement is not adequate, and will be commented on by the EWC in an Addendum by the July 29 deadline.

BDCP is a bad deal for California.

While California is now getting out from under the mountains of bonded debt it incurred to remain solvent in the previous decade, BDCP would cause the state's debt burden to increase again. BDCP lacks required financial assurances that guarantee that not only the Twin Tunnels would be built but that all of the Plan's mitigation measures would be funded throughout the 50-year term of the permits they seek. It fails to demonstrate that taxpayers would *not* be on the hook for the project if its finances falter and that ratepayers in southern California would be protected from steep, long – term rate hikes to pay its costs. It violates numerous state and federal laws, ranging from the Delta Reform Act of 2009 the federal Clean Water Act, the Porter-Cologne Water Quality Control Act, and state and federal endangered species and habitat conservation laws, to the public trust doctrine and the California's constitutional ban on waste and unreasonable use and method of use and diversion of water (adopted by California voters in 1928). It would grant veto power to the BDCP water agencies to control construction and manage restoration of habitat in the Delta with public taxpayer funds, BDCP's method for the fox to guard the chicken coop.

BDCP is an even worse deal for the Delta.

Purporting to restore Delta ecosystems and protect its most vulnerable fish species, BDCP would instead further reduce natural Delta outflows to San Francisco Bay, helping push listed, vulnerable salmon, sturgeon, and resident fish species into permanent oblivion. The people of the Delta, especially its poorest and most economically vulnerable, would endure a ten-year construction period only to find that the remaining catchable fish species would be more contaminated with mercury and selenium than they now are today. They would find that their agricultural, recreational, and regional economies would be decimated by the disruption from BDCP construction activities.

While BDCP now trumpets the risks to California's water supply of massive Delta levee failures due to earthquakes and sea level rise, BDCP lifts not a finger to address these supposed seismic levee issues. At the same time, the Department of Water Resources ignores seismic risks to other components of the State Water Project underlain by active seismic faults at the San Luis Reservoir and in the Tehachapi Range crossing of the California Aqueduct. By the 2030s the Delta residents will see their levees further deteriorated from being ignored by the state, fresh water supplies exported, prime farmlands converted, and beloved fishable, swimmable and drinkable places of recreation ruined from Delta exports to San Joaquin Valley agribusinesses and southern California suburban development. Instead of the thriving regional economy the Delta is today—integrated into the state, regional and global economies—it would by the 2030s be a subject colony of the Bay Delta Conservation Plan self-appointed "authorized entities." The parallel of this prospect with the control of Owens Valley by the Los Angeles Department of Water and Power is impossible to miss.

BDCP and its EIR/EIS are meant to sell the project and try to limit the potential for critical thinking by an otherwise skeptical public. They conceal the Twin Tunnels' ulterior purpose of increasing the State Water Project's delivery capacity for enlarging the market for cross-Delta water transfers from Sacramento Valley "willing sellers." They reveal that Delta exports won't just increase in the wetter years, they will rise in the drier years as the water market grows in proportion that the Delta is colonized and controlled by BDCP. But by selectively modeling only the contractual water volumes and not the non-contractual amounts transferred via the water market in drier times, BDCP would prefer the public think they are merely "protecting and restoring" supplies already under contract from the effects of climate change and sea level rise.

The BDCP fails to provide an adequate range of alternatives to new conveyance as required by the National Environmental Policy Act and the California Environmental Quality Act; the listed "alternatives" to the tunnels are simply variations on tunnel export capacities and operational rules, none of which have any basis in existing water quality and operational regulations in the Delta. Alternatives that significantly reduce exports from recent historical levels have been ignored despite support from numerous environmental and water agency organizations throughout California, and despite scientific evidence confirming reduced exports and increased outflows to San Francisco Bay directly benefit Delta habitat restoration and fisheries recovery.

BDCP also proffers a snake-oil hypothesis that restored habitats can substitute for the river flows to and through the Delta that are needed for true recovery of the Delta's common wealth—its fish and its healthful, flowing waters. Time and again in our comments, in BDCP's own modeling results we find evidence that this hypothesis is sheer puffery. *Fish and people need both habitat and flows to recover the Delta. BDCP will accomplish neither for the people of the Delta nor the people of California. It is a fraudulent water grab grander in scale and skullduggery than any before seen in the American West.*

Our review and detailed responses are shown in the more technical document attached to this summarizing letter. Our thanks go to Tim Stroshane and Tom Stokely and numerous EWC organizations that have collaborated to prepare the technical and detailed comments which follow.

Nick Di Croce David Nesmith

Nick Di Croce David Nesmith

Co-Facilitators
Environmental Water Caucus

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Secretary Penny Pritzker
United States Department of Commerce
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Washington, D.C. 20230

Secretary Matt Rodriquez
California Environmental Protection Agency
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Sacramento, CA 95812-2815

Comments[1] of the Environmental Water Caucus on the Bay Delta Conservation Plan and Its Environmental Impact Report/Statement

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[1] Comment preparation and consultation managed by Tim Stroshane for the Environmental Water Caucus. Contributors include Colin Bailey (Environmental Justice Coalition for Water), Barbara Barrigan-Parrilla and Jane Wagner-Tyack(Restore the Delta), Bill Jennings (California Sportfishing Protection Alliance), Carol Perkins (Butte Environmental Council), Linda Sheehan and Grant Wilson (Earth Law Center), Tom Stokely (EWC and California Water Impact Network), and Bob Wright (Friends of the River).

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I. Introduction

After eight years in the works, the Bay Delta Conservation Plan applicants have delivered a Plan that is as flawed as it is expensive and monstrous.

The Twin Tunnels project it contains would divert more of the Delta common pool to benefit state and federal water contractors at a time when California the state has over-promised, wasted, and inequitably distributed scarce water resources, when the Delta is deteriorating from state mismanagement during the current drought, listed fish species are on the brink of extinction, and low-income communities of color who rely on the Delta for subsistence fishing, jobs, and recreation struggle to survive and thrive.

The Twin Tunnels project would be a new facility provide the State Water Project (SWP) with three new diversion points (or "north Delta intakes") for water along the lower Sacramento River. These new intakes would divert the river into two gigantic tunnels that would isolate the river water from salty tidal flows for direct delivery to Harvey O. Banks Pumping Plant for export to the California Aqueduct of the SWP. This misnamed "conservation measure" would expand California's cross-Delta water transfers market, and enable the US Bureau of Reclamation to receive Sacramento River flow diversions via the intertie between the state's California Aqueduct and the Bureau's Delta Mendota Canal or via the intermingling of stored water at San Luis Reservoir south of the Delta.[2] For reasons we describe in this comment letter, there is nothing authorized or authorizable about the efforts of the BDCP Applicants.

The Environmental Water Caucus (EWC), a coalition of over 30 nonprofit environmental and community organizations and California Indian Tribes, urges the National Marine Fisheries Service, the US Fish and Wildlife Service, and the California Department of Fish and Wildlife to disapprove the Bay Delta Conservation Plan and deny incidental take permits that are requested by the plan's "Authorized Entities."[3] ***The EWC objects to the approval of the Plan, the execution of its Draft Implementing Agreement, and the issuance of incidental take permits to the Bay Delta Conservation Plan.***

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[2] This is possible in part under State Water Resources Control Board approval in March 2000 of "joint points of diversion" in Water Rights Decision 1641.

[3] According to Bay Delta Conservation Plan, Chapter 1, *Introduction*, p. 1-1, the "authorized entities" for the Bay Delta Conservation Plan include:

- California Department of Water Resources, which would own the Twin Tunnels Project described in Conservation Measure 1
- US Bureau of Reclamation (whose authorization for take is sought under Section 7 of the ESA)
- Kern County Water Agency
- Metropolitan Water Agency of Southern California
- San Luis & Delta Mendota Water Authority
- Santa Clara Valley Water District
- State and Federal Contractors Water Agency
- Westlands Water District
- Alameda County Flood Control and Water Conservation District (Zone 7 Water Agency)

In these comments EWC will refer to the "Authorized Entities" as simply "the Applicants," "the BDCP Applicants" or "Applicants." The term "Authorized Entities" implies improperly that this group of state and federal water agencies, and regional wholesaling water agencies, have already been authorized to receive incidental take permits. In actuality, at this time they are merely aspiring to be "applicants." No incidental take permits have yet been submitted to the fishery agencies because a completed application must also contain an "implementing agreement," which has not yet received public review.

We ask of BDCP: Why should BDCP Applicants be granted such legal privilege from the federal Endangered Species Act as the "regulatory stability" of the "No Surprises Rule" that would favor their conveyance investments over the "regulatory stability" of senior water right holders and a huge array of human and non-human beneficial users of water and land in the Central Valley and the Delta? What makes these Applicants worthy of the public's trust that they should be permitted to construct a second set of maelstrom-generating diversions along the lower Sacramento River to augment the hydraulic maelstrom they already operate at the South Delta export pumps, with their attendant ecological and hydrodynamic havoc? What makes them worthy of special treatment, just because they divert water from the Delta?

The EWC incorporates by reference in these comments those of several other correspondents regarding BDCP.[4]

The Bay Delta Conservation Plan is challenging to grasp. It contains both a strategic plan for habitat restoration and a quasi-project description of the proposed Twin Tunnels export facility. The Tunnels project is considered as a "conservation measure," due to hyped reduction of harm to listed species at the federal and state South Delta export pumps. Among the Plan's other conservation measures is a "reserve system" containing dispersed "restoration opportunity areas" in the legal Delta region. Its "conservation strategy" contains 21 other specific "conservation measures." The strategy also puts forward detailed biological goals and objectives, yet states that none of these goals and objectives will be used to measure compliance of the Plan with respect to the Endangered Species Act (about which more shortly). Also among its conservation measures are actions aiming to address "other stressors" to covered aquatic species. Unfortunately, some stressors, like selenium toxicity and nonnative invasive clams like *Potamocorbula amurensis*, are ignored altogether.

The Bay Delta Conservation Plan, when all is said and done, is a bad deal for California for several broad reasons and a long list of specific ones. The broad reasons include:

- It relies on a deeply flawed scientific hypothesis that habitat restoration can substitute for river flows as the chief strategy for "fixing the Delta." Its implementation will likely be catastrophic for the Delta's aquatic ecosystems, because it uses science in the service of marketing the Twin Tunnels, not for solving Delta problems.

- It is contrary to law—actually, many laws.

- Its financial and economic risks exceed benefits on offer from BDCP. Far more cost-effective water supply solutions are available to California and at far lower cost.

- If implemented, its hyper-bureaucratic organization will result in "paralysis by analysis" to the detriment of the Delta ecosystem it purports to "fix," particularly because water agencies will have veto power over changes to BDCP's non-water project conservation measures.

Section II of our comments focuses on what the Environmental Water Caucus believes are the "big picture" issues that BDCP raises, willingly or not.

BDCP's approach to habitat conservation, examined in Section III, relies on magical thinking, an excess of "adaptive management," and a clause declaring its biological goals and objectives

[4] The Environmental Water Caucus incorporates by reference the comments of Restore the Delta, Local Agencies of the North Delta, North Delta Water Agency, Central Delta Water Agency, and South Delta Water Agency, San Francisco BayKeeper, Friends of the River, Earth Law Center, Friends of the San Francisco Estuary, California Water Impact Network, California Sportfishing Protection Alliance, and AquAlliance.

irrelevant to plan implementation and incidental take permit compliance. We diagnose these problems in Section III. The key magical thoughts of BDCP's conservation strategy are that, on one hand, terrestrial and tidally-influenced wetland habitat restoration will increase overall food supplies for listed fish species. BDCP believes this "boost" to food supplies will overcome the bad effects on these same fish of operating the state and federal Delta water facilities.

On the other hand, BDCP barely acknowledges that ***invasive nonnative clam species are themselves likely to outcompete listed fish species (as they already do) as more food is made available and as salinity moves inland as a result of the new North Delta diversions.*** Controlling these clams would require greater river inflow to the Delta to successfully control their spread, not less, as is proposed by BDCP.

BDCP fails to account for the possibility that the predators of listed species will enjoy these new habitats at least as much as the listed and other covered species might. In neither case—the clams and the predator fish species—does BDCP contain conservation measures that directly addresses these fatal flaws. For the Applicants, the whole point of BDCP is to avoid having to increase river inflow and Delta outflow to achieve real ecosystem improvements in the Delta, while still claiming to have tried to help the Delta. The member organizations of the Environmental Water Caucus stoutly believe that habitat restoration is as important as ever. But from extensive review and analysis of its documents released last December 2013, we find that ***BDCP is the most lavish greenwashing campaign our members have ever seen.***

A similar level of magical thinking appears in the hyping of floodplain habitat to benefit salmonid fish and Sacramento splittail. BDCP fails to analyze the likelihood that introduced predators will find such enhance floodplains as attractive as would BDCP's covered fish species. Other flaws are identified in BDCP's approach to habitat restoration and ecosystem recovery, and are described more later. BDCP's methyl mercury management conservation measure provides little in the way of actual mitigation on Delta floodplains, while putting off to adaptive management the most difficult questions. Adaptive management would provide mere window dressing, application of scientific lipstick to what is ultimately, just a big hydraulic pig.

To add insult to injury, a clause in the Plan's conservation strategy states that ***its biological goals and objectives shall not be a basis for determining compliance with plan implementation and permit conditions***.

BDCP's financing plan and economic justification, examined in Section IV, remains sketchy at best and will externalize all the important costs of habitat restoration and selenium management onto the California electorate. In short, rate paying customers (both farmers and urban customers) will pay skyrocketing water charges for water that the Twin Tunnels project will not make available in dry years (because of the projects' junior water rights). Nearly all of the state funds for habitat restoration activities proposed in BDCP are to be paid for by water bonds not yet proposed or approved by California voters. The Tunnels would come first; habitat restoration ***maybe*** second, if at all. Early indications are that the draft Implementing Agreement reinforces this prioritization of funding for the Twin Tunnels over habitat restoration.

BDCP's governance approach, examined in Section V, is to give as much control to the Applicants as possible over Twin Tunnels operations and consequently over the Delta itself. Allowing greater control of the Delta's common water pool to the State Water Project would create a hydrodynamic maelstrom in the lower Sacramento River from Twin Tunnels diversions there. While much lip service is given to limiting the presence of political concerns in deciding important water operations and management and protection of listed fish species in the Delta, BDCP's proposed governance structure would provide veto power to the Applicants, the same folks who have already brought these same listed fish species to the brink of extinction.

The long list of statutes BDCP violates includes the state and federal endangered species acts, the Delta Reform Act of 2009, state and federal clean water acts, the California water code, the California Constitution's ban on wasteful and unreasonable use and method of diversion of water, and the Public Trust Doctrine. There is little, if any assurance that the Brown Act, which sets standards for the conduct of open public meetings by local and regional governments in California, will apply to the meetings of the group of groups and teams that proliferate from the BDCP Implementation Office, and which the Office will be tasked with herding and supporting. Our analysis is provided in Section VI.

Finally, the BDCP EIR/EIS is examined in Section VII. Despite producing in excess of 30,000 pages of analysis, BDCP's environmental documents contain an inadequately and improperly formulated purpose and need statement that:

- Omits its water transfer marketing purpose,
- Leaves yawning holes in its setting/affected environment descriptions,
- Gapes huge blind spots where it should have analyzed numerous environmental justice issues in the Delta Plan area (including toxic contamination of fish), groundwater and water transfer issues in the Sacramento Valley region and Central Valley study area, and
- Glaringly and indefensibly omits storage, levee and restoration projects from its cumulative impacts.

Thus, BDCP has it backwards when it comes to prioritizing recovery of the Delta's aquatic ecosystems and listed fish species, and its most socially vulnerable and environmentally unequal communities.

II. BDCP and Big Picture Issues

The BDCP documents—the habitat conservation plan (BDCP) and its lengthy environmental impact statement/environmental impact report (EIS/EIR) and its Draft Implementing Agreement are intended for many decisions by many different state and federal regulatory agencies. Despite its length, BDCP musters only a partial list.[5] This list omits the State Water Resources Control Board's authority over water right permit issuance under the California Water Code for new points of diversion and rediversion. This section identifies many other areas where BDCP documents will be incorporated or factored into societal decisions in California for years to come.

A. Recovering Endangered Species Populations, Habitat Conservation Plans and Incidental Take Permits

Section 9 of the Federal Endangered Species Act prohibits the take of any listed species.[6] Section 10 of the Act, however, provides that habitat conservation plans may be prepared that enable an applicant to take listed species if the take is "incidental" to, and not the purpose of, an otherwise lawful activity.[7] Habitat conservation plans are subject to specific criteria for preparation and approval, and the National Marine Fisheries Service and the US Fish and Wildlife Service promulgated regulations and published a handbook on habitat conservation plans and incidental take permits that guide the entire Section 10 process.[8] The California Endangered Species Act contains similar provisions of take prohibition followed by a path for permitted incidental take of listed species.[9]

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[5] Bay Delta Conservation Plan, Chapter 7, *Implementation Structure*, p. 7-33, lines 19-40, p. 7-34, lines 1-10. Sections 404 and 401 of the Clean Water Act (the US Army Corps of Engineers and the State Water Resources Control Board); Sections 10 and 14 of the Rivers and Harbors Act of 1899 (again, the Corps), Section 1602 of the California Fish and Game Code (California Department of Fish and Wildlife); Section 106 of the National Historic Preservation Act (Delta Protection Commission, Delta Conservancy, California Historic Preservation Commission, Native American Heritage Commission, possibly others); encroachment permits from the Central Valley Flood Control Protection Board and various Reclamation Districts for work on Delta levees; Federal Energy Regulatory Commission; and the National Environmental Policy Act and California Environmental Quality Act for full disclosure environmental review.

[6] Section 9(a)((1)(B) prohibits anyone subject to the jurisdiction of the United States to "take...any such species within the United States or the territorial sea of the United States". "Take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or to attempt to engage in any such conduct, according to Section 3 of the Endangered Species Act, subsection (19). The act is accessible online at http://www.nmfs.noaa.gov/pr/pdfs/laws/esa.pdf.

[7] Section 10(a)(1)(B).

[8] US Department of the Interior, Fish and Wildlife Service, and US Department of Commerce, National Marine Fisheries Service, *Habitat Conservation Planning and Incidental Take Permit Processing Handbook*, November 4, 1996. Hereafter cited as *HCP Handbook*.

[9] California Fish and Game Code Section 86 defines "take" to mean "hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill" a listed species. Section 2080 of the Fish and Game Code prohibits take of listed species, Section 2081(b) authorizes the California Department of Fish and Wildlife to authorize incidental take permits under which incidental take of a listed species is "minimized and fully mitigated, and 2081(c) specifies that no incidental take permit may be issued if its issuance would "jeopardize the continued existence of the species." The California equivalent of a habitat conservation plan is called a "natural community conservation plan" or NCCP. NCCPs are authorized under the state's Natural Community Conservation Planning Act (NCCPA) in California Fish and Game Code Section 2800 *et seq*., provided they meet the statutory standards provided in Section 2820 of the act.

BDCP is a habitat conservation plan (HCP) that may be employed to satisfy both California's Endangered Species Act (where it is considered a "natural communities conservation plan" or NCCP under California Fish and Game Code Section 2800 *et seq.*) and the federal Endangered Species Act, Section 10. In each law the HCP/NCCP is required as part of an application by a developer for an incidental take permit (a permit which would allow the taking, harming, or killing of listed species incidental to development or operational activities that would otherwise be lawful).

The HCP is the centerpiece of the incidental take permit application for purposes of the Endangered Species Act. It must document the expected level of take of listed species, and must provide measures that minimize and mitigate the impacts of take on those listed species so that the permitted takings "will not appreciably reduce the likelihood of survival and recovery of the species in the wild." It must document how the applicants will assure the National Marine Fisheries Service and the US Fish and Wildlife Service that the plan will be implemented as anticipated.[10]

Once each fishery agency deems the application complete and acceptable, they each provide incidental take permits and contractual assurances through the "Implementing Agreement" with the Applicants that unforeseen circumstances will not require additional commitment of land, money or water during the term of the permits.[11] The assurance come under the "No Surprises" rule. The Plan provides the analytic framework for an "Implementing Agreement" that is to contain the terms by which the fishery agencies will determine the Applicants' ongoing compliance with the terms of the incidental take permits. The Bay Delta Conservation Plan proposes that the term of the incidental take permits issued to the Applicants run for 50 years from the date of issuance. As of May 30th a draft Implementing Agreement was finally released, and the Department of Water Resources extended the comment period until July 29th, the minimum amount of time required for public review of the Agreement. The EWC will submit supplemental comments dealing with the Draft IA at that time.

B. Free Speech, Transparency, and Democracy

In late 2013, the Bay Delta Conservation Plan web site was reorganized and redesigned. The site's "Correspondence" page contains the statement: "The BDCP encourages public participation. Below is a list of correspondence and public comments that have been received in regards to the BDCP from 2007-2013." It appears BDCP's ongoing experiment in digital democracy ended in 2014, however. BDCP has precisely one comment letter posted to the Correspondence section of its web site, despite our being aware that many other comment letters have been sent to BDCP concerning its public review documents.

In January 2014, Friends of the River, Restore the Delta, and the Environmental Water Caucus sent a cease and desist demand letter to the California Resources Agency, California Department of Water Resources (DWR) and the Bureau of Reclamation about their recent decision to stop posting public comment letters and other vital information on their jointly hosted the BDCP website

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[10] *HCP Handbook*, Chapter 7, *op. cit.,* footnote 7 above, "Endangered/Threatened Species Permit Issuance Criteria," pp. 7-2 through 7-6.

[11] "Unforeseen circumstances" means "changes in circumstances affecting a species or geographic area covered by a conservation plan that could not reasonably have been anticipated by plan developers and the Service at the time of the conservation plan's negotiation and development, and that result in a substantial and adverse change in the status of the covered species." 50 CFR 17.3, as amended, February 23, 1998, *Federal Register* 63(5): 8870. See also Appendix A to this review.

(baydeltaconservationplan.com) just after issuance of the public drafts of the BDCP Plan and Environmental Impact Report/Environmental Impact Statement (EIR/EIS) on December 13, 2013.[12] When our country was formed, people peaceably assembled in order to hear each other's views on matters of public importance. Informed public debate is the hallmark of our democracy. The modern equivalent of the venerable town hall/public park assembly is the public comment process via the Internet on proposed major government actions. Americans have fought wars to retain these freedoms. The BDCP Applicants, however, seem intent upon wresting these hard-earned freedoms from the public. These freedoms have been suppressed by their decision to stop posting critical comment letters on the established project website. If we lived in Communist China, we might expect thoughtful or critical public comment to be suppressed. We do not expect this in the United States of America.

The Twin Tunnels is another effort by the same Governor and others to develop the old peripheral canal project that was defeated by a referendum vote by a margin of nearly 2 to 1 in June 1982. The Twin Tunnels are identified as Alternative 4, DWR's Preferred Alternative. (BDCP Draft EIR/EIS, 3-3). The Twin Tunnels are one of, if not the most, controversial proposed public works projects in California history, certainly since 1982.

1. Recent Website Change Regarding Posting of Comments

The initial Friends of the River comment letter was submitted to the National Marine Fisheries Service (NMFS) as instructed by the BDCP website on January 14, 2014. Receipt was confirmed by reply email from NMFS that same date also advising that "Additional information can be found at www.baydeltaconservationplan.com." What can be found on the BDCP website are the 40,000 pages of the consultant prepared Plan and EIR/EIS documents which the federal Bureau of Reclamation, NMFS and United States Fish and Wildlife Service (USFWS), have previously called "advocacy" and/or "biased" documents for the Twin Tunnels project. (Federal Agency Release, Bureau of Reclamation Comments p.1; NMFS Comments p.2): USFWS Comments p.1, July 18, 2013).

No longer found on the BDCP website is the January 14, 2014 Friends of the River initial comment letter explaining among other things that the Twin Tunnels project "is not a permissible project under the Endangered Species Act (ESA) because it would adversely modify designated critical habitat for at least five Endangered and Threatened fish species." (p.1). What also cannot be found on the BDCP website is the December 19, 2013 Environmental Water Caucus (EWC) (a coalition of more than 30 public interest organizations) letter requesting that the public review and comment period be extended from April 14, 2014 to August 15, 2014. The EWC letter explains that "there are 40,214 actual pages of the released documents" and that "these documents represent 20% more pages than the 32 volumes of the last printed edition of the Encyclopedia Britannica."

To explain the change in policy regarding posting of correspondence on the BDCP website, the following language initially appears under "Correspondence": *"In order to maintain the integrity of the formal public review period, incoming correspondence will not be available via the website beginning December 13, 2013 to the close of the public comment period April 14, 2014."*[13]

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[12] Letter transmitted via email to Sally Jewell, Secretary of the Interior; Penny Pritzker, Secretary of Commerce; Michael Connor, Commission, Bureau of Reclamation, John Laird, Secretary of California Natural Resources Agency, Mark Cowin, Director of California Department of Water Resources, and BDCP.Comments@noaa.gov from E. Robert Wright, Senior Counsel, Friends of the River, concerning *Demand to Cease and Desist Unlawful Vieiwpoint Discrimination and Denial of Public Access on BDCP Website and Comment Letter re Same*, dated January 28, 2014, 6 pages.

[13] See http://baydeltaconservationplan.com/library/Correspondence.aspx , emphasis added.

The obvious purpose of refusing to post comment letters is to hide critical comments from the public. It limits the information available to the public to the pro-Twin Tunnels documents posted in December 2013. In so doing, BDCP perversely and falsely uses NEPA and CEQA as pretenses not to post comments. This restriction is an unconstitutional and unlawful exercise of viewpoint discrimination by the State agencies, the Resources Agency and DWR, aided and abetted by the participating federal agencies, NMFS which is receiving the comments but not posting them on a website, and USFWS and Reclamation. The First Amendment prohibits viewpoint discrimination. This restriction is also an unlawful denial of public access to the comments prohibited by the California Constitution. Furthermore, the decision to withhold posting of comments is a direct violation of the environmental full disclosure purposes of both the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA).

2. The Closing of the Forum to Critical Comment Is Contrary to the Promise of Encouraging Public Participation

The State claims that "The BDCP encourages public participation." (BDCP website under "Correspondence".) Secretary Laird of the California Natural Resources Agency and numerous other state officials have claimed that the BDCP process is open and transparent. Those claims of encouraging public participation and openness are false. By refusing to post critical comment letters, the speech of the commenters on BDCP is silenced in this age of the Internet. The public is shielded from seeing the other side of the Twin Tunnels story.

Meanwhile, the BDCP Applicants continue to tout the Twin Tunnels on the website. (Spanish language posting, January 3, 2014 entitled *Breve Informativo*; English language Overview Presentation posting, January 20, 2014**).** The BDCP Applicants have been free to misrepresent and omit knowledgeable and unpalatable facts from the web site while silencing responsive correction.

Instead of encouraging public participation, the agencies are doing everything in their power to discriminate against and exclude views opposing the Twin Tunnels from the public website forum they have created. This is part of a pattern of suppression of free speech that was displayed in the summer of 2013 when CalTrans employees trespassed on private property in the Delta to remove signs carrying the message "Save the Delta! Stop the Tunnels!" That thuggery by the State only stopped after it was brought to widespread public attention by media coverage and rallies protesting the sign removals; no legal basis for the sign removals was ever provided by CalTrans.

Claiming that taking more water away from the fish will be good for the fish, that taking more freshwater away from the Delta would be good for the Delta and that a water grab for the benefit of the exporters is really a conservation plan is false propaganda intended to deceive and confuse the public. This pattern and practice of viewpoint discrimination by the BDCP proponent agencies is the strongest self-indictment that could be made of the folly, environmental destruction and economic waste threatened by the Twin Tunnels project. The government would not suppress the speech of project opponents if it had true confidence that its own claims about the asserted benefits of the Twin Tunnels.

3. Viewpoint Discrimination on the BDCP Website Violates the First Amendment

The First Amendment of the United States Constitution provides in pertinent part that there shall be no law "abridging the freedom of speech, or of the press; or the right of the people peaceably to assemble, and to petition the Government for a redress of grievances." Similarly, the California Constitution commands that "A law may not restrain or abridge liberty of speech or press" and the

people have the right to "assemble freely to consult for the common good."[14] "In a public forum, by definition, all parties have a constitutional right of access and the state must demonstrate compelling reasons for restricting access to a single class of speaker, a single viewpoint, or a single subject. When speaker and subject are similarly situated, the state may not pick and choose."[15] "Any access barrier must be reasonable and viewpoint neutral [citations]."[16] "When the government targets not subject matter, but particular views taken by speakers on a subject, the violation of the First Amendment is all the more blatant. [Citation.] Viewpoint discrimination is thus an egregious form of content discrimination. The government must abstain from regulating speech when the specific motivating ideology or the opinion or perspective of the speaker is the rationality for the restriction."[17]

Under the current regime, only those viewpoints that the government chooses will be posted on the BDCP website. For example, the website continues to include blogs purporting to debunk alleged "Myths" about the BDCP, and other materials written to promote BDCP and discount public concerns.[18] This blog suggests that a comment on the blog may be provided by clicking on a link. ("Click here to contact us with your questions or comments about the BDCP Blog.") Yet that link is the same link to the email address for submitting formal public comments on the Plan and EIR/EIS (BDCP.comments@noaa.gov). As explained clearly on the BDCP website, such comments will not be posted. The exclusion of critical comments from the BDCP website at the same time as the government agency proponents continue to post materials that promote their viewpoint that BDCP is a worthwhile project violates the First Amendment prohibition of viewpoint discrimination in forums created by the government.

4. The Denial of the Right of Access to Critical Comments Violates the California Constitution

The California Constitution provides in pertinent part that "The people have the right of access to information concerning the conduct of the people's business, and, therefore, the meetings of public bodies and the writings of public officials and agencies shall be open to public scrutiny."[19] Moreover, any authority "shall be broadly construed if it furthers the people's right of access, and narrowly construed if it limits the right of access."[20]

"Given the strong public policy of the people's right to information concerning the people's business (Gov.Code, § 6250), and the constitutional mandate to construe statutes limiting the right of access narrowly, all public records are subject to disclosure unless the Legislature has *expressly* provided to the contrary."[21]

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[14] California Constitution, Article I, § 2(a); § 3(a).

[15] *Perry Educ. Assn. v. Perry Local Education Assn,* 460 U.S. 37, 55 (1983).

[16] *Christian Legal Soc. Chapter of the University of California, Hastings College of the Law v. Martinez,* 130 S.Ct. 2971, 2984 (2010).

[17] *Rosenberger v Rector and Visitors of University of Virginia,* 515 U.S. 819, 829 (1995).

[18] See, e.g., http://baydeltaconservationplan.com/news/blog/14-01-10/Correcting_Stubborn_Myths_Part_II.aspx.

[19] California Constitution, Article I, § 3(b)(1).

[20] California Constitution, Article I, § 3(b)(2).

[21] *Sierra Club v. Superior Court,* 57 Cal.4th 157, 166 (2013) (internal quotation marks deleted).

The complexity of the BDCP and the volume of documents being circulated for public review to explain that complexity make review challenging even for professionals. For an average member of the public, the job is almost impossible. The public's ability to be informed regarding this project is facilitated by having access to comments being made by others during the review process, including non-profit environmental groups and other public agencies. The refusal to publish comment letters on the website as they come in denies the public the right of access to the comments in violation of the California Constitution.

5. The Exclusion of Environmental Information Contrary to the Opinions of the Project Proponents Violates NEPA and CEQA

NEPA and CEQA are both "environmental full disclosure laws."[22] Both laws require that an agency "use its best efforts to find out all that it reasonably can" about the subject project and its environmental impacts.[23]

Interfering with review by members of the public of comments made by other members of the public is environmental concealment, not disclosure, and is calculated to prevent the public from finding out all that it reasonably can about the subject project and its impacts.

CEQA provides that "notwithstanding any other provision of law" the record of proceedings "shall include, but is not limited to," written documents submitted by any person relevant to findings and all written correspondence submitted to the respondent public agency with respect to compliance with CEQA or the project.[24]

The NEPA Regulations require that federal agencies make comments received under NEPA available to the public pursuant to the provisions of the Freedom of Information Act and that they shall be provided without charge to the extent practicable.[25]

The CEQA Regulations provide that:

> Public participation is an essential part of the CEQA process. Each public agency should include provisions in its CEQA procedures for wide public involvement, formal and informal consistent with its existing activities and procedures, in order to receive and evaluate public reactions to environmental issues related to the agency's activities. *Such procedures should include, whenever possible, making environmental information available in electronic format on the Internet, on a web site maintained or utilized by the public agency.*[26]

Instead, the BDCP proponent agencies have selectively published environmental information favorable to the project on their website while concealing what they consider to be unfavorable information that they would rather not share with the public until it is too late for cross-pollination

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[22] *Silva v. Lynn,* 482 F2d 1282, 1284 (1st Cir. 1973)(NEPA); *Communities for a Better Environment v. City of Richmond,* 184 Cal.App.4th 70, 88 (2010)(CEQA).

[23] *Barnes v. U.S. Dept. of Transp.* 655 F.3d 1124, 1136 (9th Cir. 2011)(NEPA); *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova*, 40 Cal. 412, 428 (2007)(CEQA).

[24] Public Resources Code § 21167.6(e)(3), (7).

[25] 40 C.F.R. § 1506.6(f).

[26] 14 Code Cal. Regs § 15201(emphasis added).

of ideas to occur among the public. Making the comments available only *after* the comment period has closed makes a mockery of the promise of a fair, transparent and open process. Members of the public will have no opportunity to learn information provided by those with concerns about the BDCP in time to help them develop their own timely comments, including suggested alternatives to the project. The exclusion of comments from the website violates the environmental full disclosure purposes of both NEPA and CEQA, and the CEQA regulation requiring the posting of environmental information on the agency's website.

Exclusion of public comments from the BDCP website makes the claim that the BDCP encourages public participation a lie, and violates the First Amendment, California Constitution, NEPA and CEQA. This blatant viewpoint discrimination will not be tolerated. We demand that your agencies immediately commence posting all comment letters received on the BDCP website as soon as they are received, and confirm in writing that you are now doing so.

C. Government's Public Trust Responsibility, the Delta Common Pool, and the ESA

Enforcing the Public Trust Doctrine is an environmental justice issue, both broadly and narrowly construed. The Delta's public trust resources—the listed and covered fish species and the non-covered fish species of the Delta—are all nurtured at some point in their lives (if not their whole lives) in the Delta common pool. Protecting the commons in the Delta common pool is at stake from the proposed activities of the Bay Delta Conservation Plan. Governments have a permanent fiduciary responsibility and obligation to protect the public trust. In *National Audubon Society v. Superior Court*, the court held that "the public trust is more than an affirmation of state power to use public property for public purposes. It is an affirmation of the duty of the state to protect the people's common heritage of streams, lakes, marshlands and tidelands, surrendering that right of protection only in rare cases when abandonment of that right is consistent with the purposes of the trust."

The Public Trust Doctrine is an affirmation of the duty of the state to protect the people's common heritage in streams, lakes, marshlands, and tidelands.[27] The Delta is a common pool resource. DWR acknowledges this legal reality.[28] The application of the Public Trust Doctrine requires an analysis of the public trust values of competing alternatives, as was directed by the State Water Board in the Mono Lake Case. Its applicability to alternatives for the Delta, where species recovery, ecosystem restoration, recreation and navigation are pitted against damage from water exports, is exactly the kind of situation suited to a Public Trust analysis, which should be required by the Delta Plan and BDCP. The act of appropriating water—whether for a new use or for a new method of diversion or of use— is an acquisition of a property right from the waters of the state, an act that is therefore subject to regulation under the state's public trust responsibilities.

Aspects of the Public Trust Doctrine are taken up and fulfilled by adequate conduct of the habitat conservation planning process. For instance, both ESAs require the state and federal fishery agencies to find and demonstrate the BDCP will not result in take of listed species that would appreciably reduce their chances of survival and recovery must apply as well to what it means to protect these species under the public trust doctrine. The Services' HCP Handbook states in pertinent part:

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[27] *National Audubon Society v. Superior Court* (1983) 33 Cal 3d, 419, 441.

[28] California Department of Water Resources, *Water Transfer Approval: Assuring Responsible Transfers*, July 2012, page 3. Accessible online 16 February 2014 at http://www.water.ca.gov/watertransfers/docs/responsible_water_transfers_2012.pdf. In addition, the Delta Protection Act of 1959 also acknowledges this reality, California Water Code Sections 12200-12205.

> This finding typically requires consideration of two factors: adequacy of the minimization and mitigation program, and whether it is the maximum that can be practically implemented by the applicant. To the extent[ ]that the minimization and mitigation program can be demonstrated to provide substantial benefits to the species, less emphasis can be placed on the second factor. *However, particularly where the adequacy of the mitigation is a close call, the record must contain some basis to conclude that the proposed program is the maximum that can be reasonably required by that applicant. This may require weighing the costs of implementing additional mitigation, benefits and cost of implementing additional mitigation, the amount of mitigation provided by other applicants in similar situations, and the abilities of that particular applicant.* Analysis of the alternatives that would require additional mitigation in the HCP and NEPA analysis, including the costs to the applicant is often essential in helping the Services make the required finding.

The federal ESA further requires adequate funding for the habitat conservation plan and its associated procedures are dealt with. This funding must adequately cover "procedures to deal with unforeseen circumstances" as well.

> *...The Services must ensure that funding sources and levels proposed by the applicant are reliable and will meet the purposes of the HCP, and that measures to deal with unforeseen circumstances are adequately addressed. Without such findings, the section 10 permit cannot be issued.*[29]

Because "the adequacy of mitigation" in BDCP is *definitely* "a close call," the Plan also provides an economic analysis in an attempt to address the fishery agencies' concerns over whether additional mitigation is needed before approving the BDCP. Thus, in the ESA regulatory framework, the implementation of assured mitigation requires an economic analysis of each take alternative examined in the habitat conservation plan.[30]

Unfortunately, the benefit-cost analysis called for in HCP guidelines and in BDCP need only consider whether the benefits of the Plan outweigh costs to the Applicants.

The public trust doctrine requires government to go further. In the case of the Bay Delta Conservation Plan, it demands an accounting of the benefits of nature's services and the cost to society of replacing what ecosystem services are damaged by water development under BDCP. This way, government assesses whether the BDCP represents net benefits over its costs to society as a whole, beyond the net benefits to the Applicants, as provided under the ESAs. Put another way, the ESA economic analysis asks what the net payoff is to the Applicants of the project, while the public trust doctrine requires of examination of the overall net benefits to society as whole, including to future generations. It can be successfully used to value nature's services.[31]

But the HCP process for obtaining incidental take permits and "no surprises" in endangered species treatment flies in the face of the public trust doctrine. In the absence of any legal analysis, we are deeply concerned that the State of California would contract away its obligation to protect Delta public trust resources as the ink dries on the BDCP, its Implementing Agreement, and the incidental take permits. The EIR/EIS fails to disclose and analyze this crucial issue. In so doing, it fails to

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[29] *HCP Handbook*, pages 7-3 and 7-4. Emphases added.

[30] *Bay Delta Conservation Plan.*, November 2013, Chapter 9, p. 9-38, lines 12-15, p. 9-39, lines 1-4.

[31] ECONorthwest, *Bay-Delta Water: Economics of Choice*, prepared for the California Water Impact Network as part of comments on the Delta Stewardship Council's Delta Plan, January 11, 2013. Accessible online at http://www.c-win.org/webfm_send/282.

address our introductory question: why are the BDCP Applicants deserving of 50 years of regulatory stability when their activities to date have caused the problems they claim BDCP will solve? Without this information, decision makers cannot make fully-informed decisions as required by the California Environmental Quality Act and the National Environmental Policy Act.

The Delta Stewardship Council and the State Water Board clearly have trustee responsibilities in balancing the public trust here in California. However, the final Delta Plan and BDCP both gratuitously mention the public trust obligation but provide no analysis.[32]

D. Restoring the Delta for All

An environmental justice vision of the Delta reflects principles that apply beyond the life of the BDCP planning process and can be used to guide future Delta planning decisions. A sustainable Delta that provides for the needs of environmental justice communities, currently spread broadly across the legally defined Delta, will provide a safe, livable environment for all current and future residents of the Delta. That environment will include necessary infrastructure for water, flood protection, adequate transportation, etc., and will include economic opportunities for current and future community residents.

Environmental justice and disadvantaged communities face multiple barriers in trying to address the needs of their communities. These include:

- Competing priorities. These communities face multiple challenges that, due to a lack of resources, are often addressed on an emergency basis, if at all.
- Lack of access to decision-making processes, including language translations and meeting interpretation.
- Limited data on the scope of their issues
- Lack of resources

Achieving a BDCP—or, preferably, some set of actions that literally "restores the Delta" for all its species, residents and visitors—that addresses these barriers will require special focus on communities that lack the financial flexibility to easily adapt to substantial changes in the way of life in the Delta, as well as when planning for climate change and catastrophic events. There are key elements and considerations necessary to ensure that EJ communities do not suffer disproportionately and, conversely, that EJ communities benefit equitably from new policies governing the Delta, its economy, and its common pool resources.

1. Procedural Elements

- *The Delta decision-making structure must recognize and address the differing capacity for participation among interested stakeholders in order to ensure a fair and balanced BDCP.*
- *Planning and implementation of the BDCP must incorporate meaningful stakeholder engagement that contributes to and impacts the outcome of the BDCP.*
- *Data gaps relevant to disadvantaged and environmental justice communities must be identified and addressed.*

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[32] Environmental Water Caucus, *Response Letter to the Final Delta Plan, Recirculated Draft PEIR and Rulemaking Package*, January 14, 2013, page 5. Accessible online 16 February 2014 at http://ewccalifornia.org/reports/ewcdeltaplancommentsfinal.pdf.

- *Decisions based upon inconclusive data should be made in a provisional and reversible manner.*

A sustainable Delta will be governed by a diverse and representative set of agencies and interested stakeholders. The best and most defensible decisions are made with full participation of all interested stakeholders. The current and historical make-up of Delta policy decision-making structures focus representation on those stakeholder groups with the most powerful voices. Not surprisingly, this has limited the range of discussion to focus on areas of conflict. Broadening the stakeholder base increases the range of topics to be discussed, but also provides an opportunity to reach consensus on issues that have not previously been central to the discussion.

Enabling meaningful engagement and statewide investment in Delta restoration and management will require education and capacity building around the state. California's residents, by and large, have no idea where the Delta begins and ends or the role it plays in providing for California's water resources. Education can serve multiple purposes including the development of a greater investment in the Delta that may translate into support for additional resources to sustain the Delta. In addition, education can help to build capacity for more meaningful participation. Delta planning will benefit greatly from a more informed and engaged community who can impact the Delta through their individual behaviors (i.e.: conservation, reduced pesticide use, alterations in boating practices, etc.) and in their contributions to the greater decision-making process.

Implementing agencies and impacted communities need basic information upon which to base decisions and evaluate outcomes. For impacted communities, a lack of data monitoring and evaluation means that information about cumulative impacts is absent from decision-making, and that funding opportunities are missed. For agencies, decisions made on this uncertain foundation are subject to challenge. The BDCP process must, as part of its recommendations, identify areas in which key information must still be gathered to support its conclusions.

The Delta is a dynamic system. Any ideal developed in a one-time process will fail to account for unknowns that are difficult to predict. Thus, the most important element of a new vision for the Delta is a governance structure that will be flexible, and able to make decisions in a timely fashion and in the face of uncertainty, but will also provide full opportunity for participation and review of previous decisions and course change as necessary to achieve a sustainable delta. The proposed BDCP does neither. We don’t see such a governance structure in BDCP.

2. Water Supply/Water Quality

- *Drinking water quality and supply, both groundwater and surface water, must be adequate for all people who live in California.*

- *The public health impacts on subsistence fishers from eating unsafe amounts of contaminated fish must be addressed through efforts to improve water quality and to reduce exposure to mercury and other harmful bio-accumulative contaminants.*

While the major focus in the BDCP has been on water supply, water quality is a key component of a functional Delta. High quality water is necessary for the proper functioning of the ecosystem, drinking water supply, and provision for dietary subsistence.

Any water quality requirements set for the Delta must take into consideration the fact that people eat the fish swimming through the Delta. We estimate that more than 20,000 people, including young children, eat fish from the Delta as a dietary staple. These families often lack the economic flexibility to purchase alternative sources of nutrition. Because it will take generations to reduce

mercury contamination in fish, risk reduction activities must be developed with community input and implemented—*that will actually reduce their risk of exposure and mitigate health impacts when they occur.* We believe selenium toxicity in fish is understated in BDCP documentation (see elsewhere in Section II and III).

In addressing the clear and pressing issues of surface water quality in the Delta, the continuing deterioration of groundwater quality within the Delta and its source watersheds must also be of concern. A BDCP that ignores groundwater quality condemns a significant number of California residents to continue reliance on substandard drinking water supplies, and ignores the potential for great improvement in water supply reliability that can be made through groundwater conjunctive use south of the Delta.

3. Land Use

- *Impacts on low-income homeowners, such as threats to public safety and lowered home values must be addressed as part of any proposed land use changes called for by the new BDCP.*

- *Affordable housing opportunities must be maintained as land use changes are implemented.*

- *The disproportionate impacts of flooding on renters must be mitigated for all resident of the Delta, including those who work and live in the Delta, but do not own land.*

- *The impacts on existing communities of alterations in land use plans must be evaluated, particularly the potential for increased vulnerability to flooding.*

- *Emergency response plans must address the needs of the low-income and Latino populations at disproportionate risk from flood events.*

A sustainable Delta will require dramatic changes in land use decisions. The Delta is already over-developed limiting choices for flood attenuation and increasing the potential for catastrophic damage associated with a seismic event. As those choices are made the potential exists to provide equitable benefits in planning for EJ communities, but there is also the threat of disproportionate impacts on those same communities. For this reason, a sustainable vision for the Delta must identify and account for the particular impacts on EJ communities.

Changes in allowable land use patterns must be an element of a sustainable Delta. Current patterns of development will leave entire communities at risk in the event of seismic activity or flooding. We are deeply concerned that BDCP facilities and alignments may foreclose options for improving land use and affordable options for the Delta's poorest residents. A disproportionate number of these at-risk developments are populated by low-income, predominantly Latino residents. Changes in flood mapping and zoning will have a profound effect on their investments, while their ability to recover from a flood event is limited. Moreover, these existing communities may be detrimentally impacted by the advent of upper scale developments protected by new "super levees," which have the potential to re-route flood waters in ways that may negatively impact lower income communities.

In addition, Hurricane Katrina ("Katrina") provided a vivid illustration of the potential impacts of a catastrophic event. Katrina made it very clear that the people with the fewest resources tend to suffer the most, and as many remaining homeless families in New Orleans will tell you, recover the slowest from a catastrophic event. If we want to avoid a similar tragedy any BDCP must protect communities remaining in the Delta and expedited emergency evacuation plans with special focus

on educating environmental justice communities to be aware of the plan and with the resources necessary to actually evacuate these communities.

At an even greater disadvantage are communities that reside in, but don't own property in, flood plains—including tenants and farmworkers. These communities receive less assistance than property owners after a flood event and are more likely to be permanently displaced. Any emergency plan must target the special needs and vulnerabilities of these residents as well as their leadership capacity, if supported with resources.

Finally, as development becomes limited and/or more expensive in flood plains, the supply of low-income housing will be curtailed. Any land use changes must include a plan for provision of affordable housing for the current and expected population in the Delta region. This BDCP fails on each of these points.

4. Local and State Economies

- *Proposed changes in agricultural practices or other economic activities must evaluate the potential impacts of those changes on Delta residents, particularly farmworker and other disadvantaged communities.*

- *Implementing the BDCP should provide economic opportunities to current Delta residents.*

The "legal" Delta is largely an agricultural and recreational economy. As such, many of the employment opportunities require only lower levels of educational attainment. Changing crops, fallowing or retiring land, shifts in recreational opportunities and supporting service industry will impact Delta communities who provide this labor force. Such dislocations go beyond the paycheck these individuals receive, to include loss of the very communities where these individuals live. While they may comprise migrant communities, in fact these are stable, established communities, often now for the past two generations. Any changes in the economic viability of these communities must be accommodated in a sustainable BDCP.

Conversely, proper care-taking of the Delta and its resources can provide new economic opportunities that should be targeted at these residents. Water quality monitoring, wetland restoration, and levee reconstruction and repair all provide new or continuing job opportunities for Delta workers.

5. Environment

- *A sustainable Delta must provide necessary water flows to maintain the common pool and ecosystem, and regulators must have the flexibility to amend these flows as circumstances dictate.*

- *Ecosystem impacts, beyond flow, must be considered and altered to improve ecosystem health.*

- *BDCP must recognize the impact of upstream source control and flood attenuation activities on the health and viability of the Delta.*

The collapse of Delta smelt and other fish populations calls for sober reflection on the dangers of unintended consequences. Environmental justice communities have a similar unfortunate history; that is, the dismissal of cumulative impacts on their communities as insignificant until such time as their impact on the community's health is undeniable and perhaps irreversible.

To ensure that community health and the environment are protected in the BDCP process, we recommend that decisions on changes in conveyance and operation of Delta water infrastructure be incremental and reversible, dependent upon the measured impact on the ecosystem. This can only be done by having habitat restoration proceed first, so that society knows it will succeed. Success for the Delta common pool resources should be assured before any Twin Tunnels project is deemed safe to develop. Agricultural and storm water discharges be limited to protect water quality. Remediation of mine sites and stream beds be prioritized and ecosystem restoration projects be prioritized, sited, and designed so as to limit the potential for additional methylation of mercury and the related health impacts to wildlife and human health.

E. The Delta Plan

The Bay Delta Conservation Plan enters a larger context beyond the state and federal Endangered Species Acts. In 2009, the State Legislature approved new initiatives in California water policy. Key among these was creation of the Delta Stewardship Council (with its Delta Science Program) and the Council's Delta Independent Science Board. The legislation required the Council to complete a Delta Plan that regulates "covered actions" in the Delta. BDCP and its Twin Tunnels project is one such covered action. The legislation describes criteria for how the Council and the California Department of Fish and Wildlife must consider the Bay Delta Conservation Plan for inclusion in the Delta Plan. DFW is responsible for making findings under the state's Natural Communities Conservation Planning Act and the California Environmental Quality Act. Once these findings are made and the Department issues its incidental take permit approval, the law requires the Delta Stewardship Council to incorporate BDCP into the Delta Plan. However, the same section of the law requires the Delta Stewardship Council to hold a public hearing about the incorporation of BDCP into the Delta Plan, and allows that the Department's approval of BDCP may be appealed to the Delta Stewardship Council. By this reading of the law, the Delta Stewardship Council may have some type of veto power over BDCP.[33]

F. The State Water Resources Control Board's Bay-Delta Plan

Since 2009, the State Water Board has sought to update its water quality control plan (WQCP) for the Bay Delta Estuary. The Board is not legally bound to consider incorporating the BDCP the way that the Delta Plan is. However, Conservation Measure 1 (CM 1), Water Facilities, of the Bay Delta Conservation Plan employed modeling criteria for the Twin Tunnels project that, if elevated to the status of flow and operational objectives in the WQCP, represent the likely shape of "regime change" for water quality control in the Bay Delta Estuary should the Twin Tunnels move forward. Neither the BDCP nor its EIR/EIS acknowledge the Twin Tunnels need for "regime change." They do not analyze how it will likely force the State Water Board to revisit most if not all its current Delta water quality objectives while also adding new ones to accommodate operation of new intakes along the lower Sacramento River.

Currently, the Bay-Delta WQCP and its implementing water rights decision D-1641 regulate salinity and flow conditions for the legal Delta region's water ways. Flow objectives in the Plan currently cover Delta outflow, Sacramento and San Joaquin Rivers' inflow, the ratio of exports to inflows, the size and position of the low salinity zone (the estuarine objective, X2), and the operation of the Delta Cross Channel gates near Walnut Grove.

The modeling criteria for CM 1 would introduce "bypass flows" on the lower Sacramento River as well as new diversion objectives for the three North Delta intakes of the Twin Tunnels project that

[33] California Water Code Section 85320. This section as written is silent about the possibility of the Delta Stewardship Council upholding such an appeal, and on what legal grounds for upholding an appeal would be.

would be located between Clarksburg and Courtland. It would also introduce new Old and Middle River (reverse) flow objectives as well. It would revise the inflow-to-export ratio objective and may force reconsideration of salinity objectives at Emmaton on the Sacramento River and Jersey Point on the San Joaquin. Operational objectives for a gate at the head of Old River would be needed as well.

The State Water Board will need to prepare and adopt a new Bay Delta Plan before authorizing water rights permits for new north Delta diversions for the Twin Tunnels project, otherwise BDCP-project water rights permits will not conform to the current Bay Delta plan. The Bay Delta Plan must come first and must demonstrate compliance with the federal Clean Water Act (CWA), including its anti-degradation policy. BDCP must also comply with federal Clean Water Act regulations and water quality objectives as well. The Bay Delta Plan must also meet the obligation for state flow (and salinity) standards to protect—not "reasonably" protect under Porter Cologne provisions such as Sections 13000 and 13241—the most sensitive beneficial uses, as is required by the CWA. Where there are multiple beneficial use designations, the Bay Delta Plan must protect the most sensitive beneficial use.[34] The State Water Board typically reserves jurisdiction upon issuing new or modified water right permits.

It is our understanding that the BDCP and its Environmental Impact Report/Statement are to be employed not only for making findings to support approval of the Applicants' incidental take permits but also to support issuance of the State Water Board's water rights permits for the proposed Twin Tunnels and associated uses of water (such as increased flows for Yolo Bypass associated with the BDCP's seasonal floodplain inundation strategy). ***In their current condition, these documents are at best unready to fulfill such a role.***

Both the US Bureau of Reclamation and the California Department of Water Resources filed petitions with the State Water Board to extend the time on their water rights permits to allow additional time to complete facilities on the Central Valley Project and the State Water Project. No mention is made of these time extension requests in the BDCP or its EIR/EIS, despite several governmental and nonprofit entities filing protests of the requests with the Board.[35]

G. Availability of Water

At this time, the Bay Delta Conservation Plan's Applicants *assume* that the Twin Tunnels project will have sufficient water rights to carry out its operations. Water quality control planning efforts to date have led the Board to consider proportional tributary contributions needed to meet Delta inflow objectives from the Sacramento and San Joaquin River Basins to improve water quality and protect all beneficial uses, including fish and wildlife, in the Delta. The State Water Resources Control Board has authority over water rights in the Basins that would enable it to reallocate water usage and ensure compliance with the Board's new instream flow objectives.

[34] See 40 CFR § 131.11; *see also* 40 CFR § 131.6.

[35] Among those entities filing protests were EWC member groups California Water Impact Network, California Sportfishing Protection Alliance, and AquAlliance.

The Environmental Water Caucus has previously illustrated how the Central Valley Project and the State Water Project have failed for decades to have enough water to fulfill the contract-based demands of their numerous contractors in the Central Valley and southern California.[36]

Water availability analysis is an important method for modeling how the Board would implement new flow objectives. Testimony submitted in 2012 by EWC member organizations California Water Impact Network, California Sportfishing Protection Alliance, and AquAlliance illustrates the use of a planning-level water availability analysis for the Trinity River (much of whose flows are diverted to the Central Valley watershed of the Bay-Delta Estuary), and the major tributaries of the Sacramento and San Joaquin River Basins. The analysis incorporated the Basins' hydrologic variability, instream flow requirements based on the Board's 2010 public trust Delta flow determinations[37], and then allocated the divertable flows that remain in the system according to known publicly available water rights data and priorities. They found that under public trust protective flow determinations, the promised water represented in water rights claims exceed flow conditions available to these claims.

In addition, the California Water Impact Network has shown that total consumptive water rights claims for the Sacramento and Trinity River basins exceed annual average unimpaired flows by a factor of 5.6 acre-feet of claims per acre-foot of flow. A similar ratio occurs in the San Joaquin River Basin. The river basins of the Delta's Central Valley watershed are over-appropriated. The analysis showed that Bureau and DWR water rights had potentially clouded titles to water on the Sacramento, Feather, American, Stanislaus, and San Joaquin Rivers.[38]

The EWC objects to approval of BDCP and its EIS/EIR because they fail to disclose the root cause of Delta water supply "unreliability" and the "Delta crisis." The State Water Resources Control Board, the Department of Water Resources and the US Bureau of Reclamation are unwilling to eliminate the paper water in both the overall water rights system of the Central Valley and the excess contractual amounts of the state and federal water projects. The absence of clearly analyzed and legally reliable water availability for nature as well as for society means that the state and federal fishery agencies risk issuing incidental take permits for supply benefits to the Applicants that are based on wishes and prayers. Failure of these fictitious benefits could jeopardize the Applicants' continued ability to pay for and comply with BDCP covered activities and programs. That funding ability is crucial to adaptively manage the conservation, avoidance and minimization measures that are crucial to BDCP's conservation strategy, flawed as it is.

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[36] Letter from David Nesmith and Nick Di Croce, co-facilitators of the Environmental Water Caucus, to Katrina Chow, Project Manager, Shasta Lake Water Resources Investigation, United States Department of the Interior, Bureau of Reclamation, dated September 30, 2013, *Comments on Draft Environmental Impact Statement dated June 2013*, pp. 6-8.Accessible online 21 March 2014 at http://ewccalifornia.org/reports/shastadeiscomments.pdf.

[37] State Water Resources Control Board, *Developing Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem*, prepared pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009, August 2010, 178 pages. Accessible online 7 April 2014 at http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/final_rpt.shtml.

[38] Stroshane,T., *Testimony on Water Availability Analysis for Trinity, Sacramento, and San Joaquin River Basins Tributary to the Bay-Delta Estuary*, Submitted by the California Water Impact Network on behalf of California Sportfishing Protection Alliance, and AquAlliance on October 26, 2012, for Workshop #3: Analytic Tools for Evaluating Water Supply, Hydrodynamic, and Hydropower Effects of the Bay-Delta Plan. Accessible online at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/comments111312/tim_stroshane.pdf

The failure to adequately define and quantify "water supply reliability" renders these documents legally inadequate. CEQA and NEPA require that an EIS and EIR inform the public and decision-makers about adverse consequences of a project or program. These findings are crucial parts of BDCP's affected environment and environmental and regulatory baseline. **Absent a thorough documentation of the purpose and need for BDCP with respect to water supply reliability, decision makers cannot understand what type and level of reliability might be achieved. The National Environmental Policy Act and the California Environmental Quality Act are both violated as a result.**

The EWC has presented clear alternatives for achieving water supply reliability and Delta ecosystem restoration (Responsible Exports Plan) but our alternative was not considered in the Draft EIS/EIR. The EWC Reduced Exports Plan contains numerous actions that compensate for reduced Delta exports. This reasonable alternative has not been evaluated in the BDCP or in the Draft EIS/EIR. The EWC alternative has relied on strict enforcement of water quality laws, adoption of the State Water Resources Control Board and Fish and Game flow recommendations, shoring up of existing levees, ceasing the unreasonable use of water to irrigate toxic soils (primarily in the western San Joaquin Valley) that return pollution to the estuary, while also providing for modest export water supply with statewide water conservation, efficiency, and recycling measures to ensure existing supplies are extended to meet demand.

As we describe in Section VII, BDCP's Twin Tunnels project will function to increase the Central Valley Project and State Water Project's ability to arrange and facilitate cross-Delta water market transfers in drier and drought years. ***The very existence of the water transfer market is due to this lack of water available to fulfill SWP and CVP water right claims, and the contractual demands of their south of Delta customer agencies.***

BDCP all but ignore this crucial purpose of the Twin Tunnels project. They fail to call it out as a purpose to comply with CEQA and NEPA. The project itself increases reliance on the Delta in flagrant defiance of the Delta Reform Act of 2009, and fails utterly to justify why the Twin Tunnels are needed.

H. Reasonable Use of Water

California's constitution recognizes water rights only to the extent they are reasonable. No one has a right in California to use water unreasonably, not even the state and federal governments. (California Constitution, Article X, Section 2) Moreover, the state constitution also states that "such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water." The EWC believes that because lack of water availability and the precarious population status of listed fish species go unaddressed, the Bay Delta Conservation Plan's Twin Tunnels project (often referred to as "North Delta Intakes") in Conservation Measure 1 would be an unreasonable method of diversion of water, and that continued provision of a supposedly more reliable irrigation water supply to the drainage impaired lands of the western San Joaquin Valley, as is implied but not disclosed in the Bay Delta Conservation Plan and its EIS/EIR, would continue to be a wasteful and unreasonable use of water.

The Bay Delta Conservation Plan would violate the California Constitution's ban on wasteful and unreasonable use of water and method of diversion of water because BDCP:

- Fails to demonstrate and disclose its purpose and need,
- Reduces Delta outflow by increasing exports in violation of legal requirements to reduce reliance on Delta exports,
- More than appreciably reduces the likelihood that listed species can survive and recover in the Delta under operating conditions of the Twin Tunnels project, and

- Disconnects biological goals and objectives intended to help species survive and recover in the Delta from accountability of the BDCP Applicants for successful performance of the Plan.

I. Selenium Toxicity and Fate in the Delta

BDCP's analysis of selenium as a water quality stressor is inadequate for failing to acknowledge or address uncertainties about the regulatory and technological setting of the Grassland Bypass Project and long-term management and mitigation of selenium loading to the San Joaquin River in the western San Joaquin Valley. The California Water Impact Network provided the State Water Board with testimony about the Grassland Bypass Project's limitations and the broad overview of the challenges Grassland area farmers face in developing and implementing a cost-effective treatment technology for concentrating, isolating, managing and sequestering selenium.[39]

These projects indicate the ecological and public health risks of various scenarios of selenium loading to the Bay-Delta Estuary. BDCP irresponsibly downplays the risks and foreseeable costs and circumstances involved. See our detailed analysis of this issue in Section III.

J. Adaptive Management and the Rule of Law

Adaptive management "serves as a tool to address the uncertainty associated with the needs of species covered by" an HCP or NCCP. According to BDCP, the fishery agencies consider adaptive management to be "an integrated method for addressing uncertainty in natural resource management" that must be "linked to measurable biological goals and monitoring."[40] The EWC does not see how adaptive management can be accomplished on behalf of listed species in the Bay Delta Estuary with No Surprises rules applied to their protection and recovery. ***"Regulatory stability," No Surprises, and "adaptive management" mutually contradict each other.***

Estuaries like the San Francisco Bay-Delta are by definition areas where fresh water flows from rivers meet tidal flows from the ocean. Estuaries depend for their ecological productivity on interactions between fresh water from rivers and salt water from tides. Managing estuaries requires that resource managers and regulators have available *all* the tools they need—including fresh water inflows from major tributaries to the estuary—so they may act effectively for the good of the resource and the public trust, in real-time and over the long term.

Adaptive management has been described elsewhere as "an approach for simultaneously managing and learning about natural resources…"[41] BDCP recognizes this need to learn more about the mechanisms of flow, water project operations, and habitat functions in the Delta. To excess.

There are two adaptive management precedents for the massive restructuring of the Delta's hydrodynamics and ecology with insufficient advance knowledge of ill-conceived and damaging effects—the Central Valley Project and the State Water Project. We are still dealing with the projects' effects in an ex post facto adaptive management era that was capped by the enforcement of

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[39] Stroshane, T. 2012. *Testimony on Recent Salinity and Selenium Science and Modeling for the Bay-Delta Estuary,* prepared for the California Water Impact Network and submitted to the State Water Resources Board Workshop #1 Ecosystem Changes and the Low Salinity Zone, September 5 (and 6, if necessary), 44 pages plus appendices. Accessible online 21 March 2014 at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/cmnt081712/tim_stroshane.pdf.

[40] *Bay Delta Conservation Plan*, November 2013, Chapter 3, Section 3.6, p. 3.6-4, lines 2-3.

[41] Byron K. Williams, "Adaptive management of natural resources—framework and issues," *Journal of Environmental Management* 92 (2011): 1346.

the 2008 Delta smelt biological opinion and the 2009 salmonid biological opinion. It took four decades for adaptive management to begin to limit just the risk of jeopardy to Delta smelt and salmonids from project operations.

There is indeed much that remains unknown in the Bay-Delta estuary. BDCP's conservation strategy contains 22 conservation measures entailing at least 43 compliance actions required, 86 effectiveness monitoring actions, and 48 research actions to address uncertainties and risks of the plan. Any or all of these 175 research and monitoring-related actions could trigger further "adaptive management" actions to resolve uncertainties associated with BDCP implementation. This is a virtual, profound, and enormous reservoir of uncertainty and bureaucratic delay concerning BDCP risks. Uncertainty in one area adds uncertainty in others and must be accounted for.[42] All such delays work to the detriment of the fish species BDCP purports to help.

The Applicants request incidental take permits with 50-year terms. Under federal "No Surprises" rules, HCPs (including BDCP) are to identify which future circumstances it will accept responsibility for mitigating. All other circumstances will be deemed "unforeseen" and therefore beyond the scope of the HCP. Determining this scope of BDCP will ultimately limit the fishery agencies' authority to require additional mitigations from the Applicants in the form of land, money, or water.

BDCP's fine print (that is, the terms of the BDCP implementing agreement and the conditions of the incidental take permits) will determine how these risks and uncertainties will be apportioned according to "No Surprises" requirements. Once set, they last for 50 years.

With "No Surprises" in the ESA legal framework, the constraints of law trump the reasonable need to manage natural resources effectively. This is what we mean by adaptive management and "No Surprises" mutually contradicting each other. The "toolbox" for truly restoring the Delta and recovering listed species must include managing inflow to and outflow from the Delta. The Environmental Water Caucus would appreciate an explanation from the Applicants and the fishery agencies: How can the Bay-Delta estuary be managed adaptively if regulations, implementing agreements, and permit conditions governing the Twin Tunnels project preclude provision of additional flows from rivers controlled by the Applicants for the next 50 years? It is already the case that flows are documented to be inadequate for the protection and recovery of public trust resources (especially fish resources) in the Bay-Delta Estuary.[43] Without the ability to manage fresh water inflow to the Delta beyond parameters provided in BDCP (through No Surprises), and which currently assume Water Rights Decision 1641 (which is well-known to provide inadequate flows to the Estuary already), the Delta will continue to decline and fish species now on the brink of extinction will likely fall into it.

K. EWC Responsible Exports Plan

Development and evaluation of a range of reasonable alternatives are the declared "heart" of both the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA)

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[42] Delta Science Program Independent Review Panel, *BDCP Effects Analysis Review, Phase 3,* p. 32, 40. Accessible online 7 April at http://deltacouncil.ca.gov/sites/default/files/documents/files/Delta-Science-Independent-Review-Panel-Report-PHASE-3-FINAL-SUBMISSION-03132014_0.pdf.

[43] See Note 21 above, p. 4, where the State Water Board states: "There is sufficient scientific information to support the need for increased flows to protect public trust resources; while there is uncertainty regarding specific numeric criteria, scientific certainty is not the standard for agency decision making."

required EISs and EIRs.[44] Despite that, the alternatives section (Chapter 3) of the Draft EIR/EIS and the Endangered Species Act (ESA) required Alternatives to Take section (Chapter 9) of the BDCP Draft Plan fail to include even one, let alone the CEQA, NEPA and ESA required range of, reasonable alternatives that would increase water flows in the San Francisco Bay-Delta by reducing exports. These serious violations of law, brought to your attention by the Environmental Water Caucus (EWC)(a coalition of over 30 nonprofit environmental and community organizations and California Indian Tribes) and Friends of the River (FOR), require corrective action.

The BDCP omission of alternatives reducing exports to increase flows is deliberate. A claimed purpose of the BDCP Plan is "Reducing the adverse effects on certain listed [fish] species due to diverting water." (BDCP Draft EIR/EIS Executive Summary, p. ES-10). "There is an urgent need to improve the conditions for threatened and endangered fish species within the Delta." (*Id.*). The omission of a range of reasonable alternatives reducing exports to increase flows violates CEQA, NEPA and the ESA. The failure to include even one alternative reducing exports to increase flows is incomprehensible. Alternatives reducing the exporting/diversion of water are the obvious direct response to the claimed BDCP purpose of "reducing the adverse effects on certain listed [fish] species due to diverting water."

The BDCP agencies have been marching along for at least three years in the face of "red flags flying" in their deliberate refusal to develop and evaluate a range of reasonable alternatives, or indeed, any alternatives at all, that would increase flows by reducing exports. Three years ago the National Academy of Sciences declared in reviewing the then-current version of the draft BDCP that: "[c] hoosing the alternative project before evaluating alternative ways to reach a preferred outcome would be post hoc rationalization—in other words, putting the cart before the horse. Scientific reasons for not considering alternative actions are not presented in the plan." (National Academy of Sciences, Report in Brief at p. 2, May 5, 2011).

The EWC Responsible Exports Plan contains numerous constructive actions to compensate for our recommendation to reduce exports.[45] This is a reasonable alternative that has not been considered in the BDCP or DEIS/EIR. These actions include alternatives for achieving water supply reliability and Delta ecosystem restoration. This alternative relies on strict enforcement of water quality laws, adoption of the SWRCB 2010 Delta Outflow and Fish and Game flow recommendations, shoring up existing levees, ceasing the unreasonable use of water to irrigate toxic soils that return pollution to the estuary, while also providing for exports and water supply along with water conservation measures to ensure existing supplies are extended to meet demand.

Unless the state is willing to write off restoring vibrant Delta waterways, and abundant fish and wildlife, the state needs to plan effectively for the water needs of both Californians and California ecosystems. The vicious spiral of "use, overuse, environmental decline, then hasty and unplanned reaction" can begin to be unwound by granting waterways the right to be at the planning table from the beginning, at a level truly "co-equal" to human water uses, rather than at the end when the damage has been done.

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[44] These comments were originally provided to Bay Delta Conservation Plan officials in a joint letter from Nick Di Croce, Co-Facilitator of the Environmental Water Caucus and E. Robert Wright, Senior Counsel of Friends of the River, "Comment Letter re Failure of BDCP Draft Plan and Draft EIR/EIS to Include a Range of Reasonable Alternatives Increasing Flows and Reducing Exports Including the Responsible Exports Plan Submitted by the Environmental Water Caucus," May 28, 2014. Accessible online at http://www.friendsoftheriver.org/site/DocServer/Cmt_817.pdf?docID=8741.

[45] Accessible online 14 May 2014 at http://ewccalifornia.org/reports/responsibleexportsplanmay2013.pdf.

More than two years ago, on April 16, 2012, the Co-Facilitators of the EWC transmitted a short, 1 ½ page letter to Gerald Meral, Deputy Secretary of the California Resources Agency, sharing "concerns with the current approach and direction of the [BDCP] project and we would like to share those concerns with you." (Letter, p. 1). Most of the paragraphs in the letter dealt with the types of issues involving consideration of alternatives. The penultimate paragraph of the letter specifically pointed out:

> *The absence of a full range of alternatives,* including an alternative which would reduce exports from the Delta. It is understandable that the exporters, who are driving the project, are not interested in this kind of alternative; however, in order to be a truly permissible project, an examination of a full range of alternatives, including ones that would reduce exports, needs to be included and needs to incorporate a public trust balancing of alternatives. (Letter, p. 2).

We attached (for BDCP.Comments@noaa.gov) and incorporated by reference a copy of the April 16, 2012, EWC letter. As you can see from the letter's distribution list, the letter was also distributed to a number of other federal and State officials involved in the BDCP process and BDCP decision-making in addition to Gerald Meral who was leading the BDCP process.

On December 15, 2012 by email, and December 17, 2012 by letter, Nick Di Croce, Co-Facilitator of the EWC transmitted the EWC's Reduced Exports Plan to the California Resources Agency Deputy Secretary and requested "that you include it among the alternatives to be included in the BDCP." On November 18, 2013, FOR submitted a comment letter in the BDCP process urging those carrying out the BDCP to review the "Responsible Exports Plan [a later, more detailed version of the Reduced Exports Plan]" proposed by the EWC:

> as an alternative to the preferred tunnel project. This Plan calls for reducing exports from the Delta, implementing stringent conservation measures but no new upstream conveyance. This Plan additionally prioritizes the need for a water availability analysis and protection of public trust resources rather than a mere continuation of the status quo that has led the Delta into these dire circumstances. Only that alternative is consistent with the EPA statements indicating that more outflow is needed to protect aquatic resources and fish populations. The EWC Responsible Exports Plan is feasible and accomplishes project objectives and therefore should be fully analyzed in a Draft EIS/EIR."[46].

FOR specifically pointed out (at p. 3, fn. 1) that the plan was online at http://www.ewccalifornia.org/reports/resonsibleexpltsplanmay2013.pdf. We incorporate by this reference a copy of FOR's May 21, 2014 BDCP comment letter explaining in greater detail the failure of the Draft BDCP Plan and EIR/EIS to include the required range of reasonable alternatives as well as supporting legal citations. (The FOR letter is in the BDCP comments Record and may also be found online at www.friendsoftheriver.org/bdcpcomments). We also reiterate that the May 21, 2014 FOR comment letter attached and incorporated by reference a copy of the 39 page "Responsible Exports Plan" of May 2013 as setting forth a feasible alternative that must be considered in the BDCP process.

We repeat the EWC's demand for consideration of the Responsible Exports Plan alternative and reasonable variants on that alternative. This demand follows up EWC's similar requests which started back on April 16, 2012 but have to date been ignored in the BDCP process.

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[46] Friends of the River, November 18, 2013 comment letter at p. 3, Attachment 4 to FOR January 14, 2014 comment letter. Accessible online at http://www.friendsoftheriver.org/site/DocServer/Cmt_94.pdf?docID=7621.

We also urge you to not load up the Responsible Exports Plan alternative with "poison pills" designed to make the alternative or variants on the alternative appear infeasible or undesirable. Our suspicions of future BDCP process intentional violations of CEQA, NEPA and the ESA are heightened by the flat refusal of the BDCP agencies to develop or even consider a reasonable range of alternatives despite the clear warnings in this regard given by the National Academy of Sciences three years ago, and repeated by the EWC over the past three years. In addition, obvious variants on the Responsible Exports Plan alternative creating a range of reasonable alternatives will include reducing exports both more and less than the 3,000,000 acre-feet reduction called for by the Responsible Exports Plan alternative as well as phasing in reductions in exports over time.

Finally, the BDCP agencies have failed to produce an alternatives section that "sharply" defines the issues and provides a clear basis for choice among options as required by the NEPA Regulations, 40 C.F.R. § 1502.14. The choice presented should include increasing flows by reducing exports, not just reducing flows by increasing the capacity for exports as is called for by ***all*** of the so-called "alternatives" presented in the BDCP Draft Plan and EIR/EIS. No matter how badly the BDCP proponents do not want to reduce exports and increase flows, during the Draft CEQA, NEPA and ESA processes inclusion of such alternatives as part of a range of reasonable alternatives is mandatory. Because of the gross deficiencies in the BDCP alternatives and Alternatives to Take sections in the Draft BDCP Plan and EIR/EIS it will be necessary for the BDCP agencies to prepare and release for decision-maker and public review a ***new*** Draft Plan and ***new*** Draft EIR/EIS. Those new Draft documents ***must*** include alternatives and Alternatives to Take sections that present the required evaluation of a range of reasonable alternatives.

III. BDCP fails to provide adequate ecological assurances under the endangered species laws.

A. No Quantified Incidental Take Estimates

The Bay Delta Conservation Plan fails to provide clear, direct analysis and findings of effects of the Twin Tunnels and other elements of the Plan on take of listed species, as a result of the Twin Tunnels' effects on population abundance, distribution, and critical habitat and whether those effects could result in jeopardy to listed species.

Chapter 9 of the Bay Delta Conservation Plan addresses alternatives to take. It provides no summary of what are anticipated quantified levels of incidental take for covered and listed fish species in the BDCP "proposed action" despite having used over 37 different types of models and generated 68 different models as a whole.[47] The chapter describes how the proposed action and its alternatives to take were developed, and how the take alternatives differ from EIS/EIR alternatives (Tables 9-1 and 9-2). It provides summary descriptions of the take alternatives (Table 9-3), their conveyance facilities components (Table 9-4), and their overall comparative differences relative to the BDCP proposed action (Table 9-5). It describes the "permanent effects" by natural community type of each take alternative relative to the BDCP proposed action, and summarizes the change in take for each alternative relative to the BDCP proposed action (Tables 9-6 and 9-7). It summarizes differences in consistency of each take alternative with BDCP goals (Table 9-8). It summarizes other environmental consequences of take alternatives that vary from those of the BDCP proposed action (Table 9-9). None of these comparisons are quantified despite all the modeling done for BDCP.

Chapter 9 ranks each take alternatives' expected change in incidental take ***in relative terms*** for each covered fish species (Tables 9-10 through 9-26, pages 9-49 through 9-184). After reviewing take alternatives' effects on all covered species using this relativistic method, BDCP summarizes the relative take effects on all covered species in Table 9-31, where it can be seen that among them are several take alternatives that are deemed to perform better than the BDCP proposed action from the standpoint of decreasing take on covered fish: the so-called "portfolio alternative" (Alternative D) containing just one 3,000 cubic feet per second (cfs) intake in the north Delta; "isolated conveyance" (Alternative E) would have reduced take for nine covered fish species, and "more restoration" (Alternative H) would have reduced take for 11 covered fish species both relative to the BDCP proposed action. Also significant is Take Alternative G, calling for less tidal restoration (which would consume more terrestrial habitat currently occupied by mammals, birds, reptiles, amphibians, and invertebrates). Take Alternative G which would result in no (zero) increase in take of covered species and reduced take relative to the BDCP proposed action for 20 species (over half of whom would be birds). We still do not know how much take would be occurring and what levels would be deemed incidental to the operations of an otherwise lawful activity.

Nowhere to be found in Chapter 9 is an estimate first of the ***absolute*** incidental take quantities for each covered fish species for the Bay Delta Conservation Plan's proposed action (i.e., the Twin Tunnels project of Conservation Measure 1); and second, no quantified estimate of the take alternatives ***in comparison to the absolute take*** of the BDCP proposed action. This is the central analysis needed for the fishery agencies to understand the magnitude of incidental take and level of regulatory effort they will face should they decide to issue incidental take permits to the BDCP proposed action.

[47] Bay Delta Conservation Plan, Chapter 5, Effects Analysis, Table 5.2-5, pages 5.2-17 to 5.2-21.

As a result of this omission, it becomes impossible for the fishery agencies to quantify a magnitude, or a schedule of magnitudes, based on flow or other BDCP- or regulatory agency-controllable criteria for incidental take limits to be included in the conditions of incidental take permits.

Chapter 9 provides only ***a relative sense*** of incidental take outcomes: Alternatives D, E, and G would result in less overall incidental take of covered species (especially fish) than would the BDCP proposed action. While useful to know for whether to like one or another alternative, the relativistic analysis provided in Chapter 9 is an insufficient base of knowledge, analysis, and understanding of the covered species involved for regulating a set of 50-year incidental take permits on any of these alternatives.

What are the sizes of the population of each covered species involved? What are the permissible levels of take for each covered species for each life stage that occurs in the Delta that can be managed by actions organized under BDCP and its conservation strategy? Which alternatives would not appreciably reduce the likelihood and recovery of any of the listed species among those that are covered by BDCP? We were unable to locate this vital information in the Bay Delta Conservation Plan.

B. Inadequate Biological and Ecological Assurances

The Bay Delta Conservation Plan fails to provide adequate assurances that its biological goals and objectives will be implemented and used to hold the Applicants accountable for making progress towards recovery of listed species and minimizing incidental take, as well as compliance with the terms of the implementing agreement and incidental take permit terms.

Chapter 3, Section 3.3 of BDCP's conservation strategy discloses that:

> Failure to achieve a biological goal or objective will not be a basis for a determination by the fish and wildlife agencies of noncompliance or for the suspension or revocation of the [incidental take] permits as long as the Permittees are properly implementing the BDCP and in compliance with the Implementing Agreement and the permit terms and conditions.[48]

This passage early in the BDCP conservation strategy belittles the importance of biological goals and objectives, renders them irrelevant to the implementation of the BDCP and to whether BDCP complies with incidental take permit terms and conditions. ***This is unacceptable.*** How do the Applicants explain this passage? What is its basis, if any, in ESA law, regulation, fishery agency practice, and handbook usage? If the biological goals and objectives are irrelevant to determining compliance or making findings as to whether suspension or revocation of incidental take permits is warranted, why include the biological goals and objectives, conservation measures 4 through 10, and the entire adaptive management program contained in the draft Bay Delta Conservation Plan? If they are irrelevant to accountability of the Applicants throughout the 50-year term of the incidental take permits, then how could the fishery agencies be assured, in advance of permit issuance, that implementation of the Bay Delta Conservation Plan "*will not appreciably reduce the likelihood of the survival and recovery* of the species in the wild," as stated in the federal Endangered Species Act?

This question applies to several listed species addressed by the rest of the biological goals and objectives in BDCP: Delta smelt, longfin smelt, winter-run and spring-run Chinook salmon, and green sturgeon.

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[48] Bay Delta Conservation Plan, Chapter 3, Section 3.3 Biological Goals and Objectives, p. 3.3-2, lines 2-5. We note that the July 2013 draft implementing agreement states, "...will not be *the sole* basis…" for this clause, p. 25 of the implementing agreement. Emphasis added. We also note with concern that the November 2013 BDCP may represent the more recent formulation of this clause.

Combined with the absence of modeled estimates of quantified incidental take levels, this passage of the conservation strategy makes the thousands of pages of earnest analysis and detailed description of habitat restoration actions and covered fish species seem like an elaborate exercise in greenwashing and busy-making.

There are many more reasons to doubt, and reject, BDCP ecological assurances.

1. Flawed Habitat Restoration Hypothesis for Increasing Food web Productivity

Omitting a conservation measure that would use freshwater flow to manage nonnative invasive clam ranges and abundance is fatal to BDCP's habitat restoration plans and activities. ***Therefore BDCP cannot fulfill the Endangered Species Acts' requirements for ecological assurances that should not appreciably reduce the likelihood of the survival and recovery of listed species. The BDCP application for incidental take permits should be rejected by the fishery agencies.***

Even if the Environmental Water Caucus tries to take the habitat restoration component of the Bay Delta Conservation Plan seriously, flaws in the Plan's presentation and analysis are not addressed clearly and comprehensively. The flaws are likely fatal to success of the habitat conservation plan. They fail to provide adequate assurances for the ecological performance of its conservation strategy. Lack of realistic analysis and of planned corrective actions makes it extremely problematic for the fishery agencies to make findings on ecological and conservation assurances in support of issuing incidental take permits based on the Bay Delta Conservation Plan.

In essence, the most central ecological gamble of BDCP is that habitat and its food production capability can substitute for freshwater inflows to the Delta at key times of year in the service of protecting listed fish species so they have a chance to recover. This hypothesis is tenuous to start with, and BDCP stretches its thin threads across the relevant listed species: Delta smelt and longfin smelt and salmon smolts, Central Valley steelhead, and green sturgeon.

The hypothesis has two major components: the Twin Tunnels project (providing operational "dual conveyance flexibility" for moving water from the Sacramento Valley to the San Joaquin Valley) and physical habitat restoration. We take up the Twin Tunnels in the next section on hydrodynamics below. Physical habitat restoration is intended to protect, enhance, and restore natural habitat communities that provide food resources to covered fish species. Limited food availability is known as a factor in the catastrophic decline of Delta fish populations, including Delta smelt, longfin smelt, and juvenile salmonids since the 1970s.[49]

> Restoration of large, connected tracts of these natural communities is intended to substantially increase the extent of physical habitat for covered species (including cover, rearing habitat, nesting habitat, and food resources) and improve overall food web productivity in the restoration areas and adjacent aquatic habitat.[50]

Three principal types of terrestrial and tidal habitat are intended in the BDCP to boost food production for the listed and covered species: tidal natural communities, seasonal floodplain

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[49] For instance, the US Fish and Wildlife Service's Delta smelt biological opinion from December 2008 reported that summer copepod blooms were impaired by state and federal export pumping operations in the south Delta. Essentially, Delta smelt's major food supply and ecosystem support was being exported by the pumps, contributing to the reduction in Delta smelt abundance (page 197).

[50] Bay Delta Conservation Plan, Chapter 3, p. 3.2-10, lines 2-6.

inundation, and channel margin habitat.[51] By increasing food supplies throughout the Delta-located life stages for covered fish species, BDCP hypothesizes it will increase fish health and improve overall fish fitness for reproducing and thereby increase the abundance of covered fish populations.

The food resources to be produced from restored habitat will originate onshore or nearshore in tidal marshes and riparian corridors, or offstream altogether in seasonally inundated floodplains. How will covered fish species access the food that will be produced? Some live away from shore in open water, while salmonid smolts, may or may not frequent tidal wetlands. BDCP believes optimistically that tidal wetlands, especially in the Cache Slough restoration opportunity area at the southern end of Yolo Bypass (combined with "floodplain enhancement"), and Suisun Marsh will "provide tidal freshwater wetland structure and functions that exchange with and benefit adjacent open-water habitat [citation]."

> Tidal wetlands...have the capacity to export food resources to adjacent channels and to downstream systems [citation]. The export of food to open-water areas may include movement of phytoplankton and zooplankton by advection and tidal exchanges and the export of productivity in the form of macro-invertebrates, small fishes, and other larger organisms [citation]. Of the Delta habitats, the tidal marsh sloughs have the highest particulate organic matter and phytoplankton concentrations and support the greatest zooplankton growth."
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> …[T]here are local examples of tidal marsh production being advected [that is, lateral flow vectors from shore to open water, rather than vertical or downstream flow with gravity] and/or tidally dispersed to adjacent habitats [citation]. Production from the lower Yolo Bypass, including Liberty Slough and Cache Slough marshes [where there is currently a Delta smelt refuge population in residence], stays relatively intact as it moves down the estuary [citation]. This production may contribute significantly to the greater foodweb, ultimately benefiting open-water species such as delta smelt [citation].[52]

Elsewhere in the BDCP, it is stated:

> The main hypothesis behind CM4 [tidal natural communities restoration] is that restoration of shallow tidal marshes and associated shallow subtidal habitat will increase the growth of phytoplankton and thereby increase the amount of zooplankton that are the food base for delta smelt [citation].[53]

BDCP more directly articulates a further hypothesis that habitat restoration-generated foodweb productivity can provide greater ecosystem services than can provision of additional freshwater river inflow to the Delta for eventual outflow from the Delta.[54] "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."[55]

These two "key areas of uncertainty" are framed as four hypotheses competing within the pages of both Chapters 3 and 5 of the Bay Delta Conservation Plan:

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[51] Each type of habitat community is provided its own conservation measure discussion in the Bay Delta Conservation Plan: Conservation Measure 4 (Tidal Natural Communities), Conservation Measure 5 (Seasonally Inundated Floodplain Enhancement), and Conservation Measure 6 (Channel Margin Habitat).

[52] Bay Delta Conservation Plan, Chapter 3, p. 3.3-105, lines 7-17 and 21-25.

[53] *Ibid.*, Chapter 5, p. 5.5.1-13, lines 20-22.

[54] In particular, BDCP states, "An analysis of food change potential for juvenile delta smelt is provided...for it has considerable relevance to the Fall X2 decision tree." Page 5.5.1-13, lines 22-24.

[55] *Ibid*., Chapter 3, p. 3.3-24, lines 6-8.

- The US Fish and Wildlife Service's Delta smelt biological opinion in 2008 put forward the hypothesis 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." **Hypothesis:** Fall outflow provides key delta smelt habitat attributes, either directly or by providing delta smelt with maximum opportunity to access areas providing key habitat attributes.[56]
- Alternatively, it is hypothesized by BDCP 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 'high outflow scenario' fall outflows…."[57] **Competing hypothesis:** Population performance of delta smelt is enhanced by biotic or abiotic habitat features that are *not dependent* on fall outflow of the magnitude described by the Fish and Wildlife Service's Fall X2 requirement.
- Concerning the longfin smelt **hypothesis:** Spring outflow provides key longfin smelt habitat attributes, either directly or by providing longfin smelt with maximum opportunity to access areas providing key habitat attributes.[58]
- BDCP's **competing hypothesis** that CM4 (tidal natural communities restoration) provides a "functional lift" in the form of "enhanced productivity and expanded habitat availability and that this lift will increase longfin smelt recruitment "per unit of Delta outflow," adding:

> Under this hypothesis, substantial benefits of tidal natural community restoration provide for the conservation and management of longfin smelt and help meet the biological objectives for this species. Therefore, the high-outflow scenario for spring outflow...would not be needed.[59]

These "decision trees" for spring and fall outflow are touted as analytical processes to compare these alternative hypotheses to identify strategies most likely to achieve BDCP biological goals for longfin smelt (via spring outflow determination) and Delta smelt (Fall outflow/X2 determination).

The decision trees are also a way to delay increased outflow requirements in the Delta. The State Water Resources Control Board has already determined that flows into and out of the Delta are insufficient for recovery of public trust fish resources in the Delta.[60] Moreover, the 9th Circuit Court

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[56] *Ibid*., Chapter 5, p. 5.5.1-17, lines 9-11.

[57] *Ibid.*, Chapter 5, p. 5.5.1-16, lines 12-19.

[58] *Ibid.*, Chapter 5, p. 5.5.2-9, lines 22-24. The California Department of Fish and Game certainly acknowledges that longfin smelt are food-limited in their abundance, but their scientists argued in the 2009 incidental take permit effects analysis prepared on the operations of the State Water Project in the Delta that "food production is not the only factor involved because the X2 response [of longfin smelt abundance to high Delta outflows] has persisted [citations]." Quoted in lines 38-43, same page.

[59] *Ibid.*, Chapter 5, p. 5.5.2-12, lines 20-23.

[60] State Water Resources Control Board, *Development of Flow for the Sacramento-San Joaquin Delta Ecosystem*, prepared pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009, August 3, 2010, p. 4, where the Board states: "There is sufficient scientific information to support the need for increased flows to protect public trust resources; while there is uncertainty regarding specific numeric criteria, scientific certainty is not the standard for agency decision making."

of Appeals recently upheld the 2008 Delta Smelt biological opinion by the US Fish and Wildlife Service, including its Fall X2 provision.[61]

But the decision trees concerning spring and fall outflow/X2 are relevant to BDCP's flawed habitat restoration for another reason. The presence of nonnative invasive clams (overbite clam, *Potamocorbula amurensis*, and the Asian clam, *Corbicula fluminea*) are likely to undermine the basis for the pro-habitat hypothesis by expanding their range and abundances to consume whatever zooplankton abundance increase is created by BDCP. No matter how much foodweb productivity may be boosted by BDCP-sponsored habitat restoration, that productivity can be consumed by invasive nonnative clams, particularly that of the salt-water overbite clam.

The problems posed by these two clam species is that they graze the same water column as Delta smelt and longfin smelt. They can graze the water column clean of food every day in a hurry, making it difficult if not impossible for the two small fish species to compete for food. According to Appendix 5.F of BDCP, at typical north Bay densities, *Potamocorbula,* which tends to occupy benthic sediments in Delta and Suisun Bay waters *downstream of X2's position in fresher water areas)*, can filter phytoplankton from the entire water column more than once per day in open water Delta channels and almost "13 times per day over shallow areas." This filtration rate by *Potamocorbula* enables its consumption to exceed the phytoplankton growth rate in the Delta.[62] *Corbicula,* which tends to occupy benthic sediments in Delta and Suisun Bay waters *upstream of X2's position*, is considered in BDCP, Appendix 5.F to be less efficient than *Potamocorbula* at filtering out shallow water bodies like Franks Tract. But *Corbicula* can still "filter out the entire water column in less than a day."[63]

The good news, however, is that the invasive clams' relative abundances and location are susceptible to changes in habitat conditions, especially salinity which can be managed with applications of freshwater flows to affect their location and abundances. *Potamocorbula* larvae has a tremendous salinity tolerance range (suspended but mobile in the water column) ranging from 2 to 30 parts per thousand (ppt) salinity in the Delta.[64] This tolerance range enables *Potamocorbula* to become established upstream in the Delta during low flow/high salinity and drought years. Fresh water flows are lethal to adult *Potamcorbula* specimens. In wetter years and seasons, *Corbicula* is more adapted to freshwater conditions and can migrate downstream of the Delta into Suisun Bay sediments, displacing *Potamocorbula*'s range further downstream to some extent.

BDCP acknowledges this in Appendix 5.F:

> If Fall X2 [that is, higher fall Delta outflow] is implemented...no change in suitable habitat for *Potamocorbula* from water operations would occur. However, if Fall X2 is not implemented, X2 would occur more easterly than under [the Existing Conditions Scenario with Fall X2 implemented under the Delta smelt biological opinion], *and therefore the suitable habitat for Potamocorbula would be expanded in wet and above normal water years*. Likewise, increased tidal habitat from restoration of tidal natural communities (CM4) may facilitate recruitment and expansion of *Potamocorbula* if located in areas with

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[61] *San Luis & Delta-Mendota Water Authority, et al v. Sally Jewell*, No. 11-15871, D.C. No. 1:09-cv-00407-OWW-DLB, 168 pages, decision released March 31, 2014. Accessible online 8 May 2014 at http://earthjustice.org/sites/default/files/files/Delta_smelt_biop_ruling_3-13-14.pdf.

[62] Bay Delta Conservation Plan, Appendix 5.F, p. 5.F-110, lines 7-13.

[63] *Ibid*., Appendix 5.F, p. 5.F-111, lines 18-25.

[64] *Ibid*., Appendix 5.F, Table 5.F.7-1, p. 5.F-113.

> salinity greater than 2 ppt. *If this occurs, the foodweb benefits described [elsewhere in BDCP] may be reduced.*[65]
>
> [Also] if Fall X2 is not implemented, operations would comply with...Water Right Decision 1641 (D-1641) Delta outflow requirements. In that situation, outflow in wet and above normal years would be similar to [the Existing Conditions Scenario without Fall X2] in which X2 is more east than under [the Existing Conditions Scenario with Fall X2]. *This situation may allow for Potamocorbula to recruit farther into the Central Delta, and conversely, reduce habitat for Corbicula, which requires more freshwater conditions (<2 ppt). These invasive clams have the potential to reduce food production and export from Restoration Opportunity Areas (ROAs).*[66]

Thus, BDCP acknowledges the potential for both of these nonnative invasive clam species to consume, but ultimately discounts it in the Plan's conservation strategy. "The export of marsh production can help transfer the higher production of shallow-water habitats to the less productive deepwater habitats preferred by pelagic fish species such as delta smelt, but this process can be interfered with by nonnative clams [citation]," states BDCP.[67]

Our point is: *Flow could be used to manage the nonnative invasive clams, but under BDCP it would not be.* To address the issue of getting food resources to Delta smelt, the more desirable of the two nonnative invasive clams to have to manage would be *Corbicula* since its filtration of the water column is less efficient than the other invasive clam. *Corbicula* also coexisted with all of the covered species in the Delta since the 1940s when it first arrived in California. Given this record of *Corbicula*, ***we find it undermines the credibility of BDCP's conservation strategy that there is no conservation measure in BDCP to constructively manage the nonnative invasive clams—because it would involve managing freshwater flows differently than is now done.***

BDCP's treatment of longfin smelt is just as problematic. The Plan, based on scientific research, blames longfin smelt decline on the late-1980s *Potamocorbula* invasion and its disruption of the foodweb on which longfin smelt relies. It claims that "increasing the density of zooplankton will be further achieved through reduced water diversions from the South Delta [because more water diversions would occur through the Twin Tunnels' north Delta intakes] (and associated phytoplankton and zooplankton entrainment)."[68]

BDCP concludes that its activities will result in moderate positive change to zooplankton abundance for larval longfin smelt, low positive change to zooplankton abundance for juvenile longfin smelt, with low certainty for both.[69] ***The gap in knowledge represented by such low levels of uncertainty are put off into the BDCP adaptive management program. "Trust us," is the strongly implied message, "let us build the Tunnels, then the wetlands maybe later, and we will let you know."***

The report of an expert panel convened by American Rivers and the Nature Conservancy on BDCP also concluded of the nonnative invasive clams issue as analyzed from the March 2013 draft of the plan:

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[65] *Ibid*., Appendix 5.F, p. 5F-v, lines 26-42. Emphasis added.

[66] *Ibid*., Appendix 5.F, p. 5F-vi, lines 1-14. Emphasis added.

[67] *Ibid*., Chapter 3, p. 3.3-105, lines 18-20.

[68] *Ibid.*, Chapter 3, p. 3.3-126. **LINES?**

[69] *Ibid*., Chapter 5, p. 5.5.2-13, lines 39-46, and p. 5.5.2-14, lines 1-4.

> The BDCP documents acknowledge (but mostly ignore) that grazing by clams that settle in or near restored subtidal areas may remove all or most of the phytoplankton production and some of the zooplankton. Grazing by clams and zooplankton (including microzooplankton) removed all of the phytoplankton production in the [low salinity zone] nearly all the time from late spring through fall during 1988 - 2008 [citation]. Whether clams settle in the newly restored areas is critical in determining whether the area can export any phytoplankton [citation].
>
> ...Nevertheless, this analysis raises significant questions about the putative subsidy from restored areas to estuarine foodwebs. To address this uncertainty, long before any actual restoration takes place a program of analysis, modeling, and experimental restoration should be undertaken.
>
> *...The idea that restored marsh and floodplain will export substantial amounts of zooplankton to the open waters of the estuary is not tenable.* The ecology of shallow waters suggests that shallow areas are more likely sinks for zooplankton [because of clam grazing behavior]. Even if they were sources, simple mass-balance considerations indicate that the resulting export would produce at most a small enhancement of extant zooplankton of the open waters. *This idea should be dropped from discussions of BDCP, although experimental work should press ahead to determine under what conditions marsh habitats could be sources of significant food for delta and longfin smelt in the open waters.*[70]

BDCP will not readily drop its line of magical thinking about food for fish because it is the core concept of its greenwashing strategy. Dropping would mean their "conservation strategy" would collapse like a house of cards.

For winter-run and spring-run Chinook salmon, the benefits of habitat-as-food-source the story is similar.[71]

The BDCP conservation strategy for salmonids (that is, the various runs of Chinook salmon as well as Central Valley steelhead rainbow trout) focuses on those life stages that occur in the Delta: juvenile salmon that have left their natal streams, are rearing along the way, and undergo smoltification (the physiological process that enables these fish to osmo-regulate saltier conditions they face in ocean water where they are headed) before emigrating to sea. This strategy includes restoration of tidal natural communities to increase rearing habitat in Suisun Marsh, Cache Slough, the west Delta and the south Delta restoration opportunity areas, as well as seasonal floodplain inundation, channel margin habitat and riparian natural communities. Each of these communities contributes to food production for diffusion and advection from shallow-water, low-velocity rearing habitat for juvenile salmonids. Conservation Measure 13 is intended to control invasive aquatic

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[70] Jeffrey Mount, William Fleenor, Brian Gray, Bruce Herbold, and Wim Kimmerer, *Panel Review of the Draft Bay Delta Conservation Plan*, prepared for the Nature Conservancy and American Rivers, September 2013, p. 78, 82. Emphasis added. Accessible online at http://mavensnotebook.com/wp-content/uploads/2013/09/FINAL-BDCP-REVIEW-for-TNC-and-AR-Sept-2013.pdf. John Cain of American Rivers and Leo Winternitz of the Nature Conservancy presented the report's results to the Santa Clara Valley Water District on October 2013, reported in Maven's Notebook at http://mavensnotebook.com/2013/11/26/mavens-minutes-santa-clara-valley-water-district-bdcp-workstudy-session-part-2-american-rivers-john-cain-and-the-nature-conservancys-leo-winternitz-discuss-the-bdcp/. Mount presented this report's results orally as well to the Delta Independent Science Board on January 17, 2014. Emphasis added. See also Bruce Herbold, Donald M. Baltz, Larry Brown, Robin Grossinger, Wim Kimmerer, Peggy Lehman, Charles Si Simenstad, Carl Wilcox, and Matthew Nobriga, "The Role of Tidal Marsh Restoration in Fish Management in the San Francisco Estuary," *San Francisco Estuary and Watershed Science* 12(1): 6 pages. Accessible online 7 April 2014 at http://escholarship.org/uc/item/1147j4nz.pdf.

[71] Bay Delta Conservation Plan, Chapter 5, p. 5.5.4-22, lines 1-6.

vegetation to reduce nonnative fish predator habitat cover, such as for largemouth bass. But food production is the chief reason for habitat restoration in BDCP.

There is considerable uncertainty in the pages of BDCP's Chapter 3 and Chapter 5 as to whether the habitat restoration efforts will work as intended. It appears from BDCP's analysis that Central Valley steelhead will have little to no use for seasonal floodplain inundation or channel margin habitat, and there is "high certainty" that channel margin habitat is of most use to emigrating steelhead smolts. Yearling spring-run Chinook salmon may also prefer to migrate rather than forage in these habitats.[72] The food benefits are touted, but BDCP notes that for steelhead, zooplankton occurrence is of "low certainty" as a benefit because their seasonality may not match up for lack of "co-occurrence" and because ***nonnative invasive clams may consume most of the primary and secondary food resources created by new habitat production.*** Moreover, behaviorally, steelhead smolts prefer to migrate rather than rear when passing through the Delta.

Despite repeated acknowledgment that they threaten the near- and long-term productivity of habitat restoration efforts in the Delta, ***there is no conservation measure proposed in BDCP to manage either of the most abundant nonnative invasive clams***. Invasive vegetation has its own conservation measure. But the single greatest biotic stressor that could consume most of the new food production from BDCP's habitat restoration program intended to benefit listed and covered species in the Delta goes unaddressed: ***what to do about Potamocorbula and Corbicula? The omission strains credulity.*** Both climate change and Twin Tunnels operations have the potential to reduce Delta outflows and cause X2, the low salinity zone in the Delta, to migrate further east and upstream in the decades to come. As X2 goes, the food production from BDCP restoration opportunity areas could be fully absorbed by *Potamocorbula* (which would spread eastward into the Delta, particularly in drier years) and somewhat by *Corbicula*, turning the western Delta and Suisun restoration areas from net exporters of food for Delta smelt and longfin smelt in open water into sinks for clam production instead.[73]

2. Spreading Hydrodynamic Nightmares to the North Delta

BDCP fails the Endangered Species Acts' requirements for ecological assurances that the habitat conservation plan, with its proposed Twin Tunnels project and North Delta Intakes, not appreciably reduce the likelihood of survival and recovery of listed species. The BDCP application for incidental take permits should be rejected by the fishery agencies.

Our comments in this section focus on two hydrodynamic nightmares BDCP will create and worsen in the Delta: First, the massive disruption of the flow regime of the lower Sacramento River used seasonally and inter-annually by several distinct salmonid populations, two of which are highly vulnerable to the threat of extinction; and second, further reduction of Delta outflows and the eastward-moving position of X2 worsening the risks of entrainment, ***this time in the North Delta to go along with continuing drier year entrainment risks in the South Delta*.** This second nightmare threatens both longfin smelt and Delta smelt with extinction.

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[72] Delta Science Program, Independent Review Panel, *op. cit*., note 27 above, p. 30.

[73] Researchers Lisa Lucas and Janet Thompson of the US Geological Survey found that phytoplankton biomass and productivity in the Delta do not necessarily correlate with either water depth or the residence time of water. ***The single most important factor that determined whether shallower water depth or greater residence time of water resulted in greater phytoplankton productivity was the absence of invasive nonnative clams.*** Lisa V. Lucas and Janet K. Thompson, "Changing restoration rules: Exotic bivalves interact with residence time and depth to control phytoplankton productivity," *Ecosphere* 3(12): Article 117, December 2012, 26 pages.

In the Administrative Draft of the Bay Delta Conservation Plan issued in March 2013, the conservation strategy announced: "*The BDCP will fundamentally alter the hydrodynamics of the Delta.*"[74] This sentence has since been toned down to read, "The BDCP will modify the hydrodynamics (i.e., tidal flows) in the Delta channels," but the original formulation is truer.[75] Overall, says BDCP, east to west flows will increase; the frequency and magnitude of reverse flows in Old and Middle River will decrease because of reduced south Delta pumping in most water year types. In the north Delta, flow patterns will "change" from increased diversions to Yolo Bypass with the proposed modifications to Fremont Weir. BDCP states:

> These changes in flow patterns in the north Delta present ecosystem-level tradeoffs between habitat in the Yolo Bypass and the Sacramento River during the winter-spring migration period, resulting in both positive and negative effects on the migration and passage of fish through and within the Delta...[76]

The Twin Tunnels project is ***intended*** to:

- Improve "hydrodynamic and water quality conditions that create barriers to movement and high susceptibility to predators,"
- Reduce "risk of entrainment of covered fishes by conveying from either the north or south Delta, depending on the seasonal distribution of their sensitive life stages," and
- Create "new opportunities to restore tidal natural communities in the east and south Delta" by reducing entrainment risks for food produced in restored areas and all life stages of delta smelt and longfin smelt and juvenile salmonids and sturgeons using restored areas.[77] The flexibility that north and south Delta intakes would create—the Applicants hypothesize—would enable state and federal water exporters to "substantially reduce the entrainment of covered fish species while providing the desired average water supply."[78]

This is the stated rationale for calling the Twin Tunnels a "conservation measure." ***It is claptrap.*** On one hand, the Tunnels will increase exports and the Delta's loss of outflow at the same time, both wet and above normal years.[79] (Moreover, in drought years, the Bureau and the Department typically petition the State Water Board to have Delta water quality objectives waived, and the Board grants this request. There is little reason to believe the Twin Tunnels would change the outcome, meriting its continued designation as a BDCP "conservation measure.) On the other, the BDCP assumes it will reduce entrainment risk, but its own data shows otherwise as we will see.

BDCP's stated water operations strategy for the Twin Tunnels project and their North Delta Intakes is to maximize their use during wet and above-normal years. It would refrain from using the North Delta Intakes during periods of each year when covered fish species would be present in the lower Sacramento River channel between Courtland and Walnut Grove where the intakes would be located. (The modeling assumptions for operating the North Delta Intakes appear to double as likely proposed flow and operational criteria that could be proposed to remake how the Delta is currently

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[74] Administrative Draft of the Bay Delta Conservation Plan, March 2013, Chapter 5, *Effects Analysis*, p. 5.3-2, line 23. Emphasis added.

[75] Bay Delta Conservation Plan, November 2013, Chapter 5, *Effects Analysis*, p. 5.3-2, line 23.

[76] *Ibid.*, p. 5.3-2, lines 34-37.

[77] Bay Delta Conservation Plan, Chapter 3, p. 3.2-7, lines 24-34.

[78] *Ibid.*, Chapter 3, p. 3.2-8, lines 1-10.

[79] We take up the matter of BDCP's unacknowledged purpose of expanding opportunities for cross-Delta water market transfers in Section VII of this comment letter.

regulated by the State Water Resources Control Board through its Bay-Delta Water Quality Control Plan and Water Right Decision 1641. We discuss this in our comments on the EIR/EIS in Section VII below.)

Figure 5.B.4-1 of Appendix 5.B on *Entrainment*, summarizes visually the average modeled water exports from both the North and South Delta intakes by water year, as well as total BDCP Twin Tunnels exports compared with Existing Baseline Condition scenarios with and without implementation of the Fall X2 requirement in the 2008 Delta Smelt biological opinion. This figure reveals that at key times of year, the Twin Tunnels will *increase* average monthly exports relative to existing baseline conditions by 2025 and 2060. It shows too that from December through August in wet and above normal years, the North Delta Intakes will enable the State Water Project and the Central Valley Project to export 300,000 to 350,000 acre-feet more water in each of the months of April and May than they can currently. About 75 to 80 percent of these increased export levels stems from being able to use the North Delta Intakes instead of the South Delta pumps to draw water from the Delta.

Figure 5.B.4-1 also shows that the North Delta Intakes will be used only minimally during below normal, dry, and critically dry water years. In these years, the South Delta intakes will continue to operate as they have in the past during these years. In the 82-year record on which CalSIM II modeling is based for BDCP purposes, just 38 years have been above normal or wet; the remaining 44 years are generally much drier (dry and critically dry years account for 30 (or 37 percent) of the remaining 44 water years). Both this figure and Figure 5.B.4-4 (here in Figure 1) show that the utility of the North Delta Intakes would decrease dramatically in drier weather patterns and climate conditions. It appears to us that the analyses in these figures rely on the existing variability of California's hydrologic record and its existing frequency of water year types. What is the risk in terms to fish entrainment and cost-effectiveness of the Twin Tunnels project if in a future of climate change the proportion of dry years increases relative to wet years?

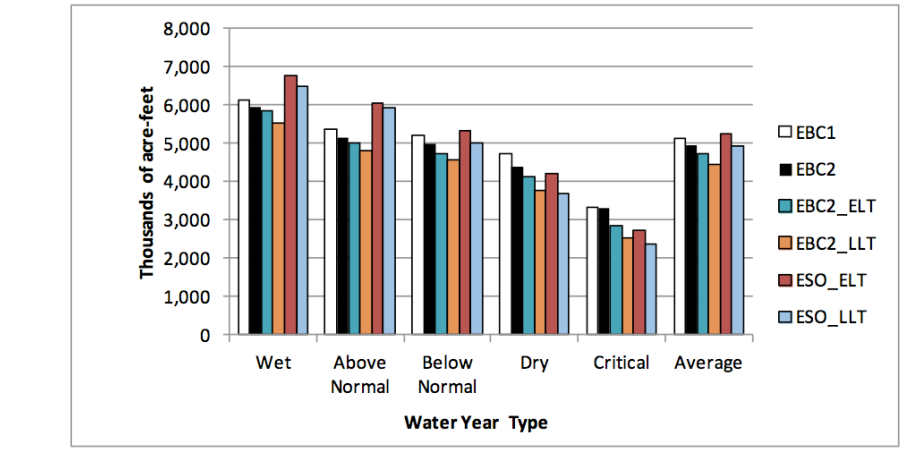


Figure 5.B.4-4. Total Exports from Combined North Delta and South Delta Pumping Facilities under the BDCP Evaluated Starting Operations (ESO) in the Early Long-Term (ELT) and Late Long-Term (LLT) Compared to the Existing Biological Condition (EBC) Baselines

Figure 1

Figure 1 (Figure 5.B.4-4 of BDCP) shows that, ***on average,*** combined Delta exports (North Delta plus South Delta intake/exports) will change little from current conditions whether BDCP operates with higher Fall X2 flows or not. ***But the Twin Tunnels and their North Delta Intakes will not be operated to the average year.*** They will be operated according to the type of water year California is in, year in and year out. In the wet and above normal years, combined Delta exports will jump dramatically by as much as 700,000 acre-feet in wet years and above normal relative to existing baseline conditions.[80] Indeed, it appears to us they expect to set Delta export records with the Twin Tunnels project for wet and above normal years. (Figure 5.B.4-4 indicates an average wet year export level of about 6.8 million acre-feet, while the record export year for the combined CVP and SWP projects was 6.67 million acre-feet in 2011, a wet year. This likely means that some wet years, when they occur in the future, will potentially enable combined exports north of 7 million acre-feet a year.)

In drier water year types, average combined exports keep pace with existing baseline conditions or are somewhat lower in future water years. However, further probing of Chapter 5 and the EIR/EIS's water transfer-related appendices reveals that BDCP intends for conservation measure 1's Delta facilities to expand dry and drought year capacity to arrange and consummate water transfers. They would occur in years when excess capacity to pump exists when Table A and CVP contract amounts to water contractors cannot be met by DWR and the Bureau (again, see Section VII for more discussion.)

We find other changed flow patterns from our review of the Bay Delta Conservation Plan:

- Flow splits in the area of the lower Sacramento River below Freeport would be dramatically altered once the North Delta Intakes go into operation. Consequently, the flow network changes for Elk, Steamboat and Sutter sloughs (on the right bank), and of Georgiana Slough and Delta Cross Channel (on the left bank) as distributaries from the Sacramento River between Freeport and Rio Vista. These aquatic crossroads are crucial to the survival of salmonid smolts and juveniles that emigrate from the Sacramento River basin to the Pacific Ocean.

- Potential reverse flows from Georgiana Slough into lower Sacramento in order to minimize movement of migrating salmonid smolts into the Central Delta where predation rates are higher.[81] This is the first we heard that there would be *reverse flows on the Sacramento River as a result of putting the North Delta Intakes there.*[82] For the Sacramento River, California's equivalent of the Mississippi River, to undergo reverse flows in its lower reach would be a travesty to the Delta and its aquatic ecosystems.

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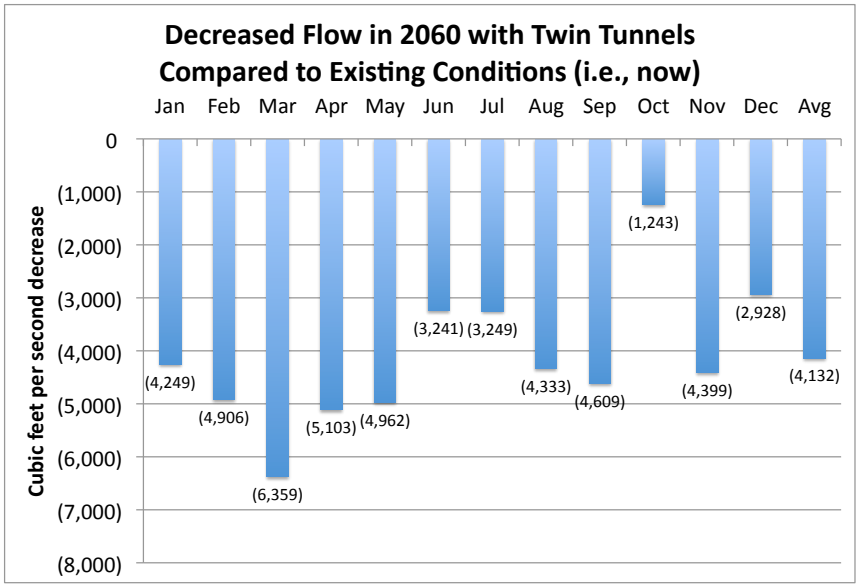
[80] *Ibid.*, Appendix 5.B, *Entrainment*, p. 5.B-19.

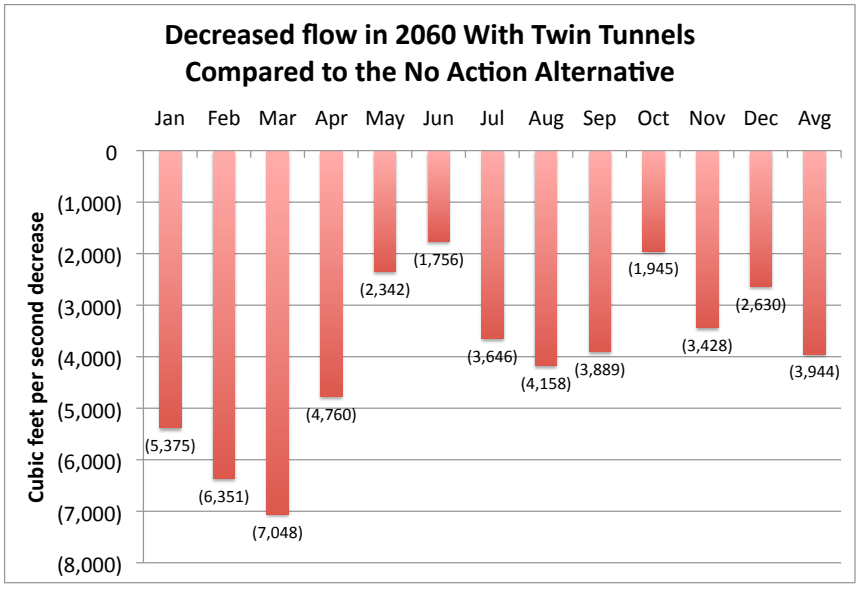
[81] *Ibid*., Chapter 3, p. 3.3-143, lines 11-20. "The north Delta intakes will be operated so as to not increase the incidence of reverse flows in the Sacramento River at the Georgiana Slough junction, thereby limiting the potential for covered salmonids to inadvertently migrate into the interior Delta. Juvenile salmonids can be drawn into alternative channels, such as Georgiana Slough and the Delta Cross Channel, and into the interior Delta region where survival has generally been shown to be lower than in the Sacramento River mainstem or Sutter and Steamboat Sloughs [citation]." Lines 11-16.

[82] There is no disclosure of potential reverse flows in the Sacramento River that we found in Appendix 5.C, Attachment 5C.A, *Modeling Results*, in either the Sacramento at Freeport or Sacramento at Rio Vista flow tables (Tables C.A-22 and C.A-29). Flow results for Georgiana Slough are combined with the results for the Delta Cross Channel (located between Freeport, the North Delta Intakes and Rio Vista), so any upstream (reverse) flows in Georgiana Slough are submerged and cannot be verified by readers of BDCP.

- Reduced Sacramento River flows ***below*** the north Delta intakes. As shown below in Figure 2, the flow differences between present conditions and in 2060 with and without the Twin Tunnels varies across months. But in both cases, these charts, and the BDCP data table on which they rely, show direct reductions every month in every year. The average flow reduction is about 4,000 cubic feet per second.

Figure 2
Comparison of Average Monthly Sacramento River Flow Reductions Below the North Delta Intake Diversions

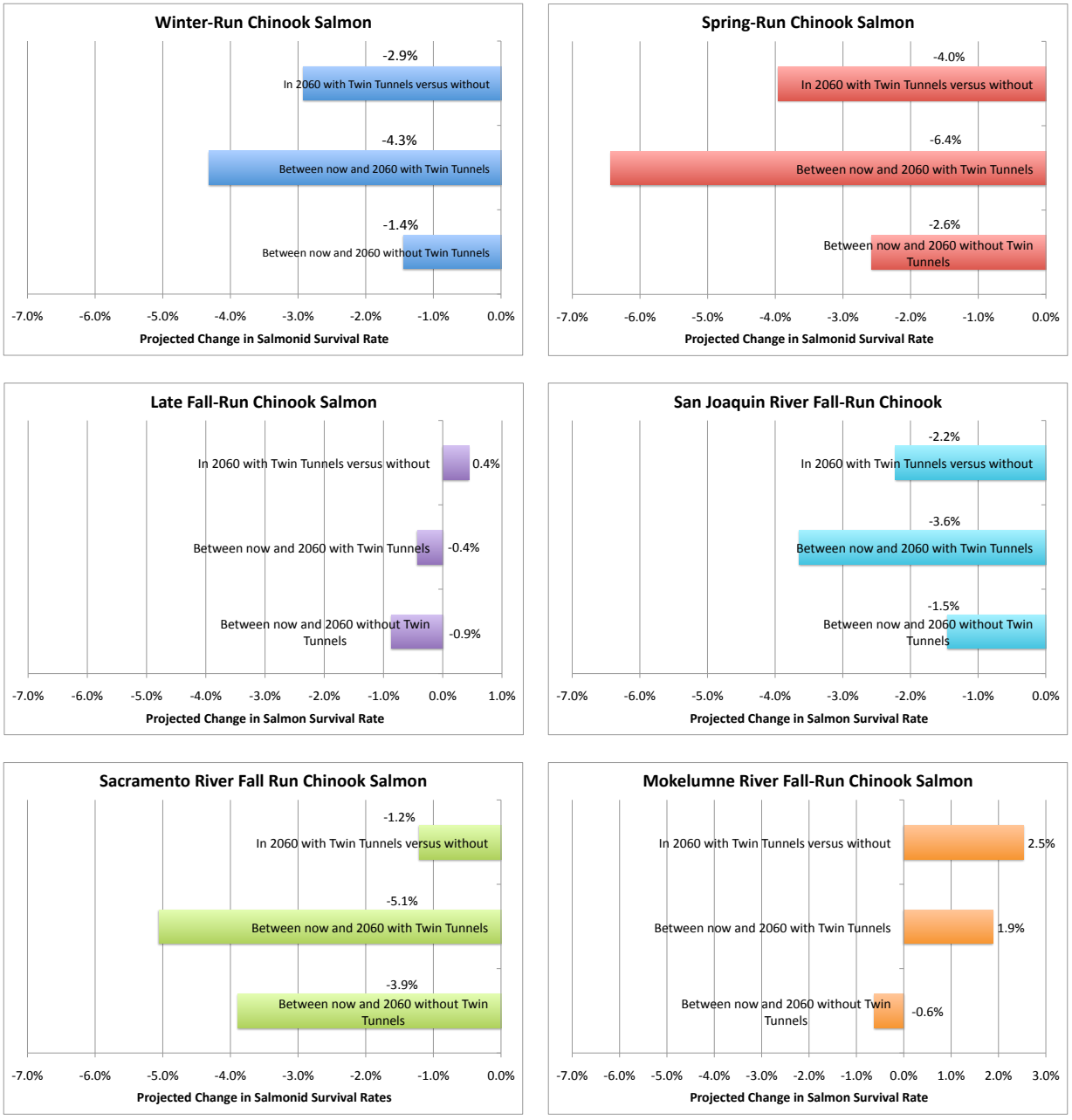




Source: BDCP, Chapter 5, Table 5.5.3-9, p. 5.5.3-26.

- The Bay Delta Conservation Plan modeling results reveal salmon smolt survival rates will decrease through the Delta as a result of Twin Tunnels operation in the North Delta (Figure 3).

Figure 3
Percentage Change in Salmon Smolt Survival Rates with and without BDCP



Source: BDCP, November 2013, Chapter 5, *Effects Analysis*, Sections 5.5.3 through 5.5.6. Based on Tables 5.5.3-10. 5.5.4-5, 5.5.5-8, 5.5.5-10, 5.5.5-18, and 5.5.5-20.

The middle bars in each graph of Figure 3 show the comparison between present baseline conditions and 2060 with operation of a Twin Tunnels project and North Delta Intakes. For Winter-

run Chinook, smolt survival through the Delta is expected by BDCP to *decrease* 4.3 percent. For Spring-run Chinook, smolt survival through the Delta is expected by BDCP to *decrease* by 6.4 percent. For Sacramento River Fall-run Chinook, smolt survival is expected to *decrease* 5.1 percent. For San Joaquin River Fall-run Chinook, smolt survival is expected to *decrease* 3.6 percent. (No model results were available for Central Valley steelhead.) ***These are significant, appreciable reductions to listed species during critical life stages as they move through the Delta.***

These decreases would come on top of massive long term declines in winter-run and spring-run Chinook salmon populations in the Sacramento River Basin, as documented by the US Fish and Wildlife Service's Anadromous Fish Restoration Program (Figure 4). Adult escapement for both of these runs has reached dangerously low levels; they are extremely vulnerable to catastrophic events everywhere throughout their range, including in the Delta. Introduction of the Twin Tunnels right in the middle of their Delta migration corridor (only a small percentage of smolts are expected to take advantage of the Yolo Bypass diversion, see next section) could be one such foreseeable catastrophe for these populations of Chinook salmon.

Figure 4
Declines of Winter-run Chinook and Spring-run Chinook Salmon
Sacramento River Basin

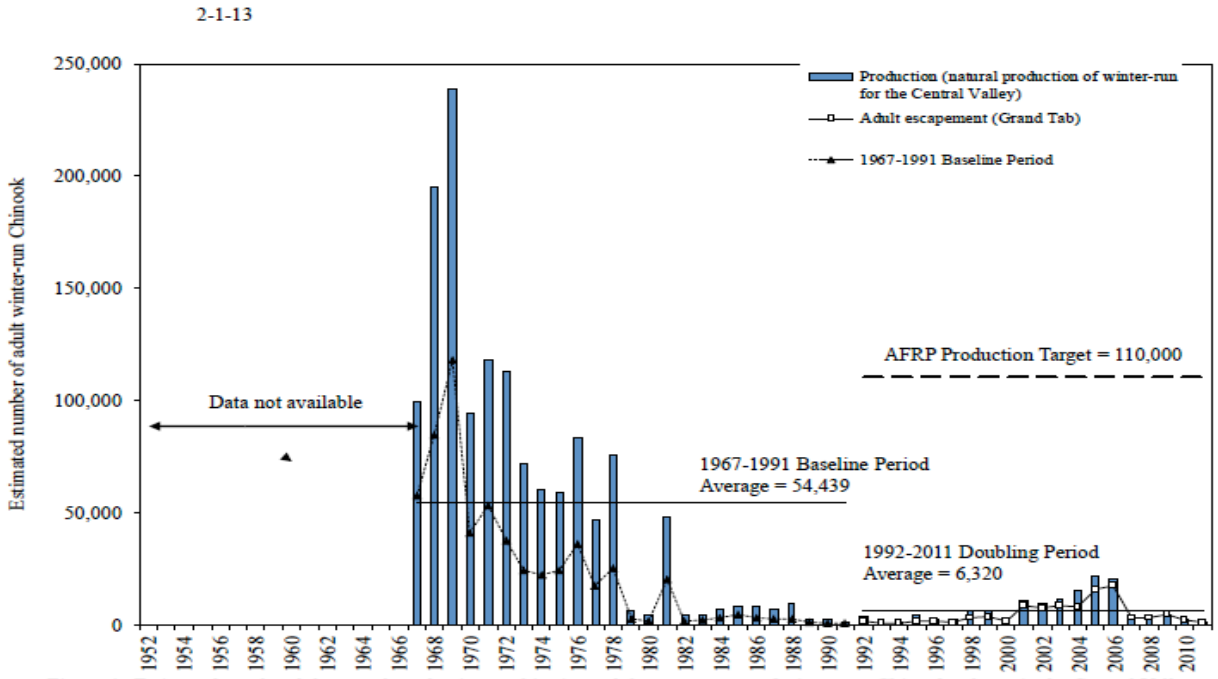


Figure 4. Estimated yearly adult natural production, and in river adult escapements of winter-run Chinook salmon in the Central Valley rivers and streams. 1992 - 2011 numbers are from CDFG Grand Tab (Apr 24, 2012). 1967-1991 Baseline Period numbers are from Mills and Fisher (CDFG, 1994).

Winter-run Chinook salmon adult escapement.

Figure 4
Declines of Winter-run Chinook and Spring-run Chinook Salmon
Sacramento River Basin

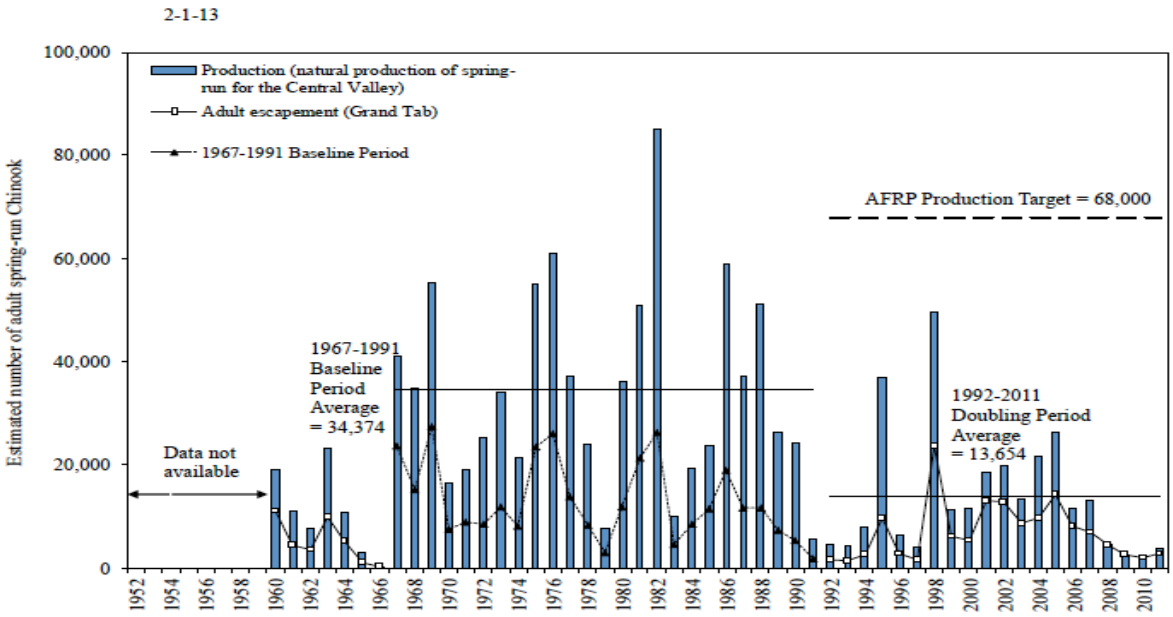


Figure 5. Estimated yearly adult natural production, and in-river adult escapements of spring-run Chinook salmon in the Central Valley rivers and streams. 1960 - 1966 and 1992 - 2011 numbers are from CDFG Grand Tab (Apr 24, 2012). 1967-1991 Baseline Period number are from Mills and Fisher (CDFG, 1994).

Spring-run Chinook salmon adult escapement.

Source: US Fish and Wildlife Service, Anadromous Fish Restoration Program, http://www.fws.gov/stockton/afrp/Documents/Doubling_goal_graphs_020113.pdf.

With Winter-run and Spring-run Chinook salmon as already-listed species, decreasing predicted trends in long-run survival rates for their smolts under BDCP activities would appreciably jeopardize the ability of these populations to avoid extinction.[83] Given that climate change threatens to reduce the size of cold water pools in upstream reservoirs and raise temperatures in upstream river reaches for these species, introducing operation of the T win Tunnels project as a human-generated threat to survival of these salmon runs is unacceptable. ***Therefore BDCP cannot fulfill the Endangered Species Acts' requirements for ecological assurances that the habitat conservation plan would not appreciably reduce the likelihood of the survival and recovery of listed species. The BDCP application for incidental take permits should be rejected by the fishery agencies.***

The other major hydrodynamic nightmare for fish posed by construction and operation of the Twin Tunnels project is whether the project's effects would increase the risk of entrainment (leading

[83] "Appreciable" is defined by the *Oxford English Dictionary* as "describing something that is large or important enough to be noticed."

directly to take of covered and listed species of fish).[84] Within this issue there are a few specific concerns:

- Are modeled entrainment risks for fish reduced at the South Delta pumps under BDCP?
- What would be entrainment risks for listed species at the North Delta Intakes for the Twin Tunnels project?
- How does climate change interact with Twin Tunnels operation to affect entrainment risk?

For most covered fish species, according to Table 5.B.0-2 of BDCP[85], entrainment risk *at the South Delta export pumps* would decrease dramatically. Juvenile salmonids would see significant reductions in entrainment on the order of 50 to 75 percent, particularly during wet and above normal years when the North Delta Intakes would be used more intensively to divert lower Sacramento River flows for export. Entrainment risks for Winter-run and Spring-run Chinook salmon smolts would decrease also between 50 to 75 percent over the 50-year term of the incidental take permits.

This table, titled "Summary of Effects of the BDCP on Entrainment of Covered Fish Species," provides modeled results only for the South Delta export pumps. There is no attempt to model results for entrainment risk at the North Delta Intakes. We could find no explanation of this omission. This information is crucial to evaluating BDCP's goal that the Twin Tunnels would provide operational flexibility to help reduce entrainment and salvage risks for fish throughout the Delta. The table only discloses as its methods "screening effectiveness analysis" and "screen passage time" analysis, and claims as results "100% screened" intakes in the North Delta with "screen passage time lower with higher sweeping velocity, shorter screen, and smaller fish." There are no quantified modeling results in which presence of listed species are correlated with times in which the North Delta Intakes would operate to indicate levels of entrainment that could occur.

This criticism holds true for Delta smelt and longfin smelt, two listed species that reside full-time (Delta smelt) or part-time (longfin smelt) in Delta channels and open water. Table 5.B.0-2 provides proportional entrainment regression results for larval and juvenile Delta smelt that show on average a 3 percent *decrease* in entrainment risk across all water year types at the South Delta pumps. Entrainment rates would decrease even further to between -16% to -24% at the South Delta pumps during wet and above normal years when the North Delta Intakes operate. Adult Delta smelt entrainment risks would be even further decreased in wet and above normal water years.

However, in drier years, when the North Delta Intakes would be used far less, ***larval and juvenile Delta smelt entrainment rates would increase over existing baseline conditions*** (i.e., relative to having no Twin Tunnels project operating in the future) throughout the 50-year term of the incidental take permits. This may have everything to do with use of the Twin Tunnels' extra capacity to transport water transfers. But it appears water transfers were not modeled or evaluate for impacts in the EIR/EIS. This would be the situation for a majority of water years assuming that the future will be like the 82 years in the CalSIM II modeling activity on which these entrainment estimates rely in part. ***If California's climate becomes drier (and more years in the future are below the present normal, dry or critically dry) then these entrainment risks would be***

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[84] "Entrainment" is not equivalent to death of individual fish from different species. Rather, it is a measure of hydrodynamic conditions overcoming fishes' swimming ability, forcing fish into water facilities that may result in their "salvage" and relocation. However, the process of handling fish during "salvage" operations can result in injury and death to fish. Entrainment can mean death as a result of predation, as in the case of fish winding up in Clifton Court Forebay where predator fish like bass species are well known to prey upon smaller fish like Delta smelt, longfin smelt, and juvenile salmonids. "Salvage" does not usually lead to salvation.

[85] BDCP, Chapter 5, *Effects Analysis*, Appendix 5.B, *Entrainment*, Table 5.B.0-2, p. 5B-vii.

expected to increase. Water transfer diversions may also have something to do with this as well. The fact that they are positive in the BDCP analysis reveals that ecological assurances for Delta smelt are overly optimistic, even hyperbolic, for reducing entrainment risk overall for Delta smelt, *even at the South Delta pumps*. This means ***it is critical for the EIR/EIS to model and analyze the effects on Delta smelt and longfin smelt at the North Delta Intakes during dry and critically dry years, since DWR and the Bureau of Reclamation hope to increase water transfers in those years.***

Larval and juvenile longfin smelt entrainment risk averaged over all water year types would also decrease at the South Delta pumps, according to Table 5.B.0-2. However, BDCP makes no attempt to model larval longfin smelt risk by water year type. This is significant because according to the California Department of Fish and Game's 2009 effects analysis for the State Water Project incidental take permit for longfin smelt, larval longfin smelt can be entrained as larvae in the early spring in the western Delta and be too small to track. They grow along the way upstream through Old and Middle Rivers where they are counted as juveniles once they reach Clifton Court Forebay and the State Water Project fish salvage facilities later in the spring or early summer.[86]

For the North Delta Intakes, BDCP indicates for "results" in Table 5.B.0-2 that the Intakes would be "100% screened" (as if that is a sure thing for avoiding entrainment, injury, or death at the intakes) and that "entrainment occurs in proportion to flow diverted, but the great majority of larvae would be downstream of the intake and not susceptible to entrainment." This language is employed for both larval Delta smelt and larval longfin smelt in the table. These assertions occur without support visible evidentiary support. The table also states that for juvenile and adult Delta smelt, there is "potential for screen contact-related mortality increases with increasing approach and sweeping velocity, by night, and with longer screens."

"Approach velocity" is flow speed whose direction is perpendicular to the face of the intake screens, and reflects the rate of diversion occurring at the Intakes. It is the cross-flow that the North Delta Intakes would generate in the flow-field of the lower Sacramento River as the Intakes are operated (that is, as they fill the Twin Tunnels). "Sweeping velocity" is the net speed of downstream flow parallel to the face of the intake screens. Generally, if the combined vector of flow is toward the Intake screen and the swimming ability (vector) of individual fish does not exceed that flow, the fish will be pushed against the screen, possibly pinned or impinged, injured or killed by the force of the intake diversion flow.

BDCP proposes for the North Delta Intakes the longest and largest fish screens ever attempted. (Imagine a fish screen as long and tall as some CalTrans sound walls along any urban California freeway, and you have some idea of the scale of the fish screens that are contemplated.)[87] Screens this size have never been used, let alone tested, as we understand the situation. While the screens would be designed to meet California Department of Fish and Wildlife and National Marine Fisheries Service fish screen design criteria, the sheer size of the North Delta Intake screens would be unprecedented.[88] Table 4-2 of Chapter 4 in BDCP provides general specifications for the North

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[86] California Department of Fish and Wildlife, Effects Analysis: State Water Project Effects on Longfin Smelt, prepared by R.D. Baxter, M.L. Nobriga, S.B. Slater, R.W. Fujimura, February 2009, four parts. See discussion of "Juvenile Entrainment," p. 31. Accessible online 14 May 2014 at http://www.dfg.ca.gov/delta/data/longfinsmelt/documents/LongfinSmeltIncidentalTakePermitNo.2081-2009-001-03.asp.

[87] Schematic drawings of North Delta Intake structures (Figures 4-6 and 4-7, Chapter 4) omit the location or extent of fish screens proposed to protect fish from entrainment.

[88] California Department of Fish and Wildlife, "Fish Screening Criteria," accessible online 14 May 2014 at http://www.dfg.ca.gov/fish/Resources/Projects/Engin/Engin_ScreenCriteria.asp. See also National Marine Fisheries Service, *Fish Screening Criteria for Anadromous Salmonids*, Southwest Region, July 1997.

Delta Intakes, and states that there will be a total cumulative fish screen length of 4,420 feet, or 0.84 miles, across three separate intakes. The screens are expected to range from 10 to 22 feet in height.[89]

A team of scientists at UC Davis led by biologist Christina Swanson developed equations for fish screen designs with sweeping velocities to optimize protection of fish attempting to pass fish screens.[90] BDCP tested these equations but found them not to their liking:

> The equations of Swanson and coauthors [citation] give very long screen passage times at certain sweeping velocity and approach velocity combinations, e.g., nearly 7,000 minutes [or about 117 hours, or nearly 5 days] for a 4.4 cm fish along a 2,000 foot screen with approach and sweeping velocities of 0.33 [centimeters per second]. Such estimates are far in excess of the duration of the experimental trials (120 minutes) used to derive the data and therefore should be treated with caution.[91]

Five days is indeed a very long time for a juvenile salmonid to be attempting to swim past what would seem like a never-ending cross-flow of water without also having additional food and opportunity to rest to sustain its journey through such a maelstrom. Such a modeled condition does not support BDCP's hoped-for reduction in salmonid entrainment through construction and operation of the North Delta Intakes and the Twin Tunnels project. Indeed, such results from Swanson's equations would lead one to conclude that building the North Delta Intakes in a crucial reach of the migration corridor of listed salmonid populations would be a recipe for salmonid jeopardy. BDCP clearly finds it easier to "treat the equations with caution" than admit the possibility that the fish screens would not work as BDCP has hyped.

Yet Swanson's work may be the "best available science" on which BDCP could rely, for BDCP presents no other more recent systematic treatment of the variables of fish behavior, fish screen design, and hydrodynamic conditions in the lower Sacramento River. ***If so, then DWR and the rest of the Applicants have shunned usage of the best available science to analyze their project, violating their duties under ESA.***

When it comes to entrainment of Delta smelt at the North Delta Intakes, BDCP soft-pedals their risk. They state that most of the time, Delta smelt at any life stage will be located downstream of the Intakes, and therefore at little risk of entrainment. For instance, they are all but absent in the fall months (September through December) from upstream Sacramento River locations in the Delta, as measured by the Fall Midwater Trawl. However, when one moves out of the shallow waters of BDCP's chapters 3 and 5 to the deeper, more open waters of Appendix 5.B on *Entrainment*, one finds

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[89] Bay Delta Conservation Plan, Chapter 4, p. 4-9, lines 7-13.

[90] Christina Swanson, Paciencia S. Young, and James J. Cech, "Swimming in Two-Vector Flows: Performance and Behavior of Juvenile Chinook Salmon near a Simulated Screed Water Diversion," *Transactions of the American Fisheries Society* 133(2): 265-278, 2004; Swanson, Young, and Cech, "Close Encounters with a Fish Screen: Integrating Physiological and Behavioral Results to Protect Endangered Species in Exploited Ecosystems," *Transactions of the American Fisheries Society* 134(5): 1111-1123, 2005; Swanson, Young, and Cech, "Close Encounters with a Fish Screen II: Delta Smelt Behavior Before and During Screen Contact," *Transactions of the American Fisheries Society* 136(2): 528-538, 2007; Swanson, Young, and Cech, "Close Encounters with a Fish Screen III: Behavior, Performance, Physiological Stress Responses, and Recovery of Adult Delta Smelt Exposed to Two-Vector Flows near a Fish Screen," *Transactions of the American Fisheries Society* 139(3): 713-726, 2010; Swanson, Young, and Cech, "Swimming Performance of Delta Smelt: Maximum Performance and Behavioral and Kinematic Limitations on Swimming at Submaximal Velocities," *Journal of Experimental Biology* 201(1998): 333-345. This latter article accessible online 14 May 2014 at http://online.sfsu.edu/modelds/Files/References/Swanson1998JEB.pdf.

[91] Bay Delta Conservation Plan, Appendix 5.B, *Entrainment*, p. 5.B-303, lines 30-33.

that BDCP is much less confident that Delta smelt would not be placed in harm's way by the North Delta Intakes and their sound-wall-scale fish screens:

> [S]eine data do indicate that adult delta smelt do occur in the reach of the river where the proposed north Delta intakes would be sited….Overall, the results from the various surveys suggest that a low proportion of the delta smelt population would have the potential to occur in the reach of the Sacramento River where the north Delta intakes will be located (River miles 37-41). There is uncertainty in the proportion of the population that could occur in this reach [because seine sampling has, as of yet, not included documentation of the delta smelt population that now occupies the Cache Slough area].
>
> Recent research suggests that delta smelt may use tidal currents to facilitate movement upstream by migrating to channel margins during ebb tides and into the channel during flood tides. [citation] Depending on which side of the channel the fish move to, such behavior may place delta smelt close to the channel margins and potentially close to the proposed north Delta intakes. Flows toward the intakes may also increase the chance of delta smelt within the vicinity encountering the screen. *The summary of percentage of flows diverted for salmonids (Tables 5.B.6-222 and 5.B.6-223) also encompasses the main period of potential delta smelt occurrence near the proposed north Delta intakes. The extent to which delta smelt would occur near the on-bank intakes is uncertain; monitoring of the north Delta intakes would provide data to reduce this uncertainty.*[92]

Complicating matters still further is the fact that Delta smelt are highly sensitive to injury easily resulting in death. Glancing blows against fish screens or other structures for them can be fatal. They are already well-known for not surviving the handling and transport they already receive from salvage at the state and federal pumps' fish facilities.

Under conditions of climate change, X2 (the isohaline marker for the location of the Bay-Delta Estuary's low salinity zone) is expected to migrate upstream as Delta watershed runoff overall decreases in the future. Reduced Delta outflow resulting from Twin Tunnels operations will contribute to this trend. Delta smelt are well known to inhabit the area of Delta waters immediately upstream (toward fresher water) of X2. The further upstream X2 moves, the closer it gets to River Miles 37 through 41 where the North Delta Intakes would be located. BDCP's entrainment appendix acknowledges this possibility:

> Delta smelt may occur more frequently in the north Delta diversions area under future climate conditions if sea level rise [and reduced Sacramento River inflow below Freeport] induces movement of the spawning population farther upstream than is currently typical.[93]

In sum, BDCP Applicants do not know (nor do they reveal from modeling results) the proportion of the Delta smelt population that could be at risk of entrainment in this reach of the Sacramento River (River Miles 37-41) from the North Delta Intakes. BDCP does not know which side of the river Delta smelt may prefer on ebb tides, and why. BDCP lacks confidence in the Swanson team's equations for modeling fish behavior, fish screen design criteria and hydrodynamic parameters.

Yet the BDCP Applicants would naively forge ahead with construction and operation of the Twin Tunnels project despite such huge uncertainties posing grave risks for listed salmonid and smelt species. They build into the BDCP a number of monitoring and effectiveness actions that strongly imply, "Let us construct these systems and we will fix them later (much the way the State Water Project and Central Valley Project were justified when it came to fish impacts). ***Trust us.***"And they include in "research actions" two potential studies that would:

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[92] *Ibid.*, p. 5.B-306, lines 2-3, 6-9, and 14-18. Emphasis added.

[93] *Ibid.*, p. 5.B-310, lines 17-19.

> 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 [citation].
>
> Develop computational fluid dynamics model to provide information on how tidal changes and flow withdrawals affect flow conditions and sweeping velocities at screening locations.[94]

The uncertainties acknowledged for these two research actions are, on one hand, the "relationship between proposed intake design features and expected intake performance relative to minimization of entrainment and impingement risks," and on the other, the "evaluation of tidal effects and withdrawals on flow conditions at screening locations." ***This reveals that fundamental scientific and design components of avoidance and minimization measures for listed species cannot assure protection and survival (let alone recovery) given the current state of scientific and engineering knowledge.***

Nowhere in BDCP is there a conservation measure to install fish screens on the South Delta export pumps or to improve operations of their fish salvage facilities as required by the 2000 CalFED Record of Decision.[95] BDCP Applicants are apparently not serious about protecting fish from the hydrodynamic nightmares they propose to inflict on the Delta's listed species and aquatic ecosystems from the Twin Tunnels, the North Delta Intakes, and related Delta facilities in "conservation measure" 1.

The Delta's fish face an extinction crisis. The Twin Tunnels would adversely modify designated critical habits and thus promote species extinction and preclude species recovery. The Twin Tunnels project is not a permissible project under the Endangered Species Act (ESA) because it would adversely modify designated critical habitat for at least five Endangered and Threatened fish species. BDCP's own modeling results indicate that Tunnels operation would appreciably reduce the likelihood of survival and recovery of listed fish species in the Plan Area of the Bay Delta Conservation Plan.

We incorporate by reference a comments from the California Advisory Committee on Salmon and Steelhead Trout to the Director of the California Department of Fish and Wildlife dated February 26, 2014.[96] The Advisory Committee concludes among other things that: "The BDCP does not meet the requirements of Fish and Game Code 2820 for an NCCP and cannot legally be approved because it will contribute to the further decline of Sacramento River Winter Run and Spring Run Chinook salmon." (Letter p. 1). The Advisory Committee also concludes that: "In summary, the Bay-Delta Conservation Plan does not meet the requirements of the California Endangered Species Act or the Natural Communities Conservation Plan Act to recover Sacramento River winter-run and spring-run Chinook salmon." (Letter p. 4).

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[94] *Ibid.*, Appendix 3.D, *Monitoring and Research Actions,* Table 3.D-3, p. 3.D-28,.

[95] CalFED Record of Decision, pages 26, 52, and 131. Accessible online June 3, 2014 at http://calwater.ca.gov/content/Documents/ROD8-28-00.pdf.

[96] Letter of California Advisory Commission on Salmon and Steelhead Trout to Charlton Bonham, Director, California Department of Fish and Wildlife, "Recommendation to deny incidental take permit and Natural Communities Conservation Plan for Bay Delta Conservation Plan," February 26, 2014. Accessible online June 4, 2014, at http://www.friendsoftheriver.org/site/DocServer/Atc_13.pdf?docID=8313.

For the same reasons, the Twin Tunnels plan likewise does not meet the Section 10 requirements of the ESA and cannot legally be approved because it will contribute to the further decline of Sacramento River Winter Run and Spring Run Chinook salmon.

3. Stranding and Entrainment Risks of Seasonal Floodplain Enhancement Measure

BDCP fails the Endangered Species Acts' requirements for ecological assurances that the habitat conservation plan, with its proposed seasonal floodplain inundation of Yolo Bypass, will not appreciably reduce the likelihood of survival and recovery of listed species. Key assurance uncertainties are put off into the plan's adaptive management process. The BDCP application for incidental take permits should be rejected by the fishery agencies.

BDCP Applicants propose to take advantage of recent scientific findings that seasonal inundation of floodplains can expand food production for covered and listed anadromous and other fish species out of the mainstem channels they use to emigrate to the ocean or to other parts of the Delta's Central Valley watershed. The fish species that are targeted for this type of restoration approach, and the related changes to flow patterns and flood control facility operations, appear from our review of BDCP to include most runs of salmon and Sacramento splittail (which is a covered species but is not ESA-listed).[97] Juvenile salmon (but not Central Valley steelhead trout) and splittail are found to grow larger faster when floodplains are available for them to rear in (periods where they feed and grow). Such growth is found by scientists to improve overall fitness of emigrating salmon smolts for reaching adulthood, surviving the ocean phase of their life history, and eventually returning to natal streams to reproduce.

The Sacramento River Basin Flood Control Project is proposed by BDCP for some alterations in its southernmost reach, Yolo Bypass. This bypass extends from the Sacramento River just west of the town of Verona south to its outlet into the Cache Slough complex just north of Rio Vista along the Sacramento River as it concludes its route through the north Delta to Suisun Bay, a distance of about 38 miles. At the northern mouth of Yolo Bypass, high flood flows during and after storms spill over a structure along the right bank of the Sacramento River called Fremont Weir. In addition, flows from the Feather River, whose confluence with the Sacramento River is located at Verona, enter the Sacramento and raise the river level still further, backing those waters up and over Fremont Weir as well, enabling Yolo Bypass to take considerable flood flow pressure off of the mainstem of the Sacramento River, thereby protecting farmlands, the City of Sacramento, and other small communities further downstream from most flood peaks.

Adult salmon will sometimes choose upstream migration routes through Yolo Bypass trying to reach their natal stream or tributary of the Sacramento River, until they find Fremont Weir obstructing further upstream progress toward the Sacramento River. These fish sometimes head up the drainage canals that enter the Bypass from the Colusa Basin and from Cache Slough to Cache Creek, but may perish from the effects of stranding without having spawned successfully. If state fish wardens and biologists become aware, they organize rescue efforts to capture and relocate these fish into the Sacramento River so they may attempt to carry on their upstream travel. They are

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[97] The main salmonid beneficiaries of Yolo Bypass inundation are Winter-run, Spring-run and Fall-run Chinook salmon, and Central Valley steelhead, which are emigrating substantially during periods (mid-November through May) that overlap with the December through April time frame of notched Fremont Weir spillage proposed under BDCP. However, Late Fall-run Chinook yearlings (November through early February) and young-of-the-year (mid-April through mid-May) will likely benefit least from seasonal inundation of Yolo Bypass. *Ibid.*, Chapter 3, Table 3.4.2-1, "Potential Operations pattern for Fremont Weir Gated Channel and Other Considerations," p. 3.4-57.

often unsuccessful, and many fish are lost, as occurred in the summer of 2013 elsewhere in Yolo Bypass and other parts of the lower Sacramento Valley.[98]

Juvenile Sacramento splittail can find their way into Yolo Bypass to spawn. Their larval and juvenile life stages rear in the shallow, warm and productive ponds and slow-moving floodplain flows. However, they too face a risk of stranding if too little water inundates the Bypass and ponds and channels dry out before their young can mature and emigrate to other Delta channels.

When Yolo Bypass is completely inundated, the wetted area there doubles the total wetted area of the Delta, according to BDCP. The Bypass is also considered inundated when the water level at Toe Drain at Lisbon Weir (at the south end of the Bypass) exceeds 8 feet NGVD.

BDCP Applicants propose to "notch" Fremont Weir so that Sacramento River flows will spill into the Yolo Bypass at lower flow levels. This will increase the amount of time water inundates areas of Yolo Bypass, and increase the amount of floodplain acreage that is stimulated into primary and secondary ecosystem productivity (from phytoplankton to zooplankton to various kinds of aquatic invertebrate organisms). The notch in Fremont Weir would be 225 feet long, as compared with the Weir's existing one-mile length (5,000 feet), and would be operable with one or more gates to regulate spillage and flow to the Bypass. The notch would lower the spill elevation of the Weir from 33.5 feet to about 17.5 feet.[99] The Applicants propose an inundation regime for Yolo Bypass that would provide flows of 3,000 to 6,000 cfs for substantial increases in fish habitat during many years. Average water depths would generally be 2 to 3 feet, with velocities of less than 2 feet per second and water travel times in the Bypass would generally be 3 to 4 days. At 3,000 cfs of flow into the Bypass over the notched Weir, about 10,000 acres and at 6,000 cfs of flow, the inundated area would reach about 20,000 acres, according to BDCP.[100] The number of days the Bypass would inundate is projected by BDCP to more than triple, from 26 days (when Sacramento River flow exceeds 60,000 cfs) in the key December through April period to about 81 days (when Sacramento River flow would exceed just 20,000 cfs or so). We estimate that this investment of seasonal spillage at Fremont Weir would cost the Sacramento River between December and April about 480,000 acre-feet to about 960,000 acre-feet of flow depending on water year type, and would contribute by subtraction to the hydrologic and hydrodynamic mayhem in the lower Sacramento River that would adversely affect fish that did not enter Yolo Bypass.

BDCP identifies the key uncertainties as "Do the modifications at Yolo Bypass function as expected, and if so, how effective are they?" To answer that question, the Applicants identify a lengthy list of potential research actions to cope with this uncertainty:

- Evaluate the effectiveness of the fish passage gates at Fremont Weir.
- Evaluate the effectiveness of sturgeon ramps.
- Determine whether stilling basin modification has reduced stranding risk for covered fishes.

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[98] Bill Jennings, "Massive loss of endangered Winter-run salmon," July 28, 2013, online at http://calsport.org/news/massive-loss-of-endangered-winter-run-salmon/. "During April, May and early June, perhaps half of this year's spawning population of endangered winter-run Chinook salmon were drawn into the irrigation channels of the Yolo Bypass and Colusa Basin and stranded. Approximately 300 fish were rescued and returned to the Sacramento River but most were lost. The majority of those rescued were in such poor condition that biologists doubted they would successfully spawn. Other winter-run were stranded in the Sutter-Butte Basin on the east side of the Sacramento but no rescues were attempted. This has been a recurring problem well known to state and federal fish agencies since the 1990s."

[99] Bay Delta Conservation Plan, Appendix 5.C, Attachment 5C.A, Table C.A-12, p. 5C.A-60.

[100] *Ibid.*, Chapter 3, Conservation Strategy, p. 3.4-44, lines 2-3; Appendix 5.C, Attachment 5C.A, *Flow Results*, Section 5C.A.3.4.4, p. 5C.A-58, lines 3-16.

- 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 Yolo Bypass during Fremont Weir operation.
- Evaluate whether the Lower Putah Creek realignment improves upstream and downstream passage by covered fish.
- ***Determine severity of predation effects on covered fish using the Yolo Bypass.***[101]

This last potential research action, concerning the potential predation effects in Yolo Bypass of enhancing fish passage and floodplain productivity to promote rearing needs far more advance planning and research than has occurred ***before the decision is made to remove a half million to a million acre-feet of water from the Sacramento River nearly every year to provide an alternative route to the comparatively efficient migration corridor of the mainstem lower Sacramento River.*** The BDCP Applicants put this research off into the dustbin of its adaptive management laundry list.[102] There is no attempt to model or otherwise estimate the effect of seasonal floodplain inundation in Yolo Bypass on listed species survival rates. Such a modeling effort must factor in the degree to which predator fish would also seek to take advantage of seasonally inundated floodplain productivity, and whether the loss of additional flows from the Sacramento River mainstem channel (and its safer distributaries in the North Delta) contribute to a net increase or decrease of survival rates of listed salmon populations. There is also no mention of methylation of mercury occurring with increased wetting and drying of the floodplain, which can cause methyl mercury levels to spike in the floodplain. The State Water Resources has found that when Yolo Bypass is flooded, it becomes the dominant source of methylmercury to the Delta, and that restoration activities with the increase in wetting and drying periods could exacerbate the existing mercury problem.[103]

4. Climate Change Analysis and Modeling Results

BDCP Applicants recognize that climate change is with us and that it must be accounted for in making plans for the future of California water and the Bay-Delta Estuary.

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[101] *Ibid.*, Table 3.4.2-3, "Key Uncertainties and Potential Research Actions Relevant to CM2," p. 3.4-61. Emphasis added.

[102] *Ibid.*, Appendix 3.D, *Monitoring and Research Actions*, provides additional detail on the depth and breadth of compliance, effectiveness monitoring and research actions that will be needed. This appendix contemplates for Conservation Measure 2 a total of 11 compliance monitoring actions, three effectiveness monitoring actions, and two research actions, one of which is described in our narrative here and contains nine sub-actions.

[103] State Water Resources Control Board, *2009 Periodic Review of the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin River Delta Estuary*, adopted resolution 2009-0065, p. 29. Accessible online 14 May 2014 at http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/periodic_review/docs/periodicreview2009.pdf; and Chris Foe, Stephen Louie, and David Bosworth, *Task 2: Methyl mercury concentrations and loads in the Central Valley and Freshwater Delta,*CALFED, August 2008. Accessible online 14 May 2014 at http://mercury.mlml.calstate.edu/wp-content/uploads/2008/10/04_task2mmhg_final.pdf.

The California Department of Water Resources projects sea level rise by 2030 at about 6 inches, and by 2060 at about 18 inches in the Delta.[104] Snowmelt will continue to decrease in California and more precipitation will fall as rain, so winter season runoff will increase this century while summer (warm) season runoff will decrease.[105] In addition, extreme weather events are expected to become larger and more frequent in many parts of California. During the 21st century, the Sacramento River Basin is expected to experience on average about 32 more hot days, 30 more frost-free in the cold season, 36 fewer extremely cold days, 47 fewer days below freezing, nearly two fewer 7-day cold spells, and a half day's worth of fewer "cold spells." The San Joaquin River Basin is expected to see 11 more hot days per year, 1.6 more "hot events," 40 more frost-free days in the cold season, 35 fewer extremely cold days, 36 fewer days below freezing, 1.2 fewer prolonged (7-day) cold spells, and 3 fewer days of cold spells than in the recent past.[106]

To incorporate climate change effects into BDCP's extensive modeling effort, the Applicants' consultants relied on downscaled general circulation models to the regional level of California. The climate "normal" was taken to be the period of 1971 through 2000 (consistent with the National Oceanic and Atmospheric Administration's practice in climate modeling), in part because it represents the most recent climate time period commonly used for analysis (although it gets more difficult to know what is normal for California as our grasp of paleoclimate records indicates[107]). For BDCP, future climate periods are denoted as "approximately 2025" (the mid-point year of 2011 through 2040, or the "early long term" [ELT] and 2060 (the mid-point year of 2046 to 2075, or the "late long term" [LLT]). BDCP chose the difference in temperature and precipitation among the two future periods to represent the increment of change attributed to climate change.

Because there are so many variables that go into climate models, there are numerous potential permutations that are grouped into large numbers of climate change scenarios. BDCP acknowledges four different potential approaches to projecting climate change effects in the Bay-Delta watershed, and settled on the "multi-model ensemble-informed approach." Their median projections of temperature and precipitation from this approach can be used to divide the scenarios' results into four quadrants. In addition, a fifth region was identified by BDCP that

> samples from inner-quartiles (25th to 75th percentile) of the ensemble and represents *a central region of climate change*. In each of the five regions, the sub-ensemble of climate change projections, made up of those contained within the region bounds, is identified. The Q5 scenario is derived from the central tending climate projections and thus favors the consensus of the ensemble.[108]

BDCP performed further testing on the climate change ensembles to test their sensitivity to a loss of variability in the climate change ensembles due to combining the ensembles. The state and federal fishery agencies agreed to accept BDCP's approach to climate change ensembles, their approach to

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[104] *Ibid.*, Appendix 2.C, *Climate Change Implications and Assumptions*, Table 2.C-8, p. 2.C-13.

[105] *Ibid.*, p. 2.C-10, lines 2-4.

[106] *Ibid.*, Table 2.C-1, "Projected Weather Extremes in the Delta," p. 2.C-16.

[107] B. Lynn Ingram and Frances Malamud-Roam, *The West Without Water*, Berkeley, CA: University of California Press, 2014. Ingram and Malamud-Roam conclude that the American West, in which California figures prominently, will likely see much warmer and drier conditions punctuated by extreme flood events. It is arguable how use of central tendencies from the last 150 years of comparatively wet conditions in California can be used to model this expected future accurately.

[108] BDCP, Appendix 5A. 2, *Climate Change Approach and Implications for Aquatic Species*, p. 5.A.2-6, lines 15-19. Emphasis added.

bounding the sensitivity of the various quadrants, and the reliance on the fifth quadrant as a "consensus" characterization of climate projections.[109]

This approach to incorporating climate change effects into water resources and ecosystem planning is based on a fundamental fallacy in the era we are entering: that of "***stationarity***." The assumption of stationarity means that planners and decision makers rely on the range, central tendency and variability of a known sequence of past records of various environmental attributes in planning activities for decision-making about the future—in short, they make decisions relying on a belief that the future will resemble California's recent past.

Contemporary understanding of past climate records and future climate change forces us to break with the assumption of "stationarity." Currently, California water resources planning, particularly for droughts, is premised on an assumption that the "worst case scenario" for drought contingencies is a six-year drought like the one California experience between 1987 and 1992. However, paleoclimate researchers have examined tree rings and sediment records from Great Basin and other lakes, the Bay-Delta estuary, and the Santa Barbara Channel, as well as geomorphological evidence. They find that there have been several extended 100 to 300-year periods in the last two millennia that have been as dry or drier than the last century of historical records available to California.[110] Looking toward the future, other climate researchers and modelers find that "stationarity is dead."

> Stationarity is dead because substantial anthropogenic change of Earth's climate is altering the means and extremes of precipitation, evapotranspiration, and rates of discharge of rivers [citation]. Warming augments atmospheric humidity and water transport. This increases precipitation and possibly flood risk, where prevailing atmospheric water-vapor fluxes converge [citation]. Rising sea level induces gradually heightened risk of contamination of coastal freshwater supplies. Glacial meltwater temporarily enhances water availability, but glacier and snow-pack losses diminish natural seasonal and interannual storage.[111]

On one hand, BDCP cautiously acknowledges that the loss of stationarity has some merit, but clings on the other hand to its reliance on standard statistical "central tendencies." Its climate change analyses acknowledge that "natural variability is often greater than the magnitude of change expected over several decades" under climate change conditions. But the Applicants begin working stationarity back into their modeling projections, because the modeling systems are what they have to work with:

> In many water resource management areas, it is the extreme events (droughts and floods) that drive the decision-making and long-term planning efforts. Thus *there is a need* to combine the climate change signal with the range of natural variability *observed in the historical record*.
>
> *…[C]limate change is unlikely to manifest itself in a uniform change in values.* In fact, the climate projections indicate that the changes are nonlinear, and shifts in the probability distributions are likely, not just the mean values.[112]

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[109] *Ibid*., p. 5.A.2-6, lines 20-44, and p. 5.A.2-7, lines 1-11.

[110] Ingram and Malamud-Roam, *op. cit.*

[111] P.C.D. Milly, Julio Betancourt, Malin Falkenmark, Robert M. Hirsch, Zbigniew W. Kundzewicz, Dennis P. Lettenmaier, and Ronald J. Stouffer, "Stationarity is Dead: Whither Water Management?" *Science* 319(2008): 573-574, February. Accessible online at http://wwwpaztcn.wr.usgs.gov/julio_pdf/milly_et_al.pdf.

[112] Bay Delta Conservation Plan, Appendix 5.C, Attachment 5.A.2, *Climate Change Approach and Implications for Aquatic Species*, p. 5.A.2-8, excerpted from lines 2-12. Emphasis added.

So BDCP embarked on a process of incorporating both the climate change signal and the natural variability of the historical record to create "an expanded series that allows use of the long-term observed records." This kind of approach has been used in the Pacific Northwest and the lower Colorado River Basin, according to BDCP.[113]

BDCP's "need to combine the climate change signal with the range of natural variability observed in the historical record" signals the Applicants' unwillingness to operationalize the recognition that the past is no longer prologue in water resources planning. This is also signaled by their earlier statement that assumes that combining the various quadrants of climate change scenarios somehow represents "consensus." ***Whose consensus? EWC believes this consensus belongs entirely to the Applicants supporting BDCP.*** A related question is "why need consensus around a central tendency in the future climate of California?" *Why not* develop plans as though California should expect an *increase* in the number of below normal, dry and critically dry years in the future as our climate changes and the shifts in precipitation and temperature play out? We doubt that scarce ratepayer and taxpayer funds would be spent for a Twin Tunnels project were that sort of planning effort undertaken.

So while BDCP has acknowledged the reality of climate change with rising temperatures, reductions in future snowpack, the shift of runoff from spring peaks to late winter peaks, and so on, it has retained stationarity to bracket future climate variability within the "fifth quadrant" that gathers the central tendencies of its climate change scenarios together. This "ensemble approach" may take account of climate change central tendencies, but those tendencies have little to do with how climate change is likely to unfold during the rest of the 21st century.

Even with this fundamental problem in the BDCP approach to climate change modeling and analysis, there are some important results to acknowledge here.

- Expected sea level rise is expected to range from 6 inches in 2025 to 18 inches in 2060.
- Tidal amplitude is uncertain and may be negated by habitat restoration activities in the Delta Estuary.
- Air temperatures are expected to increase at Central Valley Project and State Water Project reservoirs by 1.7 to 2.0 degrees F on average by 2060.[114]

BDCP confirms our characterization of their approach to climate modeling, stating, "The climate change adjustments to runoff and reservoir inflow did not modify the historical sequence of conditions; *the annual runoff sequence remained similar to the historical record with only incremental changes in each month*."[115] BDCP acknowledges implicitly it is assuming stationarity of the sequence of runoff events when the future is likely to be quite different in terms of both sequence and the frequency and magnitude of variable climate events, dry and wet. We question the efficacy of this approach to climate change. It serves the Applicants first and foremost, not the covered fish or the people of California as a whole, and it fails to provide assurances that BDCP relies on the best available climate change science.

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[113] *Ibid.*, p. 5.A.2-8, lines 14-19.

[114] *Ibid.*, p. 5.A.2.2-10, Figure 5.A.2-3; and Table 5.A.2.3-2, p. 5.A.2-19. The reservoirs modeled include Trinity, Shasta, Oroville, Folsom, Whiskeytown, and New Melones.

[115] *Ibid.*, p. 5.A.2-44, lines 11-13.

Figure 5

Climate Change Approach and Implications for Aquatic Species Appendix 5.A.2

Table 5.A.2.7-2. Percentage of Years with "Good" Conditions for Winter-Run Chinook Salmon Habitat Metrics in the Upper Sacramento River (from SacEFT)[1]

Metric	EBC2	EBC2_ELT	EBC2_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT
Spawning WUA[2]	58	46	32	12	26
Redd Scour Risk	98	98	98	0	0
Egg Incubation	97	88	74	9	23
Redd Dewatering Risk	40	37	25	3	15
Juvenile Rearing WUA	32	32	31	0	1
Juvenile Stranding Risk	0	0	0	0	0

[1] Please refer to Appendix 5.C, *Flow, Passage, Salinity, and Turbidity* Attachment C.B, *SacEFT Documentation*, for definition of "good" for each performance measure.

[2] WUA=Weighted Usable Area.

Note: The SacEFT model classifies spawning habitat conditions based on WUA, which was derived from the River 2D simulation model, fitted to data obtained and parameterized by Mark Gard (U.S. Fish and Wildlife Service 2005a).

Although SacEFT operates on a daily time step, results are presented in terms of the percent of years that are classified as good, which is defined differently for each parameter analyzed (see SacEFT documentation for further details). SacEFT classifies spawning habitat conditions as good in 58% of the years under EBC2 (Appendix 5.C, Table 5.C.5.2-10).

BDCP projects climate change effects on fish upstream and in the Delta. Table 5.A.2.7-2 (excerpted above) shows that climate change's effects on Winter-run Chinook salmon will reduce spawning habitat upstream dramatically, will decrease available cold water for egg incubation, and increase risks in the future of dewatering redds.[116]

[116] *Ibid.*, Table 5.A.2.7-2, p. 5.A.2-106.

Figure 6

Climate Change Approach and Implications for Aquatic Species Appendix 5.A.2

Table 5.A.2.8-1. DSM2 Temperature Results for Delta Smelt in Plan Area

Subregion	Criteria	EBC2	EBC2_ELT	EBC2_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT
Cache Slough	Median Spawning Day (Adult)	130	126	116	4	14
	Number of Stressful Days (Juvenile)	74	90	111	16	37
	Number of Lethal Days	0	0	1	0	1
East Delta	Median Spawning Day (Adult)	132	128	115	4	17
	Number of Stressful Days (Juvenile)	84	96	118	12	34
	Number of Lethal Days	0	0	2	0	2
North Delta	Median Spawning Day (Adult)	132	129	116	3	16
	Number of Stressful Days (Juvenile)	82	95	114	13	32
	Average Lethal Days	0	0	6	0	6
San Joaquin Portion of the South Delta	Median Spawning Day (Adult)	125	121	123	4	2
	Number of Stressful Days (Juvenile)	90	101	101	11	11
	Number of Lethal Days	0	0	0	0	0
South Delta	Median Spawning Day (Adult)	124	119	117	5	7
	Number of Stressful Days (Juvenile)	85	97	113	12	28
	Number of Lethal Days	0	0	1	0	1
Suisun Bay	Median Spawning Day (Adult)	134	129	121	5	13
	Number of Stressful Days (Juvenile)	73	87	111	14	38
	Number of Lethal Days	0	0	0	0	0
Suisun Marsh	Median Spawning Day (Adult)	131	125	117	6	14
	Number of Stressful Days (Juvenile)	73	88	109	15	36
	Average Lethal Days	0	0	0	0	0
West Delta	Median Spawning Day (Adult)	136	129	119	7	17
	Number of Stressful Days (Juvenile)	77	90	113	13	36
	Number of Lethal Days	0	0	0	0	0

In the Delta, water temperature is closely related to air temperature because of the relatively shallow channels in the Delta and the relatively slow flow velocities at certain times of year. BDCP projects in Table 5.A.2.8-1 (Figure 6, excerpted above) that for Delta smelt there will be significant increases in the median spawning day of the year for adult Delta smelt, and will occur two weeks earlier by 2060, and that the number of "stressful days" (defined as days with daily average temperatures of 68 to 77 degrees F) increases from about 10 to 13 weeks at present (about 74 to 90 days depending on the sub-area of the Delta) to nearly four months (with increases ranging from 11 to 38 more stressful days).[117]

BDCP modeling results suggest the Delta will become a more stressful place for Delta smelt to live than it is today with potentially fewer refuges to escape to, even with habitat restored under BDCP. No similar analysis is provided for longfin smelt or other covered resident fish species to enable either the fishery agencies or the public to discern whether habitat restoration efforts create

[117] *Ibid.*, Table 5.A.2.8-1, p. 5.A.2-108.

adequate refugia to which Delta smelt may escape from rising Delta water temperatures by either 2025, let alone 2060.

BDCP's climate change analysis also informs the modeled effects of the Twin Tunnels versus scenarios without the Twin Tunnels, as shown in the sequence of charts for February through June Delta outflow and X2 position in the Delta.

As indicated in Figure 7 (below), the Delta's low salinity zone (as measured by the position of X2, the 2 ppt isohaline) will migrate upstream over time due in part to sea level rise and decreased upstream runoff, and it will take more inflow to maintain the LSZ in the same position. Without more inflow, Delta smelt habitat will move close to the North Delta Intakes. Construction and operation of North Delta Intakes for the Twin Tunnels would significantly increase, not decrease, entrainment threats to Delta smelt and longfin smelt in the long-term especially when combined with the continuing threats posed by the South Delta export pumps in below normal, dry, and critically dry years.

In January 2014, civil engineer and hydraulic modeler Walter Bourez of MBK Engineers in Sacramento presented results to the Delta Independent Science Board of a modeling study he performed of BDCP operations for a number of non-BDCP water agencies and water contractors involved in the Central Valley watershed of the Bay-Delta Estuary.[118] Bourez concluded from his modeling review of BDCP operations modeling that:

- There were "several shortcomings" with respect to climate change and operational adaptation to climate change.
- Using a more recently updated and improved version of CalSIM II incorporating operator adaptation to climate change, these shortcomings were corrected.
- Key operational results changed considerably as a result of modeling revisions:
  - Total Delta exports (South and North Delta sources) *increased* by about 200,000 acre-feet annually over current BDCP modeling results;
  - Total South Delta exports *decreased* by about 466,000 acre-feet on average relative to current BDCP modeling results; and
  - Total North Delta diversions *increased* by about 686,000 acre-feet on average relative to current BDCP modeling results.[119]

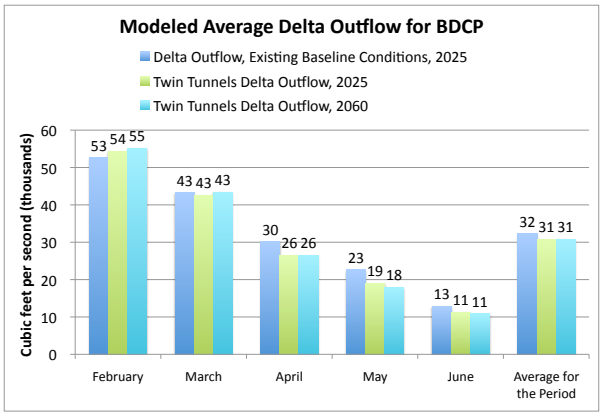
The export splits for north versus south Delta diversions changed dramatically, with much more exports occurring directly from the lower Sacramento River/North Delta Intakes than BDCP has previously disclosed, and total exports increased only somewhat.

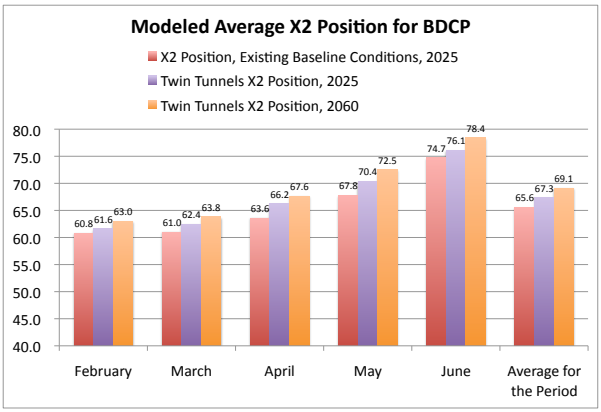
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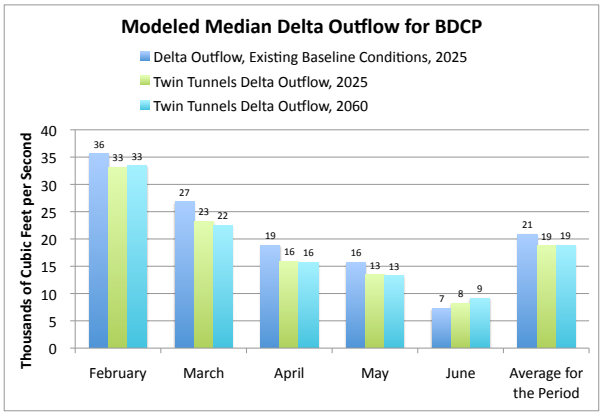
[118] MBK Engineers, *BDCP Operations Modeling Review*, January 17, 2014, presented to the Delta Independent Science Board, 21 slides. Bourez presented his results to the Delta Independent Science Board on January 17, 2014. Among the funders of Bourez's operational modeling review are Friant Water Authority, San Joaquin River Exchange Contractors, Contra Costa Water District, San Joaquin Tributaries Authority, East Bay Municipal Utilities District, Tehama Colusa Canal Authority, and the North Delta Water Agency.

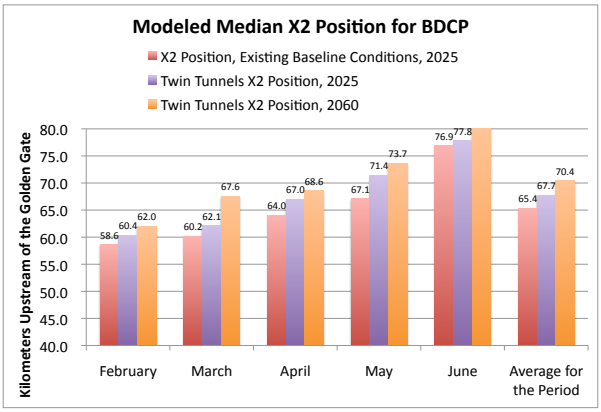
[119] *Ibid.*, slide 11.

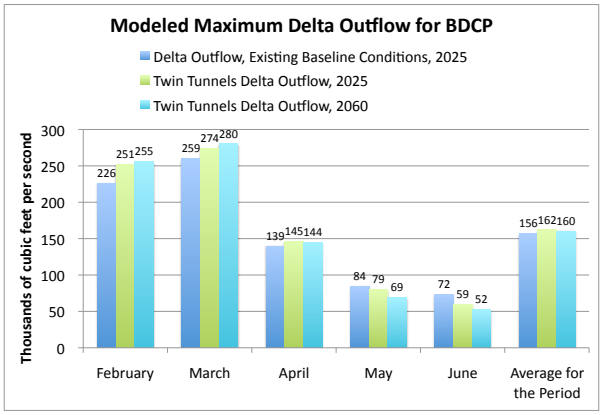
Figure 7
Delta Outflow to Decrease in Future Scenarios with Twin Tunnels, Average X2 Position to Move Eastward with the Twin Tunnels

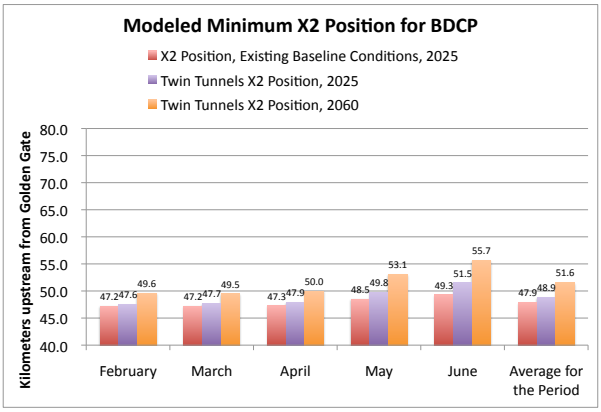












The average value is skewed somewhat by presence in the data of high outflow and low X2 years. The median is the value where half of all other values in the dataset are greater than the median value, and half are less. Delta outflow and X2 are inversely related. Greater outflow means less distance of X2 from the Golden Gate.

Sources: Bay Delta Conservation Plan, Appendix 5.C., Attachment 5C.A, Table C.A-41, p. 5C.A-174; and Table C.A-42, p. 5C.A-176.

Mr. Bourez's water agency clients wanted to factor in climate change adaptation by water facility operators into their modeling assumptions. So they worked in an aspect of climate change into the operator side of the modeling, rather than in the hydrologic side.

Mr. Bourez explained to the Delta Independent Science Board, that BDCP's modeling effort began with the 2009 version of CalSIM II. BDCP's modeling effort was largely completed in 2010, and was not updated for release of the current set of public review documents, even though the California Department of Water Resources subsequently updated and improved CalSIM II. The MBK approach starts with reliance on the CalSIM II modeling used by DWR to construct the 2013 SWP reliability study. Mr. Bourez praised DWR's CalSIM II 2013 improvements, and stated his belief that had this version of CalSIM II been used by BDCP, it would have yielded a different answer than is now seen in BDCP's modeling results.[120] After altering the underlying CalSIM II assumptions, they layered on the BDCP facilities and operations.[121] ***As a result of this disclosure by Mr. Bourez, it appears that the BDCP modeling effort is not based on the best available science as called for under the federal Endangered Species Act.***

Mr. Bourez also stated that it was "unrealistic" to model BDCP's High Outflow Scenario by placing all of the high outflow releases onto Oroville operations. The Coordinated Operation Agreement between DWR and USBR would require that this "debt" be repaid to the SWP somehow, but it is not revealed in BDCP modeling. However, NMFS specified that "high outflow scenario" (HOS) flows should not come from Shasta or Folsom in order to protect cold water pools. ***Therefore, water transfer programs would become the "source" to provide the flows needed for the high outflow scenario in BDCP.*** Water transfer market activity (which, in recent years, has relied heavily on groundwater substitution as the proxy supply enabling Sacramento Valley growers to sell surface water south of the Delta) would become the "source" to provide flows needed for the high outflow scenario in BDCP in drier years. (See our discussion in Section VII.) "There are no defined operating criteria for HOS as of yet," he stated. So actual operating criteria for the High Outflow Scenario remain, from a modeling standpoint, undefined, and impacts resulting from it go unrevealed in BDCP's existing modeling results.

Of the total combined exports increase, about 170 TAF would go to CVP south of Delta contractors, and 40 TAF (again, round numbers) would go to SWP contractors).[122] Mr. Bourez stated that Delta outflow would *decrease* by about 200 TAF on average, although there would be an average increase across all water years in the month of October (largely from implementation of Fall X2 requirements under the Delta smelt biological opinion).[123]

According to Mr. Bourez, ***there would be significantly higher North Delta diversions and much lower inflows to the Delta along the lower Sac River. This portends greater potential for reverse flows in Georgiana Slough.*** Over time as X2 migrates upstream due to climate change, it threatens to draw Delta smelt and longfin smelt closer to entrainment risk at the north Delta diversions especially in July and August (prime months for juvenile rearing and growth), even more than is implied in BDCP's present operational modeling. Greater usage of North Delta Intakes in October, as shown in Mr. Bourez's presentation, indicates greater risk of delayed passage for adult Fall-run Chinook salmon as they attempt to head to their natal streams to spawn, and greater risk of

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[120] Mr. Bourez's remarks were recorded in the personal notes of Tim Stroshane, EWC consultant, present at the Delta Independent Science Board meeting, January 17, 2014.

[121] MBK Engineers, *BDCP Operations Modeling Review*, January 17, 2014, presented to the Delta Independent Science Board, slides 7 and 8.

[122] *Ibid.*, slide 12.

[123] *Ibid*., slide 13.

entrainment and impingement for juvenile Winter-run and Spring-run Chinook salmon and their smolts emigrating to the ocean in the fall.

Mr. Bourez's operational modeling review methodology included climate change adaptation practices that reservoir operators would employ. Factoring in such behavior at the major CVP and SWP reservoirs, Mr. Bourez's results found greater summertime storage in dry years when operators try to manage cold water pools for fish, and no dead pools. So this finding bodes improved upstream effects than now expected by BDCP modeling results on salmon rearing, spawning, and protection of redds as well as less chance of "superposition" competition among spawning fish for space in river gravels (where spawning females lay their redds atop previously laid redds due to a lack of sufficient wetted habitat in upstream locations).

We present Mr. Bourez's critical review of BDCP modeling as evidence that the best available science and methods were not employed in the development of the Bay Delta Conservation Plan nor its Environmental Impact Statement/Environmental Impact Report. Mr. Bourez readily acknowledges that his BDCP operational modeling review for MBK Engineers and their clients does not include the hydrological/climatic effects of climate change and is thus itself a limited form of analysis. ***But Bourez's remarks spotlight omissions and oversights in the conduct of BDCP modeling, including of climate change effects, that render the analyses of the documents released by BDCP Applicants in December 2013 inadequate to the task of providing ecological assurances needed by the fishery agencies to support issuance of incidental take permits to the BDCP Applicants.***

5. Real-Time Protective Operations and Adaptive Management

BDCP fails the Endangered Species Acts' requirements for ecological assurances. The habitat conservation plan, through its anticipated reliance on extensive use of real-time operations (RTOs) and adaptive management, provides a highly unstable analytical basis for ecological assurances. This makes it likely that BDCP will appreciably reduce the survival and recovery of listed species. Key assurance questions are put off into the plan's adaptive management process. The BDCP application for incidental take permits should be rejected by the fishery agencies.

The current draft Bay Delta Conservation Plan fails to clearly distinguish between the roles of real-time protective water facility operations and adaptive management of operations.

Section 3.4.1.4.5 of Chapter 3, Conservation Strategy, in the Bay Delta Conservation Plan begins with this "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 the CVP. This section is therefore preliminary. The final BDCP document will describe operational criteria to guide project operations.[124]

The fishery agencies are obligated by ESA regulations to cooperate with habitat conservation planning applicants to make their plans as effective as possible. The presence of a note like this indicates that there is still considerable controversy between the Applicants, Reclamation, and the fishery agencies over how "real-time operations" are to be handled in the context of Twin Tunnels operations. ***The issue is crucial because the complexity of "flexible" operations touted for the Twin Tunnels means that the North Delta Intakes must be operated in part according to whether listed or covered fish species are present in the vicinity of the Intakes to warrant***

[124] Bay Delta Conservation Plan, Chapter 3, *Conservation Strategy,* p. 3.4-26, lines 10-13.

sharp reductions in diversions. If ESA-listed or BDCP-covered fish suddenly appear in the vicinity of River Miles 37 through 41 unexpectedly, the RTO team—at least in concept—would have the discretionary power to shut down or dramatically curtail diversions in order to protect the fish that are present. It is next to impossible to model RTOs; by definition they are not predictable, which is why they are called "real-time" operations.

The essential purpose of real-time operations (or "RTOs"), as described in BDCP, is 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 [i.e., the Twin Tunnels project and related facilities], which will be periodically evaluated and possibly modified through the adaptive management program [citation]. 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."

When developing adjustments to Twin Tunnels operations in real-time, the RTO team[125] would consider covered species risks, actions needed to avoid adverse effects on covered fish species, water allocations currently or in future years, "end of year [reservoir] storage," the San Luis Reservoir low point[126], delivery schedules for any SWP or CVP contractor, and "actions that could be implemented throughout the year to recover any water supplies reduced by actions taken by the RTO team."[127] These criteria for consideration place a great deal of pressure on the RTO team to minimize water costs to North Delta Intake diversions, lest they be compensated later.

RTO team activities would be needed under BDCP not only at the North Delta Intakes, but at the Delta Cross Channel gates, Head of Old River gate, the Fremont Weir operable gate, and the "nonphysical barriers" intended to shoo fish away from certain channels without actually blocking river flows.

The RTO team will attempt to plan RTOs as part of BDCP's "Annual Delta Water Operations Plan," by anticipating periods when RTOs may be employed, alternative responses to be considered, the intended benefits to covered species, any expected effects on water supply, and the monitoring and analysis procedures used to track adjustments. RTOs will necessitate an elaborate range of accounting procedures since the state and federal water projects will not tolerate net losses of water exports just because covered fish show up unannounced and uninvited at the North Delta Intakes or the South Delta pumping plants.

This section of Chapter 3 in BDCP states some "salvage density triggers" for Old and Middle River flow adjustments between January 1 and June 15 affecting the South Delta export facilities.[128] At the

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[125] The Real-Time Operations Team would comprise one representative each from the three state and federal fishery agencies and from DWR and the Bureau of Reclamation.

[126] San Luis Reservoir has a "low point" of about 300,000 acre-feet of storage below which the intakes for San Felipe Project contractors (Santa Clara Valley Water District and San Benito County Water District) are unable to withdraw water due to the potential for algal bloom contamination and other water quality concerns, due to the fact that when San Luis Reservoir gets that low, temperature and water quality conditions make it economically infeasible for San Felipe Project contractors to treat the water to an acceptable level for beneficial use.

[127] Bay Delta Conservation Plan, Chapter 3, p. 3.4-26, lines 34-39, and p. 3.4-27, lines 1-4.

[128] *Ibid.*, p. 3.4-28 to 3.4-29, Table 3.4.1-3.

North Delta Intakes, RTO monitoring will manage bypass flow operations from December through June, but the "exact triggers and responses for RTO at the north Delta diversions are still under development." Generally they are intended to manage north Delta diversion bypass flows:

- within a preset range when juvenile salmonids are emigrating downstream past the intakes.
- within a preset range when adult sturgeon are migrating upstream.
- 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.)
- and to 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.[129]

A clear distinction of real-time operations from adaptive management activities has been submerged between the description of RTOs in the March 2013 administrative draft of BDCP and the November 2013 draft. In March 2013, RTOs were described as providing for "discretionary changes that may be taken for the purpose of providing additional benefits to covered fish species….Real-time operations do not substantially alter the values of water operations criteria, but provide a mechanism to alter those values for periods of a few days or weeks within specified bounds." As performed at other Delta facilities such operational activities "have been found to produce substantial beneficial outcomes for salmonids and smelts—outcomes incremental to those predicted in the BiOps."[130] The purpose of RTOs is to

> increase fish benefits without compromising water supply availability provided under the Plan and its regulatory authorizations. Should the agencies choose to make a real-time operations adjustment to provide a short-term fisheries benefit, the resulting impact on water supply will be calculated. Subsequent real-time operational actions will be taken to restore any water supply impact resulting from the prior decision.[131]

The March 2013 version of the BDCP disclosed that "real-time operational decisions are separate and distinct from the adaptive management process." RTOs are short-term adjustments to operations with subsequent compensations for water cost involved to the state and federal operators, while BDCP's adaptive management process is intended to address adjustments that may be needed, based on best available science, in conservation measures, "including operational criteria," should ongoing monitoring of Plan implementation suggest that changes are needed to improve "the effectiveness of the Plan and advance biological goals and objectives." Adaptive management changes will be based on "best available science."[132]

None of this language from the March 2013 draft BDCP clarifying the differences between RTOs and the adaptive management process is retained in the current November 2013 version of BDCP. And yet there are clearly important and undisclosed relationships between the adaptive management process and RTOs. For example, operation of the Fremont Weir notch's operable gate(s) may have to be the subject of adaptive management research if recommended by the adaptive management team. And yet, BDCP also contemplates that the 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." It is unclear in the November 2013 Draft BDCP where

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[129] *Ibid*., lines 13-22.

[130] Administrative Draft Bay Delta Conservation Plan, March 2013, p. 3.4-20, lines 32-36.

[131] *Ibid.*, p. 3.4-20, line 43, and p. 3.4-21, lines 1-5.

[132] *Ibid.*, lines 6-14.

RTOs stop and adaptive management begins, and there may be other such gray areas between adaptive management and real-time operations at the other facilities where RTOs will be carried out—and those will have to be coordinated with each other.

Without disclosure of the RTO triggers for the North Delta Intake and other proposed BDCP facilities' RTOs, and without clear delineation between where RTOs stop and adaptive management begins, it is impossible for decision makers to be adequately informed about the promise or problems of real-time operations and how they would be applied. This violates NEPA and CEQA. Moreover, the impossibility of modeling RTOs casts doubt using BDCP modeling as a guide to actual Twin Tunnels and other BDCP CM 1 facilities operations. Given the likely use of RTOs, the expected heavy reliance of BDCP on adaptive management for handling biotic and abiotic uncertainties, and the narrow definition of "foreseeable circumstances" that defines allowable modifications to the Plan (about which more below), ***the fishery agencies are faced with enormous potential for a grand bait-and-switch from the Applicants toward operations in the Delta once incidental take permits are issued. But by then, it will be too late for the fishery agencies to regain much control over real-time operations.***

The recently released "Stipulation Study" experiment in real-time operations intended to benefit Central Valley steelhead smolts' migration routes and survival rates through the Delta provided little support for the potential effectiveness of real-time operations to protect salmonids from entrainment at the South Delta pumping facilities. It raises serious questions about the magnitude and timing of flow signals that would be needed to affect the migration routing of smolts, none of which are accommodated at present in BDCP and Twin Tunnels approaches to real-time operations and adaptive management.[133]

6. Selenium Analysis and Residence Time of Delta Water Under BDCP

BDCP errs in assuming decreasing selenium loads during the term of the incidental take permits.

As noted above in Section III, there is another reason for concern about the likely expansion of the range of the nonnative invasive clam *Potamocorbula* in the Delta eastward into the Delta as sea level rises and with construction and operation of the Twin Tunnels. Not only does this clam filter-feed great volumes of food from the water column and threaten to undermine the productivity of habitat restoration efforts to be sponsored by the Bay Delta Conservation Plan; it turns out that *Potamocorbula* is a highly efficient bio-accumulator of the metalloid selenium. In high tissue concentrations, selenium can be either toxic or lethal. *Corbicula* is also known to bioaccumulate selenium, though not at the same rates as *Potamocorbula*.

The nonnative invasive clams are discussed in detail in Appendices 5.D, *Contaminants*, and 5.F, *Biological Stressors on Covered Fish*, out of sight of the Plan's main chapters. In Section 5.F.6.4, BDCP states that increased selenium uptake in the food chain via invasive clams is *not* an anticipated result of covered activities. This is because, Appendix 5.F states, residence time of Suisun Bay water will not increase from BDCP activities

[133] California Department of Water Resources, *Stipulation Study: Steelhead Movement and Survival in the South Delta with Adaptive Management of Old and Middle River Flows*, prepared by David Delaney, Paul Bergman, Brad Cavallo, and Jenny Melgo, Cramer Fish Sciences, February 2014, 150 pages. Accessible online 15 April 2014 at http://baydeltaoffice.water.ca.gov/announcement/Final_Stipulation_Study_Report_7Feb2014.pdf.

> and an increase in residence time would be critical for increased uptake of selenium by the clam population. However, there is uncertainty associated with this conclusion because of the complexity of factors that determine selenium biogeochemistry and bioavailability.[134]

Residence time is critical because the longer a parcel of water containing contaminants or other chemical stressors remains in the same general place, the greater potential there is for toxic interactions of those contaminants with organisms co-occurring in that water. Not only is there uncertainty associated with BDCP's conclusion that the clams would not experience increased uptake of selenium, but this conclusion is doubly suspect because Suisun Marsh and West Delta residence times are projected by BDCP to *increase* on a seasonal basis by 2025 under Twin Tunnels operations, as shown in Figure 8 below. How their residence times would increase and Suisun Bay's would not (given its direct hydraulic connection to the Marsh and West Delta) needs explanation from BDCP.

These charts summarize particle tracking studies that model the number of days it takes buoyant particles injected in various sub-regions of the Delta to exit the Delta, either via exports (as in the South Delta) or via Suisun Bay to San Pablo Bay. Each chart compares three scenarios: existing conditions at present, conditions in 2025 upon approximate completion and launch of Twin Tunnels operations, and conditions in 2060 with restoration projects completed and the Twin Tunnels in operation. ***As can be seen in these charts, all areas of the Delta will see dramatically increased residence time of water with completion and operation of the Twin Tunnels (red bars in Figure 8) as compared with blue bars representing existing conditions.*** Between 2025 and 2060 with the Twin Tunnels, the picture gets more complex, according to BDCP. Residence times continue to rise in the South, East, North and West Delta in all seasons and in the average measures every year under BDCP. But BDCP modeling projects that residence times will dramatically decrease by 2060 in both Suisun Marsh and the Cache Slough area.

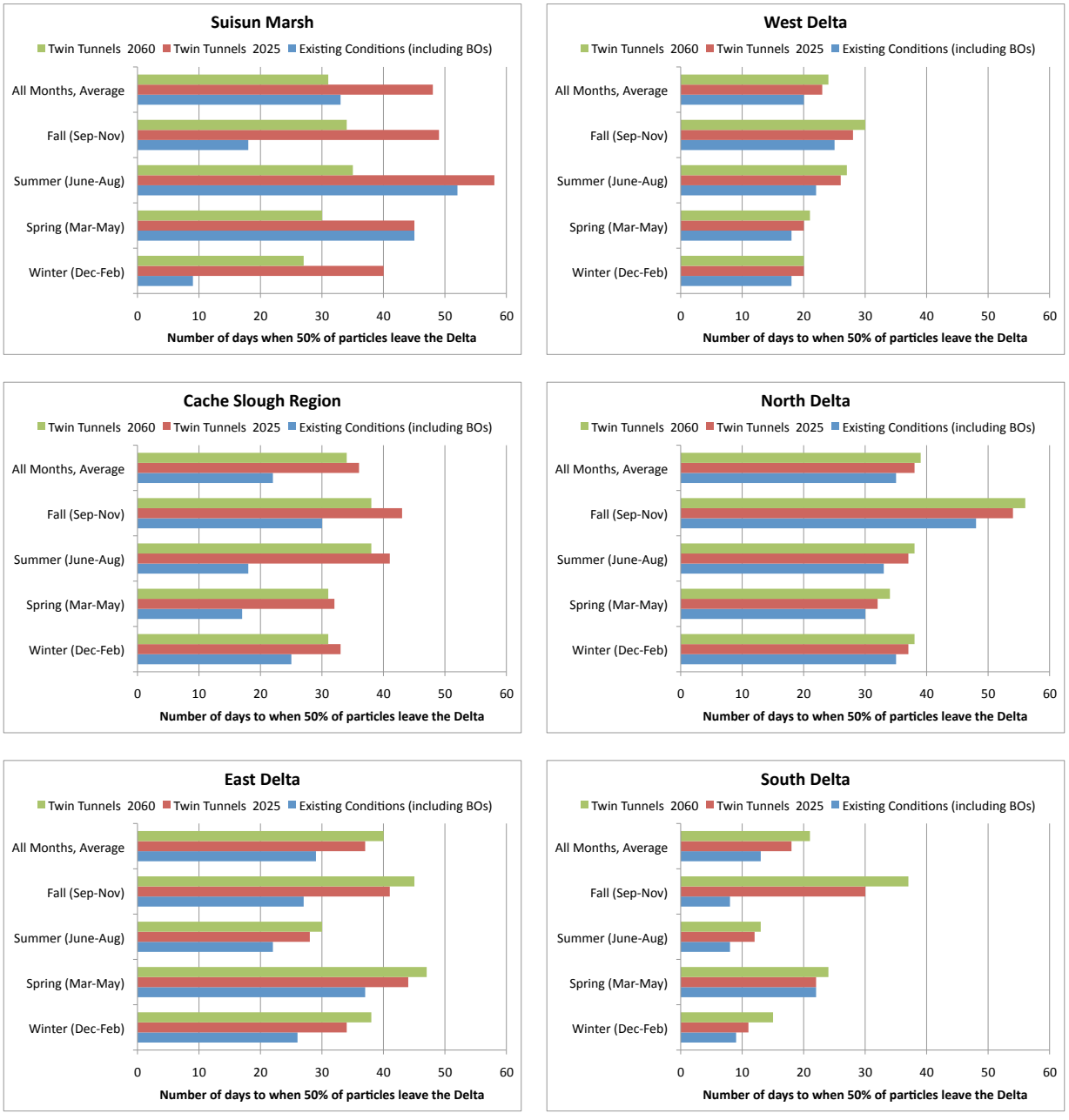
Consider the Cache Slough and Suisun Marsh charts season by season. In Suisun Marsh, the annual average residence time of water decreases by about one day, but in the fall residence times will increase by about 14 days and winter residence times will increase by about 18-19 days by 2060. Spring and summer residence times are already high now in Suisun Marsh (averaging about 45 and 52 days respectively) presumably due to current irrigation season diversions of inflow directly from the marsh as well as CVP and SWP export operations that force use of the Suisun Marsh Salinity Control Gates to protect water quality there. The early operations of the Twin Tunnels (by 2025 or thereabouts) are projected to maintain residence time at about 45 days before it is projected to decrease by 2060 to 30 days in the spring and from 58 to 35 days in the summer. Would this decrease be due to reoperation of the Suisun Marsh Salinity Control Gates combined with habitat restoration actions? If so, what are the mechanisms (either biotic or abiotic) the Applicants anticipate that would account for such dramatic decreases in residence time in Suisun Marsh under Twin Tunnels operations?

We also note that Suisun Marsh's residence times across each season will become much less variable if BDCP residence time modeling is correct. Under current conditions, this variability in residence time means that there are periods of the year, especially fall and winter, when shorter residence time means that Marsh channels are being flushed out with fresher waters (probably from irrigation return flows as well as early storm water runoff in to the Marsh watershed). What will the loss of that variability mean for water quality in the Marsh, and for longfin smelt, which is often found in Suisun Marsh channels during spring and summer months?

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[134] *Ibid.*, Appendix 5.F, *Biological Stressors on Covered Fishes*, p. 5.F-123, lines 29-34.

Figure 8
Residence Time of Water in Various Delta Regions



Source: Table 5C.5.4-14, p. 5C.5.4-84, Bay Delta Conservation Plan.

In Cache Slough in all seasons (a potential permanent refuge for Delta smelt, as hoped in BDCP), Twin Tunnels operations would only slightly decrease residence time of water between 2025 and 2060, and Twin Tunnels operations would have significant (i.e., greater than 10 to over 50 percent) *increases* in residence time from current conditions to Twin Tunnels operation by 2025. The Cache Slough area would be positioned at the downstream end of seasonally-inundated floodplain lands in Yolo Bypass, especially during winter and spring, which may account for flows that decrease residence time of water by 2060.

West Delta residence time is significant here as well since that area is just downstream of Cache Slough outflow and just upstream of Suisun Marsh, so it most closely approximates the residence time of water present in Delta outflow to Suisun Bay. According to BDCP modeling presented in Figure 8 above, Twin Tunnels operations will *increase* residence time in all seasons and in the annual average, and residence time will increase under Twin Tunnels operation between 2025 and 2060. West Delta residence times retain their clear seasonally-increasing trend, where they are lowest in winter, increasing through spring and summer somewhat to fall when residence times are about 25 to 33 percent higher than in winter (e.g., 30 days of residence time in the fall versus 20 days under Twin Tunnels operations by 2060).

But residence time of water is projected to increase, sometimes significantly, throughout the rest of the Delta. Higher residence time means slower flow velocities in channels and open water areas. ***Slower flow velocities provide greater opportunity for dissolved selenium to enter partitioning processes in the water column and become more bioavailable.***

BDCP presents the details of its analysis of the risk of selenium contamination to the Delta in Appendix 5.D using two fish species, largemouth bass and sturgeon (either green or white) to represent predators at the top of distinct food webs found in the Delta. Only one of these foodwebs, however, is based on benthic bivalves like *Potamocorbula* and *Corbicula*, both of which can be consumed by sturgeon. Our comments will focus on BDCP's sturgeon related analysis, and highlight some unresolved issues that contribute to great uncertainties.

BDCP stresses in its analysis that the modeling results for sturgeon are "long-term, worst-case conditions" but do not explain how or why their results represent a worst-case condition.[135] This claim appears to be based on their argument that

> Given the variability of concentrations at the individual level, decreasing concentrations in source waters to the Delta and Suisun Bay expected as described above, and the uncertainties in the water concentration modeling and subsequent bioaccumulation modeling presented above, it is unlikely that the increases in whole body Se [selenium] for sturgeon modeled would be measurable in the environment, and there is also uncertainty about the biological significance of these increases, given the uncertainty of the actual threshold for biological effects in sturgeon.[136]

The analysis in Appendix 5.D then claims that "discharges of selenium to the Delta will continue to decrease in accordance with regulatory requirements, specifically for the North San Francisco Bay Refineries, and agricultural discharges in the San Joaquin Valley."[137] The analysis further assumes that continuing future decreasing concentrations of selenium in source waters are due to the Grassland Bypass Project, an area of the western San Joaquin Valley west of Firebaugh and southwest of Los Banos.

BDCP acknowledges that habitat restoration activity in the Delta could mobilize selenium in the sediments and soils of proposed restoration areas, particularly in the South Delta.[138] Despite what BDCP stated in Appendix 5.F about Suisun Bay residence time, in Appendix 5.D, BDCP states that Suisun Bay "is also of concern" because of *Potamocorbula* densities there. High residence time in this area could lead to "increased selenium bioaccumulation" in sturgeon. This section adds:

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[135] *Ibid*., p. 5.D-33, line 26.

[136] *Ibid.*, p. 5.D-34, lines 1-4.

[137] *Ibid.*, p. 5.D-33, lines 27-29.

[138] Bay Delta Conservation Plan, Appendix 5.D, *Contaminants*, p. 5.D-35, lines 15-23.

> CalSIM modeling results indicate that *outflow and residence time in Suisun Bay will not change substantially under the BDCP*. Comparison of the monthly mean residence time (averaged over the years 1992 through 2003) indicates that residence time in Suisun Bay may change from a decrease of 13 days to an increase of 5 days.[139]

This description of un-presented CalSIM II results is at best unclear, and conflicts with BDCP's earlier reported claim that residence time *decreases* in Suisun Bay under Twin Tunnels operation. It is followed by this conclusion:

> Given the decrease in loading of selenium to the Delta...and that the selenium would be mobilized into the food chain under a narrow set of conditions, the overall effects within the Plan Area [the Delta] are likely low. The potential is highest for increased mobilization of selenium in and near the San Joaquin River and the South Delta ROAs [restoration opportunity areas], where selenium concentrations in soils are expected to be highest, and potentially in Suisun Bay where filter feeders are the food source for benthic feeding covered fish species.[140]

BDCP and the fishery agencies would err to premise their analysis of selenium toxicity risk to Delta ecosystems on the Grassland Bypass Project resulting in steadily decreasing selenium concentrations in source water from the San Joaquin River to the Delta on into the future. There is evidence that much of the selenium load and concentration reductions that have been achieved so far have come from land retirement in the Grassland and northern Westlands Water District area. Even the State Water Resources Control Board, which has maintained a relatively light regulatory touch, approved a basin plan amendment for Grassland Bypass Project that only goes through 2019 when it must decide whether another extension for the project is warranted.

Grassland Bypass Project attempts to bioconcentrate selenium in salt-tolerant plants and discharge remaining effluent into a segment of the San Luis Drain that ultimately drains into Mud Slough (north), thence to the San Joaquin River. This method is insufficient to reduce the selenium threat to the sloughs tributary to the San Joaquin River. So the Grassland drainers obtained a grant through Panoche Drainage District to attempt a pilot project to treat selenium-contaminated drainage. The facility is estimated to cost $37 million, or about $78,000 per acre-foot of treated drainage water. The efficacy of treating this water has yet to be proven, particularly given the fact that its cost per acre-foot of drainage treated far exceeds most other technologies for recycling water. There are indications that the treatment project will not prove to be cost-effective. Its discontinuance would undermine a key assumption of BDCP's analysis of selenium as a contaminant stressor in the Delta.

Mostly, the reduced selenium loads in the San Joaquin River appear attributable at best to retirement of lands from irrigation service. What drainage is generated in the Grassland area and in the Westlands Water District is largely held on-site as groundwater drainage containing selenium, and selenium in soil and source rock upslope of these lands. The longer irrigation continues on these lands, the more selenium drainage and soil contamination will build up. Flood events can mobilize pulse loads that can be quite large (see "context" discussion above and Table 2), and their toxicity long-lasting in downstream water bodies from Mud Slough all the way to the Delta and Suisun Marsh.

Retirement of the drainage impaired lands of the western San Joaquin Valley has been found time and again to be the most cost-effective solution to the problem of selenium-tainted irrigation

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[139] *Ibid.*, p. 5.D-36, lines 6-9. Emphasis added.

[140] *Ibid.*, p. 5.D-37, lines 11-17.

drainage.[141] Land retirement is the best and cheapest option for slowing the rate at which selenium loads and concentrations reach the Delta, and for sequestering selenium in its source rock and soils longer into the future. Stop applying water exported from the Delta to these lands so that no more seleniferous drainage is intentionally created. The natural reservoir of selenium has been documented to hold up to at least another 300 years' worth of tainted drainage at current rates.[142] The National Research Council's 2012 report on Bay-Delta sustainable water management cited this selenium reservoir as well, stating in part:

> Irrigation drainage, contaminated by selenium from those soils, is also accumulating in western San Joaquin Valley groundwaters. The problem is exacerbated by the recycling of the San Joaquin River when water is exported from the delta. While control of selenium releases has improved, how long those controls will be effective is not clear because of the selenium reservoir in groundwater.
>
> ...Other aspects of water management also could affect selenium contamination. For example, infrastructure changes in the delta such as construction of an isolated facility could result in the export of more Sacramento River water to the south, which would allow more selenium-rich San Joaquin River water to enter the bay. The solutions to selenium contamination must be found within the Central Valley and the risks from selenium to the bay are an important consideration in any infrastructure changes that affect how San Joaquin River water gets to the bay.[143]

Of course, ending the imports of Delta waters to the western San Joaquin Valley's to irrigate drainage impaired lands could reduce the need for deliveries to the San Luis Unit of the Central Valley Project by up to a million acre-feet per year. ***This reduction in deliveries through the CVP could provide by itself dramatically improved reliability of other CVP contractors' allocations, without the investment of billions for the Twin Tunnels project and BDCP.***

But in the absence of such adjustments to how drainage impaired lands are managed by local irrigators and the US Bureau of Reclamation, and in the absence of any action by the Bureau to end deliveries to these lands in the San Luis Unit, there appears no end to the vicious cycle of selenium transport to the Delta and Suisun Bay via the San Joaquin River. ***BDCP errs in assuming decreasing selenium loads during the term of the incidental take permits.***

7. Temperature Conditions and Cold Water Pool Management

The Draft EIS/EIR analysis of cold water carryover storage is misleading and inaccurate. The EIS/EIR does not disclose significant impacts to cold water storage and decreased downstream salmon survival as a result of warming rivers.

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[141] "Land retirement is a key strategy to reduce drainage because it can effectively reduce drainage to zero if all drainage-impaired lands are retired." Page 2, USGS Open File Report 2008-1210, Technical Analysis of In-Valley Drainage Management for the Western San Joaquin Valley, California. Accessed at http://pubs.usgs.gov/of/2008/1210/of2008-1210.pdf.

[142] T. Stroshane, *Testimony on Recent Salinity and Selenium Science and Modeling for the Bay-Delta Estuary*, plus appendices, prepared for the California Water Impact Network, August 17, 2012, for Workshop #1, Ecosystem Changes and the Los Salinity Zone, before the State Water Resources Control Board.

[143] National Research Council, Committee on Sustainable Water and Environmental management in the California Bay-Delta, *Sustainable Water and Environmental Management in the California Bay-Delta*, Washington, DC: The National Academies Press, 2012, p. 94. Accessible online 8 May 2014, at http://www.nap.edu/catalog.php?record_id=13394.

Reservoir minimum storage is defined as the amount of water in a reservoir at the end of the water year at the end of September (EOS), also referred to as carryover storage. The purpose is to ensure that there is enough cold water in reservoirs for salmon to have suitable temperatures downstream of dams for holding, spawning, incubating and rearing. Only two of the major CVP reservoirs have minimum storage criteria- Shasta and Trinity. The Sacramento River and the Trinity River both have temperature water quality objectives contained in their respective Water Quality Control Plans (Basin Plans), approved by the Central Valley[144] and North Regional Water Quality Control Boards,[145] the SWRCB and the U.S. Environmental Protection Agency as state and federal clean water act standards. The intent of the Shasta and Trinity minimum storage requirements is to meet the downstream Basin Plan Temperature objectives.

The minimum storage requirements for Shasta and Trinity reservoirs are contained in Biological Opinions by the National Marine Fisheries Service dated 2009[146] and 2000[147], respectively. Lake McClure, owned and operated by the Merced Irrigation District has "minimum pool" requirements in its SWRCB water permits for Bagby, Exchequer (Lake McClure) and Snelling reservoirs. [148]

The Draft EIS/EIR analysis claims that there will be no significant impacts to cold water storage in Shasta and Trinity reservoirs from operation of BDCP. The EIS/EIR claims that long term impacts to cold water reservoir storage in Shasta, and Trinity are a result of climate change and not BDCP operations. However, at the January presentation by Walter Bourez (described elsewhere in Section III), he stated that it was "unrealistic" to model BDCP's High Outflow Scenario by placing all of the high outflow releases onto Oroville operations. The Coordinated Operation Agreement between DWR and USBR would require that this "debt" be repaid to the SWP somehow, but it is not revealed in BDCP modeling.

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[144] See Water Quality Control Plan for the Sacramento River and San Joaquin River Basins, Table III-4, page III. 8.0, accessed at http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/index.shtml

[145] See Water Quality Control Plan for the North Coast Region, Table 3-1, page 3-6.00, accessed at http://www.waterboards.ca.gov/northcoast/water_issues/programs/basin_plan/basin_plan.shtml

[146] http://www.epa.gov/espp/litstatus/wtc/carbama-biop-4-20-09.pdf

[147] http://www.fws.gov/arcata/fisheries/reports/technical/TREIS_BO_NMFS.pdf

[148] For a description of the Merced Irrigation District's Minimum Pool requirements in their SWRCB water licenses, see page 5 of SWRCB temporary urgency order for licenses 11395 and 11396 (Applications 16186 and 16187), accessed at http://www.waterboards.ca.gov/waterrights/water_issues/programs/applications/transfers_tu_orders/docs/mid_temp_order_mod052214.pdf

"IV. MID shall maintain the water surface elevation in its reservoirs as high as possible, consistent with operational demands throughout the period April through October each year, and shall maintain minimum pools of the following capacities for operation of the project and maintenance of fish and wildlife:

Bagby Reservoir	30,000 af
Exchequer Reservoir	115,000 af
Snelling Reservoir	20,000 af"

Absent a replacement source of water such as water transfers that was not modeled either, the additional Delta outflows would come from Shasta, Trinity and Folsom, thereby reducing minimum storage, cold water pools and the ability to meet downstream temperature objectives. The Draft EIS/EIR's evaluation of minimum storage and the ability to meet Basin Plan temperature objectives as well as NMFS' target minimum pool objectives for various listed salmonids is therefore inadequate.

In addition, while the EIS/EIR evaluated the impact of climate change on minimum storage and the ability to meet Basin Plan temperature objectives, as we previously discussed, the BDCP climate change models use a "fifth quadrant" that assumes stationarity (see Climate Change discussion above) in climate change. For reasons previously discussed in the EWC comments, this is inadequate to predict the range of future climate conditions, including, but not limited to runoff volume and timing, reservoir inflow temperatures, reservoir heating and in-river heating. Thus the evaluation of climate change on reservoir operations and water temperatures (Appendix 29C) is inadequate and inaccurate.

A September 12, 2012 string of e-mails from the National Marine Fisheries Service[149] obtained through the Freedom of Information Act reveals the conflict between meeting Trinity River Basin Plan temperature objectives and protection of salmonids in the Sacramento River through meeting Shasta storage targets from BDCP. "Combined Scenario 5" (CS-5) is an attempt by the fishery agencies and BDCP proponents to provide adequate Delta outflows while meeting Sacramento River temperature objectives. Unfortunately, as indicated by the e-mail string, changing the timing of Trinity River exports to the Sacramento River causes summer temperature violations on the Trinity River. CS-5 did not resolve the problem and the problem has apparently been ignored by modeling all Trinity operations the same, even though it is highly unlikely that operations will mimic the modeling. Again, the Draft EIS/EIR does not disclose impacts to Shasta and Trinity temperature compliance and reservoir storage requirements.

The BDCP and its EIR/EIS claims that the Applicants are not obligated to show or analyze potential and probable impacts to the Trinity River due to implementation of the project because the modeling utilized assumed incorrectly that there would be no changes in operations of the Trinity River Division of the CVP. However, even under Existing Conditions and No Action Alternatives, as well as all other alternatives, the Trinity River and lower Klamath rivers are at great risk of catastrophic fish kills similar to 2002[150] and 1977[151] from warm water, low flows and crowded conditions for returning adult salmon and steelhead as well as rearing hatchery

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[149] See September 12, 2012 e-mail string between Seth Naman, Michael Tucker, Garwin Yip, Bruce Oppenheim and Ann Garrett, NMFS, accessed at https://www.c-win.org/webfm_send/436

[150] For information on the historic and unprecedented 2002 salmon fish kill in the lower Klamath River, see reports by the US Fish and Wildlife Service, California Department of Fish and Game and the Yurok Tribe respectively at http://www.fws.gov/arcata/fisheries/reports/technical/Klamath_River_Dieoff_Mortality_Report_AFWO_01_03.pdf and http://www.pcffa.org/KlamFishKillFactorsDFGReport.pdf and http://www.yuroktribe.org/departments/fisheries/documents/FINAL2002FISHKILLREPORTYTFP.pdf.

[151] For a description of the loss of 500,000 yearling salmon and 200,000 advanced steelhead fingerlings at the Trinity River Hatchery during the 1977 drought see http://www.c-win.org/webfm_send/406.

juveniles. Things have to change with how the Trinity River is managed; the questions are what is to be done? How will new Trinity River management approaches that address paper water and cold water pool management for the benefit of fish and the Trinity River watershed communities? And finally, how to ensure the Bureau follows the rules?

There is nothing in the BDCP Draft project documentation to assure that the Trinity River and its beneficial uses will be protected for existing or future CVP and SWP operations. To the contrary, BDCP predicts a decline in cold water storage in Trinity Lake due to "*a combination of higher runoff in January and February that cannot be captured due to flood storage limitations, higher releases to meet Fall X2, and lower carryover storage from previous years due to higher releases for Fall X2 in wet and above normal years, and increased system demands by water rights holders, especially in El Dorado, Placer and Sacramento counties*." (DEIS/R, page 5-60) Furthermore, the DEIS/R states that "The frequency of Trinity, Shasta, and Folsom Lakes dropping to dead pool storage would increase by about 10% under the No Action Alternative as compared to Existing Conditions." (DEIS/R, page 5-61) However, despite these risks, BDCP does nothing to mitigate or prevent catastrophic loss of cold water storage and basic flows to keep fish in good condition below Trinity and Lewiston Dams.

Regardless of how the BDCP is modeled, removal of pumping constraints in the Delta will increase the risk to the Trinity and Lower Klamath rivers of losing the cold water stored in Trinity Lake to out of basin export. It is essential to note that Trinity River water provides beneficial uses for Coho and Chinook salmon, as well as steelhead, Pacific Lamprey, green sturgeon and other species important to Tribal, recreational and commercial fishing communities.

The Trinity Record of Decision fishery flows and the 50,000 AF Humboldt County area of origin reservation of water are components of the 1955 Trinity River Division (TRD) federal legislative authorization (PL 84-386) as amended by the 1992 Central Valley Project Improvement Act (PL 102-575, Section 3406(b)(23)).

Trinity River temperature objectives to protect salmon and steelhead have been adopted by the North Coast Regional Water Quality Control Board[152], the State Water Resources Control Board and USEPA[153], but have not been put into water permit requirements for the Bureau of Reclamation. In 1958, the Bureau of Reclamation, pursuant to section 8 of the 1902 Reclamation Act applied to the state for water rights to operate the TRD, but those water rights contain minimum fishery flows of only 120,500 AF. Trinity ROD flows and Humboldt County's 50,000 AF amount to a weighted annual average of 644,000 AF. Modeling for BDCP should include Humboldt County's 50,000 AF, but does not. The complete failure to include variables such as the question of the 50,000 AF due to Humboldt County from original Trinity River contract obligations reveals the absolute inadequacy of the BDCP Draft EIS/R in analyzing potential and probable impacts of the project on the Trinity and Lower Klamath Rivers.

Reclamation has admitted that it does not operate to any specific carryover storage requirement

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[152] "Water Quality Control Plan for the North Coast Region" Footnote 5, Table 3-1, page 3-8.00: Accessed at http://www.waterboards.ca.gov/northcoast/water_issues/programs/basin_plan/083105-bp/04_water_quality_objectives.pdf

Daily Average Not to Exceed	Period	River Reach
60°F	July 1- Sept 15	Lewiston to Douglas City Bridge
56°F	Sept 15-Oct 1	Lewiston to Douglas City Bridge
56°F	Oct 1- Dec 31	Lewiston to North Fork Confluence

[153] See letter from USEPA Region IX Administrator to Chairman of California SWRCB approving Trinity River Basin Plan temperature objectives, March 13, 1992. Accessed at http://www.c-win.org/webfm_send/416

and does not consider water quality objectives[154] contained in the "Water Quality Control Plan for the North Coast Region" (Basin Plan) as water permit terms and conditions.

Reclamation does consider Water Right Order 90-05 (WRO 90-05) to be a permit term and condition. WRO 90-05[155] includes Trinity River North Coast Basin Plan temperature requirements for the September 15- December 31 period but omits the Basin Plan temperature objective for the Trinity River July 1- September 15 period. Additionally, the WRO 90-05 September 15 through December temperature requirement only applies to transfers of Trinity River water to the Sacramento River for temperature control. All other uses of Trinity River water sent to the Sacramento River are not covered by the temperature requirements of WRO 90-05. Reclamation refuses to acknowledge that North Coast Basin Plan requirements are Clean Water Act Section 313 standards that they must comply with because they are not water permit terms and conditions.[156] Thus, comprehensive Trinity River Basin Plan temperature objectives should be included in Reclamation's water permits. Failure to even mention or include analysis of this variable in the BDCP environmental documentation is another serious omission that confirms the inadequacy of the project review in terms of probably and potential impacts on the Trinity River.

The NMFS 2000 Biological Opinion[157] for the Trinity River, is not even mentioned in the BDCP DEIS/ DEIR. It includes a minimum carryover storage on September 30 of 600,000 AF and requires reconsultation if storage falls below that level. However, other analyses have found that a 600,000 AF minimum carryover storage is inadequate. A 2012 report by Reclamation found that September 30 carryover storage requirement of less than 750,000 AF is "*problematic*" in meeting state and federal Trinity River temperature objectives protective of the fishery.[158]

In 1992 Balance Hydrologics found that a minimum carryover storage of 900,000 AF was necessary to meet Basin Plan temperature objectives.[159]

Analyses completed for Trinity County for the Trinity Record of Decision by Kamman Hydrologics indicated that September 30 carryover storage of at least 1.2 million AF on September 30 is necessary at the beginning of a simulated 1928-1934 drought in order to meet Basin Plan temperature objectives.[160] We are now into a third year of drought and Trinity Lake storage is below levels necessary to survive a historic multi-year drought such as 1928-1934. The risk already exists and BDCP does nothing to reduce the risk; in fact it threatens to increase it. Of

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[154] See 2/23/11 letter from Paul Fujitani, Chief of CVP Ops to Brian Person, Chairman Trinity Management Council; accessed at: http://www.c-win.org/webfm_send/141

[155] http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/orders/1990/wro90-05.pdf

[156] Ibid http://www.c-win.org/webfm_send/416

[157] National Marine Fisheries Service (2000), Biological Opinion for the Trinity River Record of Decision, accessed at: http://www.fws.gov/arcata/fisheries/reports/technical/TREIS_BO_NMFS.pdf

[158] See Bender MD (2012) Trinity Reservoir Carryover Storage Cold Water Pool Sensitivity Analysis. Technical Memorandum No. 86-68220-12-06, U.S. Bureau of Reclamation, Technical Service Center, Denver, CO. Accessed at http://odp.trrp.net/Data/Documents/Details.aspx?document=1813

[159] See Balance Hydrologics (6/26/1992) "The Need for Standards for Minimum Carryover Storage in Trinity Reservoir" Accessed at http://tcrcd.net/trl-stor.htm

[160] Memorandum from Greg Kamman to Tom Stokely and Mike Deas on Carryover Storage Analysis Simulated (1928-34) Period, 5/22/1998. Accessed at http://www.c-win.org/webfm_send/414

particular relevance for this comment letter, the failure to analyze this risk or consider this variable in the BDCP Draft EIR/S demonstrates again the inadequacy of the project review.

Furthermore, Reclamation's Mid-Pacific office also produced a preliminary technical memorandum on the problem of excessive heating of Trinity Dam releases[161] when they pass through the shallow 7-mile long Lewiston Reservoir. While Trinity Dam releases are normally 43-44°F, summer heating in Lewiston Reservoir can be severe unless approximately 1,800 cfs is being released from Trinity Dam. Given that Trinity River summer base flows are only 450 cfs, water must be diverted to the Sacramento River to keep the Trinity River cold enough to meet Basin Plan temperature objectives. However, during severe drought or under certain operational circumstances, there may not be adequate water to provide base fishery flows and to divert water to the Sacramento River to keep the Trinity River cold. Several structural solutions have been identified in Reclamation's preliminary technical memorandum; however, a full feasibility study and environmental document would need to be prepared to select a solution and no such plans exist at this time.

Therefore, in order for the Trinity River to be protected, BDCP and its EIR/EIS must at a minimum include a recommendation that the SWRCB convene a Trinity-specific water right hearing as directed in SWRCB Water Quality Order 89-18. [162] The water right hearing shall license Reclamation's eight Trinity River water permits as follows:

- Conformance with the instream fishery flows contained in the Trinity River Record of Decision.

- Provision for release of Humboldt County's 50,000 AF in addition to fishery flows per the 1955 Trinity River Act.

- Inclusion of permit terms and conditions to require Reclamation to comply with the Trinity River temperature objectives contained in the Water Quality Control Plan for the North Coast Region (NCRWQCB) for all relevant time periods and for all uses of Trinity water diverted to the Sacramento River.

- A requirement to maintain an adequate supply of cold water in Trinity Reservoir adequate to preserve and propagate all runs of salmon and steelhead in the Trinity River below Lewiston Dam during multi-year drought similar to 1928-1934.

- Eliminate paper water in Reclamation's Trinity River water rights.

- Require Reclamation to solve the temperature issue in Lewiston Reservoir through a feasibility study and environmental document to follow up on the 2012 preliminary technical memorandum by Reclamation.

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[161] See USBR (2012) Lewiston Temperature Management Intermediate Technical Memorandum, Lewiston Reservoir, Trinity County, California. Report by U. S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA. accessed at http://odp.trrp.net/Data/Documents/Details.aspx?document=1814

[162] See SWRCB Water Quality Order 89-18 (pages 18 and 19) at http://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/1989/wq1989_18.pdf

8. Methyl Mercury

The fishery agencies should disapprove the Bay Delta Conservation Plan and deny issuance of incidental take permits because the Plan lacks sufficient ecological assurances that it will mitigate methylmercury production and bioaccumulation resulting from construction and operation of the proposed Twin Tunnels Project and the construction and management of new habitat restoration associated with BDCP conservation measures 2 through 11.

Conservation Measure 12, *Methylmercury Management*, is ***intended*** to mitigate the potential effects of methylmercury (MeHg) mobilization into bioavailability and bioaccumulation resulting from water and habitat development activities of the Bay Delta Conservation Plan. But CM 12 does not pretend that its provisions represent mitigation.

> 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.***[163]

This means that CM 12 is itself not a mitigation method at all, but a list of adaptive management issues to be handled later. Again, ***the implied message is "trust us" to build the Twin Tunnels project and BDCP will handle this problem later.*** Sulfur, carbon and acid-rich environments are conducive, in the presence of many different kinds of wetland bacteria, to methylation of elemental mercury into MeHg. These research approaches include:

- Characterize soil mercury concentrations and loads on a project-by-project basis.
- Sequester MeHg using low-intensity chemical dosing techniques using metal-based coagulants like ferric sulfide or poly-aluminum chloride. These floculants bind with dissolved organic carbon and MeHg to flocculate and deposit mercury out of solution.
- Minimize microbial methylation activity in restored wetlands.
- Design restored wetland habitat to enhance photodegradation of MeHg.
- Remediate sulfur-rich sediments with iron to prevent the biogeochemical reactions that methylate mercury.
- Cap mercury-laden sediments (essentially entomb and bury them permanently to keep from mobilizing and methylating mercury).

Little is understood by scientists about how methylation of mercury actually occurs chemically, except that they know that bacteria common to wetlands facilitate the process.[164] The single largest increase in food web MeHg bioaccumulation occurs between its aqueous form taken up by algal cells or phytoplankton. Alpers et al (2008, part of the Delta Regional Ecosystem Restoration Implementation Plan, or "DRERIP") report that this concentration increases typically in the range of 10^5 to 10^6. Consumption of algae and phytoplankton by higher trophic levels of the food web are much less bioaccumulative. ***But the huge concentration increase at the bottom of the food web is sufficient to pass on MeHg in concentrations that can be harmful to higher consumers in the food web such as fish and human beings.***[165]

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[163] Bay Delta Conservation Plan, Chapter 3, Section 3.4.12, *Methlmercury Management*, p. 3.4-260, lines 17-21.

[164] Charles N. Alpers, et al, *Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan, Ecosystem Conceptual Model: Mercury*, prepared January 24, 2008, pp. 12-13. Accessible online at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=6413. "The net formation of …(MeHg) in sediment and/or water is the result of competing microbiological and abiotic reactions…"

[165] *Ibid.*, p. 19.

Mercury's toxicity depends on the path by which humans, fish, and wildlife are exposed. Methylmercury is highly toxic and can pose a variety of human health risks, according to the DRERIP conceptual model. It can concentrate as high as 95 percent of the total amount of mercury found in fish muscle tissue, though MeHg in fish can be lower and more variable.[166] Illness from MeHg can take the form of loss of sensation in the hands and feet, and in extreme cases loss of gait coordination, slurred speech, blindness, and mental disturbances. For pregnant women, exposure of the fetus and young children can lead to cerebral palsy and/or mental retardation many months after birth, all effects that indicate MeHg's ability to cross the placenta as well as the blood-brain barrier. It can be excreted in breast milk consumed by babies.[167]

There are numerous factors that affect the ecological mobilization and eventual health effects on fish and wildlife of MeHg, as shown in the DRERIP models. Fish can experience altered hormone expression, reduced spawning success and reduced reproductive output, liver necrosis, and altered predator avoidance behavior. More subtle behavioral effects may occur at lower concentrations of MeHg.[168] The greatest concentrations of MeHg in tissue of fish and wildlife (birds and mammals) are derived through dietary exposure—consumption of lower trophic level species that are contaminated with MeHg.

The DRERIP conceptual model of mercury summarized limitations of the state of MeHg research relating to wetland restoration:

> The major limitation regarding effects for fish and wildlife is the lack of species-specific toxicity information on those organisms most at risk in the San Francisco Bay-Delta Estuary. Current threshold levels are all based on species such as loons or mallards which may have different sensitivities (higher or lower) than birds such as Forster's terns, black-necked stilts, least terns, and clapper rails, which have concentrations that may put them at risk to impairment from mercury….Moreover, to our knowledge, there is currently no information related to mercury concentrations in aquatic mammals in the Delta. Our toxicity assessment indicates that species found in the Delta, such as otters, may be sufficiently sensitive to mercury that there is substantial risk of impairment. Finally, it is clear that *there is currently little if any information on effects of methyl mercury on amphibians and reptiles*, and we are aware of little data on exposure of such taxa to methyl mercury in the Delta or possible effects.[169]

The research "measures" BDCP proposes do not include basic toxicological research into mercury's effects on these and other fish and aquatic species found in the Delta.

The CM 12 measures (since they do not "mitigate" for CEQA or NEPA purposes as part of the project's evaluation) are acknowledged by BDCP to have challenges associated with them, as the EIR/EIS concludes concerning NEPA findings:

> Because of the uncertainties associated with site-specific estimates of methylmercury concentrations and the uncertainties in source modeling and tissue modeling, the effectiveness of methylmercury management proposed under CM12 to reduce methylmercury concentrations would need to be evaluated separately for each restoration effort, as part of design and implementation. Because of this uncertainty

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[166] *Ibid.*, p. 26.

[167] *Ibid.*, pp. 27-28.

[168] *Ibid.*, pp. 29-36. General types of effects on fish and wildlife include DNA alteration, tissue and organ damage, abnormal development, reproductive toxicity and endocrine disruption, behavior problems, immune-system effects, and population-level effects.

[169] *Ibid.*, p. 37. Emphasis added.

> and the known potential for methylmercury creation in the Delta this potential effect of implementing CM2-CM22 is considered adverse.[170]

The idea in CM12 of minimizing microbial methylation activity is especially problematic. The EIR/EIS states that such an approach could defeat the purpose of doing all the habitat restoration BDCP proposes.

> …[T]his approach could limit the benefit of restoration areas by limiting the amount of carbon supplied by these areas to the Delta as a whole. In some cases, this would run directly counter to the goals and objectives of the BDCP. This approach should not be implemented in such a way that it reduces the benefits to the Delta ecosystem provided by restoration areas.

In other words, taking the step of removing from new wetlands habitat the same bacteria that help recycle other nutrients yet cause methylation of mercury would dramatically reduce the productivity of these same newly inundated wetlands to such an extent that it "would run directly counter to the goals and objectives of the BDCP," as the EIR/EIS states. This approach to managing methylation of mercury would destroy the very habitat producing strategy that is intended by BDCP to help restore food supplies and ecosystem productivity to the Delta. But with it comes the likelihood that the legacy contamination of mercury in the Delta from the Gold Rush era could reignite an epidemic of mercury toxicity in Delta ecosystems if not managed extremely carefully.

Other proposed "mitigations" may have potential for addressing MeHg occurrence, but the apportionment of these engineering parameters (tamping down sulfide with iron; relying more on photodegradation of MeHg, and so on, short of capping and entombing MeHg-laden sediments) could boost productivity, but may limit other wetland design parameters. For instance, nonnative invasive clams like *Potamocorbula* thrive in shallower, saltier conditions, and photodegradation could be best achieved in shallow wetland regimes. ***Suffice it to say that methylmercury contamination in the Delta makes habitat restoration success far from assured for the purposes of BDCP, especially given other uncertainties we have identified in our comments.***

BDCP documents provide little insight into the geographic extent and occurrence of sediment-based MeHg. Figure 8-28 of the EIR/EIS provides largemouth bass tissue mercury concentrations at different locations around the Bay. Fish move around, however. This map, however, provides no insight for decision makers as to where sediment in the Delta carry mercury concentrations. Nearly every BDCP conservation measure involves some amount of construction activity and CMs 4 through 7 involve thousands of acres in the Delta slated for habitat restoration construction and inundation. Construction activity could cause mercury concentrations in water to spike as sediments are disturbed. Once disturbed, mercury can become more bioavailable and thereby sharply increase risk of bioaccumulation into Delta food webs and into human fish consumption.

The BDCP EIR/EIS reveals that mercury concentrations in largemouth bass fish tissue already exceed mercury guidance concentrations recommended by the US Environmental Protection Agency. For each alternative evaluated in the EIR/EIS, mercury in fish tissues is likely to rise by 2060 with or without implementation of the Bay Delta Conservation Plan. BDCP's modeling results show that mercury fish tissue concentrations will worsen with BDCP activity in many parts of the Delta by 2060. Central Delta locations are projected to have higher mercury tissue concentrations than do areas where flows are greater and there is more open water, such as near the mouths of the San Joaquin and Sacramento rivers.

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[170] Bay Delta Conservation Plan Environmental Impact Report/Environmental Impact Statement, Chapter 8, *Water Quality*, p. 8-260, lines 30-35; p. 8-446, lines 39-42, and p. 8-447, lines 1-2. Hereafter "BDCP EIR/EIS" or "EIR/EIS."

But in all cases, the existing mercury guidance concentration is exceeded by at least 20 percent to as much as twice the level recommended for fish tissue (Figure 9). And at these locations it appears BDCP activity consistently worsens conditions relative to the No Action Alternative.

Figure 9
Mercury Concentrations in Largemouth Bass (355 mm) Tissue Exceed Toxicity Thresholds by 2060 With and Without the Bay Delta Conservation Plan
All Years and Drought Years

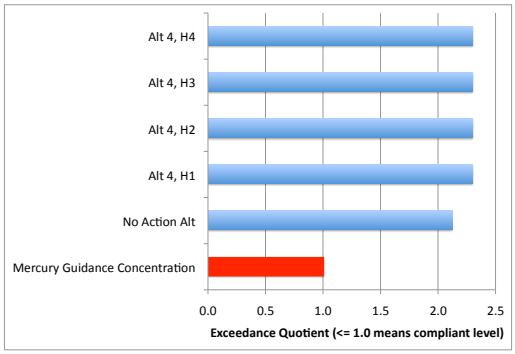
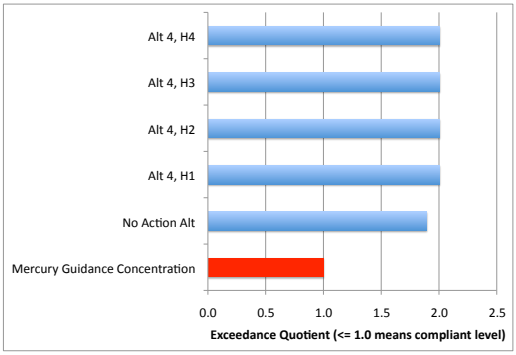
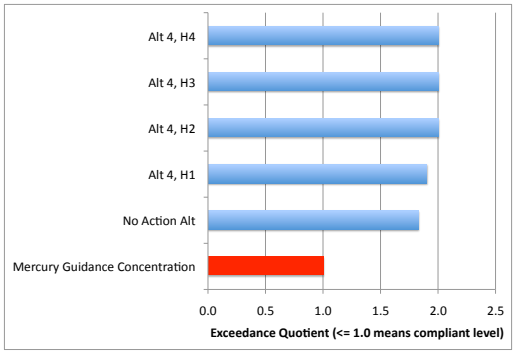
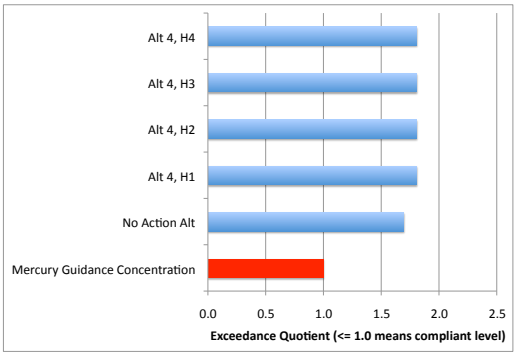
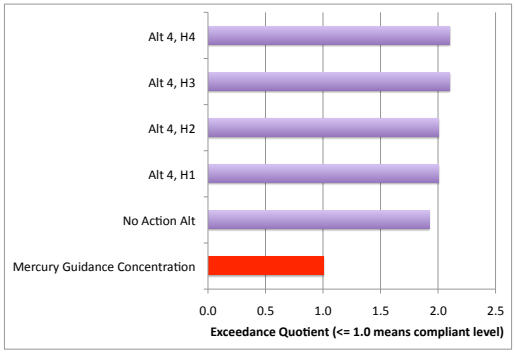
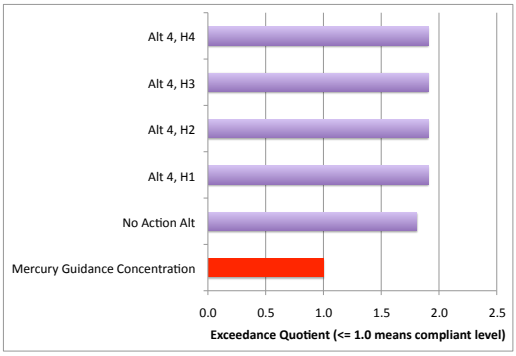
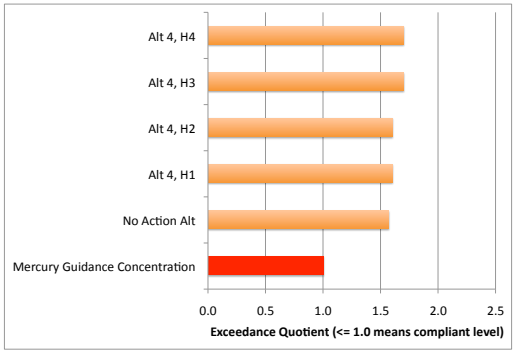
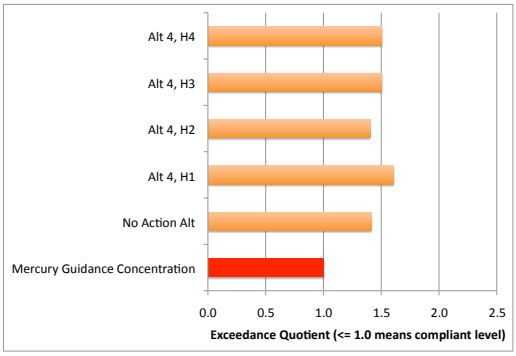
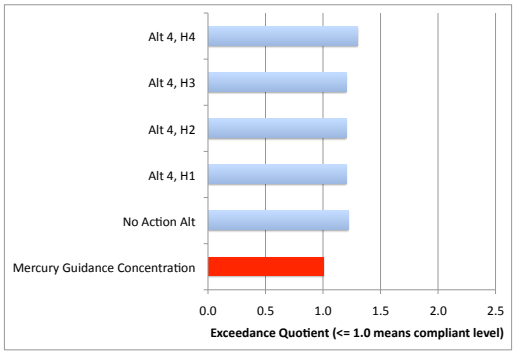
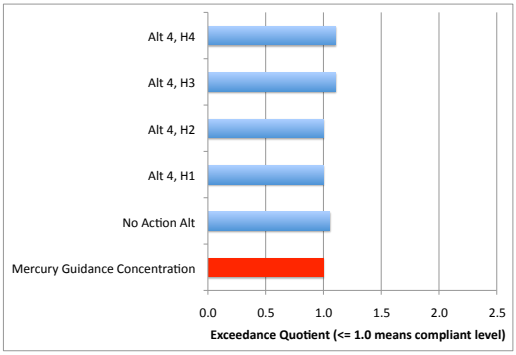
Location	Average of All Years	Average of Drought Years
Mokelumne River (S Fork) at Staten Island		
Franks Tract		
Old River at Rock Slough		

Figure 9
Mercury Concentrations in Largemouth Bass (355 mm) Tissue Exceed Toxicity Thresholds by 2060 With and Without the Bay Delta Conservation Plan
All Years and Drought Years

Location	Average of All Years	Average of Drought Years
San Joaquin River at Antioch		
Sacramento River at Mallard Island		

Notes: "Exceedance Quotient" is the ratio of estimated concentrations of Mercury (mg/kg of wet weight) to the Delta TMDL guidance concentration of 0.24 mg/kg ww of Mercury. In every alternative and existing conditions, "Exceedance Quotients" are greater than zero, meaning that in every case, the guidance concentration recommended by USEPA is violated. All Exceedance Quotients reported here are based on Equation 1 calculations in Appendix 8I of Bay Delta Conservation Plan EIR/EIS. A ratio of 1.0 or less would mean compliance with the mercury guidance concentration.

Source: Bay Delta Conservation Plan, Appendix 8I, *Mercury*, Tables I-7a, I-15Aa, I-11Ba, I-11Ca, I-11Da.

C. No Surprises and Unforeseen Circumstances

If such funding assurances to support permanent selenium sequestration, management and disposal is not forthcoming from the Applicants, the fishery agencies should disapprove the Bay Delta Conservation Plan and deny issuance of incidental take permits because the Plan lacks sufficient ecological assurances that it will not appreciably reduce the likelihood of survival and recovery of listed species covered by the Plan.

Changed circumstances are those events and processes affecting a species or geographic area covered by the BDCP that have been "reasonably anticipated by "the Permittees" and the federal

fishery agencies.[171] Such circumstances are acknowledged within the scope of the Implementing Agreement for BDCP.

Unforeseen circumstances are those events and processes "that could not reasonably have been anticipated by the Permittees" and the fishery agencies at the time of BDCP's negotiation and development, and that "result in a substantial and adverse change in the status of a Covered Species, and in the context of the NCCPA, means changes affecting one or more species, habitat, natural community, or the geographic area covered by a conservation plan that could not have been anticipated at the time of Plan development, and that result in a substantial adverse change in the status of one or more Covered Species."[172]

If unforeseen circumstances arise, states the State's NCCPA law:

> additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources shall not be required without the consent of plan participants for a period of time specified in the implementing agreement, unless [CDFW] determines that the plan is not implemented consistent with substantive terms of the implementing agreement.[173]

Similar language applies in federal regulations implementing the Endangered Species Act.[174] In short, changed circumstances are defined and incorporated in the habitat conservation plan and adaptive management program; unforeseen circumstances are excluded from the plan. Unless the fishery agencies can justify the need for the Applicants to mitigate effects of such circumstances, the BDCP Applicants would be immune to changes in how their BDCP activities could be regulated for the next 50 years—the very definition of "regulatory stability." [175]

The November 2013 Draft Bay Delta Conservation Plan lists the following as the only "changed circumstances" through which modifications to the Plan may be made (that is, these are the foreseeable changed circumstances which may involve modification of the Plan):

- Levee failures
- Flooding
- New species listing
- Drought
- Wildfire
- Toxic or hazardous spills
- Nonnative invasive species or disease
- Climate change beyond certain parameters
- Vandalism[176]

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[171] "The Permittees," according to the Draft July 2013 Implementing Agreement, are "DWR and the SWP/CVP Contractors" according to Section 3.43. Under the Natural Communities Conservation Planning Act, "changed circumstances" are defined as "reasonably foreseeable circumstances that could affect a Covered Species or the Plan Area." *Ibid.*, Section 3.12, p. 7.

[172] *Ibid.*, Section 3.56, p. 12.

[173] California Fish and Game Code Section 2829(f)(2), cited in BDCP, Chapter 6, *Plan Implementation*, p. 6-30, lines 9-13.

[174] 50 CFR Part 17.22(b)(5)(iii).

[175] BDCP refers to application of the No Surprises policy to its actions and activities as "regulatory stability."

[176] *Ibid.*, p. 6-45, lines 23-30.

The Bay Delta Conservation Plan would exclude from defined "changed circumstances" in its scope features of state and federal water project operations in the Delta watershed that are endemic to current impacts in and upstream of the Delta.

In our view, continuing to irrigate western San Joaquin Valley drainage impaired lands under operation of the Twin Tunnels constitutes a foreseeable circumstance under the Endangered Species Act. Yet it is not a "toxic or hazardous spill" as BDCP interprets this circumstance.[177] It is foreseeable, as well, that the Grassland Bypass Project may not result in decreasing concentrations and loads of selenium to downstream water bodies along and including the San Joaquin River, the Delta, and Suisun Bay and Marsh. A lot can happen in 50 years—the duration of the incidental take permits—to cause increased discharge of selenium loads into the San Joaquin River. Unlike methyl mercury contamination which has its own conservation measure, there is no BDCP conservation measure to address potential selenium contamination. BDCP success is premised, in pertinent part, on selenium concentrations decreasing, despite foreseeable scenarios in which local land values could collapse, federal and state budgets contract (not unlike what happened in 2007 through 2010 nationally and throughout California). Political decisions can be made that delete grant or other funding support for experimental reverse osmosis and other treatment technology. Even a new distillation process[178] that has lower energy costs still yields solid residues that must be disposed of —and selenium residues often exceed allowable concentrations, above which they have been classified as hazardous waste.

At a minimum therefore, selenium contamination must be included in Chapter 6's list of "changed circumstances." The potential cost to the BDCP Applicants (which include Westlands Water District and Kern County Water Agency, whose regions include areas where at a minimum selenium treatment and source control are pressing concerns) of maintaining selenium sequestration in the upper San Joaquin Valley must be accounted for and included in the real costs of BDCP.

There is a clear nexus between prospective operation of the Twin Tunnels and therefore the need for continuing long-term selenium management. Assuming that BDCP moves forward to obtain incidental take permits, via the Twin Tunnels it will continue deliveries to drainage impaired lands of the western San Joaquin Valley. It follows that funding assurances provided by the Applicants to the fishery agencies must include diligent, continuous, and full financing for continuation of the Grassland Bypass Project and other selenium treatment activities under way in the western and southern San Joaquin Valley. Funding assurances should also include provision for sequestering, managing and disposing of selenium hazardous waste streams and other naturally occurring contaminants from the western San Joaquin Valley's drainage impaired lands. This will ensure they are properly managed for the long term. ***If irrigation of these impaired lands is perpetuated by some Applicant agencies benefiting from the Twin Tunnels project, the Applicants must pay their fair share of costs of sequestering, managing, and disposing (that is, from cradle to grave) of the hazardous selenium contaminant waste that is generated from irrigating***

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[177] *Ibid.*, 6-39 to 6-40, Section 6.4.2.2.6, *Toxic or Hazardous Spills*. Such spills are defined to occur only in the Plan Area as "resulting from a BDCP action." The scope of remedial actions would be limited to 4,000 acres of reserve system lands, inclusive of restoration sites. This is a very narrow definition that clearly excludes the foreseeable, if undesirable, circumstance of increased selenium loading via the San Joaquin River to the Plan Area. To BDCP this is "unforeseeable." This means that what is unforeseeable, under the NCCPA and Section 10 of the ESA is in the eye of the beholder, independent of socially knowable possibilities.

[178] Kevin Fagan, "Purifying water by using the sun: Solar desalination system appears to be cost-effective," *San Francisco Chronicle* March 18, 2014, p. A1, A9.

western San Joaquin Valley soils contaminated with selenium and other naturally-occurring contaminants.

D. Undue, Improper and Excessive Reliance on Adaptive Management

The Bay Delta Conservation Plan relies to excess on adaptive management to defer water and fishery management decisions and actions until such time that gaps in scientific conceptual models are filled. The standard for action to protect and recover listed species under the federal ESA is not perfected knowledge and fully discovered mechanisms; rather the standard is for the fishery agencies to act based on the "best available scientific knowledge."

The EWC does not see how adaptive management can be accomplished on behalf of listed species in the Bay Delta Estuary with No Surprises rules applied to their protection and recovery. "Regulatory stability" and "adaptive management" mutually contradict each other.

There are numerous areas where unanswered scientific questions about each of the conservation measures are put off into "adaptive management." ***This is not in the least a "conservation strategy" but a thinly veiled attempt to justify a monstrous water project in a location that is crucial to key life stages of several listed fish species and would likely contribute to their extinction. Having such a large "adaptive management" program is hardly a sign of the Bay Delta Conservation Plan's sophistication and virtue. It is a sign of looming disaster unless it is stopped in its tracks.***

Other areas where adaptive management is invoked include:

- Fish screen technology; flow vectors (approach vs. sweeping velocities) and where Delta smelt and salmon smolt vulnerabilities discounted by BDCP (described above).
- Evaluation of Yolo Bypass fisheries enhancement actions under Conservation Measure 2 (also discussed above).
- Conservation Measure 16's non-physical fish barriers
- Predators usage of restored habitats
- Spring outflow importance for longfin smelt
- Fall X2 and outflow importance for Delta smelt
- Methylmercury "management"

Most fundamentally, however, BDCP is an experiment with real-life (or likely "real extinction") consequences. This is evident in the remarks to the Delta Stewardship Council by Carl Wilcox of the California Department of Fish and Wildlife. In his remarks, Wilcox emphasizes how BDCP grapples with uncertainty about how things would work out through plan implementation.

> "The level of assurances are how the conservation plan is structured to allow for implementation," said Mr. Wilcox, "and that's one of the things that we're wrestling with right now is how to structure that so that there's more certainty. To some degree, what you see in the decision tree, relative to the idea of [whether] habitat really works or other stressor conservation measures, can potentially offset the need for outflow and that kind of thing, and that's a key component of it. … The concept there is that *there's more certainty in the effects of flow based on what we know over 40 years as opposed to some of the other aspects, and we're going to have to learn about those through the adaptive management process."*[179]

[179] Maven's Notebook, "The Bay Delta Conservation Plan's regulatory assurances discussed at the Delta Stewardship Council Meeting," March 12, 2014 coverage of the Council's February 27, 2014, meeting. Accessible online 7 April 2014 at http://mavensnotebook.com/2014/03/12/the-bay-delta-conservation-plans-regulatory-assurances-discussed-at-the-delta-stewardship-council-meeting/. Emphasis added.

If we read this quote correctly, Mr. Wilcox informed the Delta Stewardship Council that the scientific enterprise that is BDCP knows more about the effects of flow than is known about the likely effects of habitat restoration in the Plan Area of BDCP.

It is wise public policy to emphasize use of the known over the unknown in public and environmental affairs. BDCP apparently inhabits a world where it quests into the unknown on behalf of a monstrous water project.

The Delta Stewardship Council's Delta Science Program retained an Independent Review Panel to evaluate the Effects Analysis of the Bay Delta Conservation Plan. That panel summarized its critique of uncertainty and adaptive management in BDCP this way:

> The concept of adaptive management is appropriately described and allocated a prominent role in the implementation structure. However, the commonly acknowledged process of adaptive management is easily misunderstood and misapplied, often resulting in a loss of rigor and commitment in application. Because of the extensive uncertainties surrounding the assumptions and predictions of the BDCP, the Panel strongly emphasizes institutionalizing an exceedingly rigorous adaptive management process. This is critical in order to avoid the high risk associated with ecological surprises that will be difficult or impossible to reverse once they have occurred. BDCP must make a commitment to the fundamental process, and specifically the required monitoring and independent science review, not just the concept of adaptive management.[180]
>
> While the adaptive management plan is considerably more developed in the BDCP…, it remains characterized as a silver bullet but without clear articulation about exactly how key assumptions will be vetted or uncertainties resolved to the point that the BDCP goals and objectives are more assured.[181]
>
> Perhaps the largest challenge to achieving the stated goals and objectives of the BDCP is how many of these critical uncertainties can be addressed by adaptive management given the baseline and the required monitoring? For example, some of the key uncertainties identified in the Effects Analysis [citation], often associated with conservation measures 4, 5, 7, and 11, include:
>
> - The ability of the restored habitat to meet the objectives and expected outcomes, including the time it takes to meet the biological objectives….
> - The risk that the restored habitat will be colonized by invasive species such as nonnative submerged vegetation, nonnative predatory fish, and/or clams. (Hardly uncertain, but controllable?)
> - The change in magnitude of predation mortality on covered fish. (Doesn't this require an existing reliable estimate[] of predation mortality?)
> - Food web responses to habitat restoration actions on both a local and a regional scale.
> - The Risk of adverse effects resulting from unsuitable changes in water quality and exposure to toxic contaminants. (How much can be modeled?)
> - The proportion of the covered species population that actively inhabit restored habitats and the change in growth rate, survival abundance, life-history strategies, and population dynamics. (A very difficult baseline to quantify!)[182]

The fishery agencies are asked to issue incidental take permits that would grant a *carte blanche* to BDCP and the Twin Tunnels project to experiment on a patient (the Bay-Delta Estuary) which is at present on life support, already hammered by waivers of water quality objectives to boost exports

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[180] Delta Science Program, Independent Review Panel, *op. cit.*, note 27 above, p. 9.

[181] *Ibid.*, p. 41.

[182] *Ibid.*, p. 43.

to San Joaquin Valley growers under the guise of protecting "health and safety" during the current drought.

The BDCP Implementing Agreement will be crucial to determining how the BDCP is translated into concrete actions. It is part of the package of documents that comprise the full application for incidental take permits to the fishery agencies. The Agreement is supposed to identify how conflicts between the Applicants and the fishery agencies will be resolved for the 50-year term of the permits. Mr. Wilcox also informed the Council:

> "There are meet and confer provisions within the implementing agreement and allowed for under the Act to remedy this situation short of pulling the permit," said Mr. Wilcox, "and mechanisms, particularly through the adaptive management process, to look at how effective any particular conservation measure may be within the context of the plan and whether or not resources that are associated with that one may be better put towards achieving other objectives."
>
> "I don't know that there's a clear answer," he said. "It's a relatively dynamic process short of just being totally out of compliance and having to reassess the situation in moving forward. Keep in mind that in the context of NCCPA, this is a conservation plan – it's not a mitigation plan so at some point, you may revert to standard permitting processes if all else fails."[183]

We quote Mr. Wilcox at some length here, because he was not very clear in his presentation. A lack of clarity in thinking and speaking signals to those listening that the speaker is himself not very clear on what is at stake with implementing BDCP. What, for example, will be the role in adaptive management in determining whether permits should be revoked or not? What will be the role of adaptive management, if any, for determining whether the biological goals and objectives of BDCP need to be changed, and if so how does the Implementing Agreement handle that? We anticipate taking up these questions in our supplemental comments on the Implementing Agreement in late July 2014.

The complexity of BDCP quickly spirals once one starts to ask such questions. Whatever happened to the "KISS" principle, "keep it simple, stupid"?

The National Research Council's committee on Sustainable Water and Environmental Management of the Bay Delta Estuary suggested using a technique to determine whether adaptive management is an appropriate strategy before it is undertaken. The technique probes three direct criteria:

- the existence of information gaps
- good prospects for learning at an appropriate time scale compared to management decisions, and
- the presence of opportunities for adjustment.[184]

In the case of BDCP, the NRC committee concluded that adaptive management is appropriate for use in BDCP, but further concluded that "BDCP needs to address...difficult problems and integrate

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[183] Maven's Notebook, "The Bay Delta Conservation Plan's regulatory assurances discussed at the Delta Stewardship Council meeting," March 12, 2014. Accessible online at http://mavensnotebook.com/2014/03/12/the-bay-delta-conservation-plans-regulatory-assurances-discussed-at-the-delta-stewardship-council-meeting/.

[184] National Research Council, Panel to Review California's Bay Delta Conservation Plan, *A Review of the Use of Science and Adaptive Management in California's Draft Bay Delta Conservation Plan,* Washington, DC: National Academies Press, 2011 p. 39. Accessible online 7 April 2014 at http://www.nap.edu/catalog.php?record_id=13148. Emphasis added.

conservation measures into the adaptive management strategy ***before there can be confidence in the adaptive management program***." The NRC committee also stressed that it is critical that the results of adaptive management efforts have a mechanism by which the information is incorporated into management decision making.

Alas, there are no guarantees that scientific findings can successfully and meaningfully inform intensely political water decisions by mostly bureaucratic water managers. We are concerned the scientists place too much faith in the water and environmental managers who will govern the Twin Tunnels and implement BDCP. There is no reason, after 40,000 pages of BDCP, to think that the Twin Tunnels will be operated with any more environmental sensitivity than the existing Delta export pumping plants are today when it comes to the public trust values of the Delta, the recovery of listed species, the senior water right holders, and the rate payers of state and federal water contractors on the receiving end of water exported from the Delta by the state and federal water projects, be they farmers or suburbanites.

The alternative is to regulate the Delta on the basis of ***the precautionary principle***: First, do no harm. If you aren't sure what you're doing, you should proceed slowly and carefully, or perhaps not at all. Better safe than sorry.[185] If you must, export water from the Delta responsibly, not profligately.[186]

Please also see Section V.B of these comments for additional comments on the relationship of adaptive management to BDCP's governance structure.

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[185] Peter Montague, "The Uses of Scientific Uncertainty," *Rachel's Environment and Health Weekly* #657, July 1, 1999.

[186] See Environmental Water Caucus, *Responsible Exports Plan*, 2013. Accessible online 14 May 2014 at http://ewccalifornia.org/reports/responsibleexportsplanmay2013.pdf.

IV. BDCP fails to provide adequate funding assurances.

The Bay Delta Conservation Plan's economic analysis[187] is inadequate to the purpose of providing funding assurances needed to meet the required statutory findings by which the fishery agencies may issue incidental take permits.[188]

The purpose of the Bay Delta Conservation Plan's economic analysis is to demonstrate the Twin Tunnels' financial feasibility for the Applicants (DWR, the Bureau, and the state and federal water contractors, who are the primary source of the Tunnels' investment capital). Such an analysis is required under the federal and state Endangered Species Acts to demonstrate funding assurances required to implement the habitat conservation plan.

BDCP's economic analysis should not be construed as adequate economic and financial justification for the people of California to support the proposed BDCP facilities. BDCP's economic analysis is also aimed to persuade water contractors to commit to funding and receiving water from the proposed Twin Tunnels project.

Such a separate and distinct evaluation differs from whether the facilities are a good enough investment for the people of California given the ecological condition of the Delta and concerns about the long-term sustainability of north state groundwater resources. Such an evaluation demands a public trust balancing, including use of Benefit-Cost Analysis, discussed earlier in these comments.[189]

Congress requires the federal fishery agencies to adhere to a policy of "No Surprises." The fishery agencies are to impose no new mitigation requirements (such as additional money, land, or water) on applicants once an incidental take permit is issued without consent of the BDCP Applicants. The fishery agencies are also authorized under the Endangered Species Act and through statutory criteria of issuance for incidental take permits, to seek and receive assurances of funding from those same applicants that will cover "unforeseen circumstances" and to weigh benefits and costs of alternative courses of action, to ensure that the BDCP will be implemented as agreed.[190]

The BDCP economic analysis focuses exclusively on the benefits and costs that would be experienced by the state and federal water contractors. This assessment is presumed to provide sufficient financial assurances to the fishery agencies.

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[187] The BDCP economic analysis is defined here as those portions of Chapter 8, Chapter 9, and Appendices 9.A and 9.B that address costs, benefits, net benefits, affordability, price and income elasticity of demand for water, and comparison of water supply alternatives.

[188] The federal ESA's incidental take permit process in Section 10 for requiring financial assurances is neither designed nor intended to address *all* concerns that may be associated with a project of such massive scope and complexity as the Twin Tunnels project. The criteria of assurances and practicability mandated for habitat conservation plan (HCP) review under the federal Endangered Species Act are not sufficiently broad to accommodate all of the economic issues raised by the Twin Tunnels project and BDCP.

[189] See ECONorthwest, *Bay-Delta Water: Economics of Choice*, Eugene, OR, January 11, 2013, 34 pages. Accessible online 8 June 2014 at http://www.c-win.org/webfm_send/282.

[190] See footnote 9, above.

Funding Assurances

The most credible assurances of funding from the state and federal water contractors result from an economic benefits analysis...and two primary conclusions of the analysis.

- The costs of CM1 [the Twin Tunnels facilities] and associated mitigation are *affordable* by the ratepayers of the urban and agricultural agencies receiving federal and state water supplies delivered through the Delta.

- *The benefits* of the preferred project to these ratepayers *will exceed the total costs* of CM1 and associated mitigation. Thus, the relevant water contractors have an underlying economic incentive to implement CM1.[191]

Chapter 8 of BDCP asserts that assurances of funding from the state and federal water contractors are anchored in the "direct economic benefits of the BDCP to their customers." Contractors' support for BDCP is "essential" to implementing the plan. Summing up the importance of economic analysis in BDCP's case, Chapter 8 states:

> There is no inducement for water purveyors to participate if costs of the Plan exceed costs without BDCP. *The best assurance of contractor funding for the BDCP proposed action is if there is a business case to be made for it; that is, if the economic benefits of the BDCP are well in excess of the present value of the costs that are assumed to be assigned to the contractors.*[192]

Actually, showing a net positive benefit for BDCP is not the sole criterion by which funding assurances can be meaningfully demonstrated to the fishery agencies. Other key criteria go into making a sound business case for a large infrastructure project. The Environmental Water Caucus identifies four other aspects to making a sound business case that are ignored or poorly handled in BDCP's economic analysis:

- Are assumptions reasonable?
- Are there less costly alternatives to increase water supply reliability?
- Is the project affordable to potential water contractors and customers?
- Who would "step up" to bail out the project if anticipated financial commitments fail?

BDCP Chapter 8 summarizes the implementation costs and sources of funding for the entire conservation strategy.[193] In that chapter, Tables 8-33 through 8-36 present undiscounted and discounted capital and operating/maintenance costs for the entire conservation strategy (i.e., all 22 conservation measures). Table 8-37 shows the costs that the state and federal water contractors appear willing to bear in support of BDCP.[194]

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[191] BDCP, Chapter 8, p. 8-98. Emphasis added.

[192] *Ibid*., p. 8-102. Emphasis added. Footnote 69 on this page adds, "Other economic costs and benefits beyond those evaluated to date are being assessed by DWR and are expected to be released prior to completion of the BDCP."

[193] "Conservation strategy" refers to all of the Conservation Measures 1 through 22 that are described in Chapter 3 of BDCP.

[194] Bay Delta Conservation Plan, Chapter 8, *Implementation Costs and Funding Sources*, Table 8-37, pp. 8-65 and 8-66.

Ninety-five percent of the water contractors' investment in BDCP is to support the construction and operation of the water facilities described in BDCP's Conservation Measure 1.[195]

Compared with the entire BDCP conservation strategy (including 20 additional conservation measures), the contractors' funding assurances account for 68 percent of all BDCP costs disclosed to date.[196] The state and federal governments supposedly pay for none of the water facilities and operation costs, according to Chapter 8 of BDCP. Their contributions are confined to use of existing funding programs for various aspects of research and restoration. Two new, undrafted and unapproved water bonds are proposed to account for another 15.2 percent of BDCP funding sources, primarily for restoration. These imaginary bonds would account for $3.7 billion of the state's proposed contribution of $4.1 billion to BDCP restoration activities. Federal agencies would contribute another $3.5 billion to these activities.

The BDCP economic analysis assesses the relative benefits of the BDCP proposed action and other take alternatives relative to a pair of existing flow scenarios for the Delta without BDCP. It also provides the contractors with a sensitivity analysis, based on the outcomes of the two "Decision Tree" processes. The "Decision Tree" processes bracket this sensitivity analysis and will determine whether greater outflows benefiting listed fish species will occur in the spring and in the fall.[197]

The BDCP evaluates a total of nine alternatives (including the Applicants' preferred alternative) by comparing direct benefits and costs to the contractors. The direct benefits measured in the study are water supply reliability, water quality, and seismic risk reduction. Costs are estimated only for the capital and operating components of the Twin Tunnels and other water facilities in Conservation Measures 1 and 2. Interest payments on bonds and a contingency factor for cost-overruns are omitted.

A. Unreasonable Baseline Assumptions

There is great instability and uncertainty in the future of water exports from the Delta. Taking account of the range of reasonably foreseeable future of Delta exports shows dramatic effects on the Twin Tunnels' incremental water cost and financial performance. This instability fatally undermines BDCP's capacity to provide credible funding assurances.

In Table 9.A-2 of Appendix 9.A in BDCP (which is taken directly from BDCP), total estimated costs are subtracted from total estimated benefits to arrive at a net benefits estimate for each alternative or scenario. Of the alternatives, the BDCP economic analysis finds that only Alternatives D and E would have negative net benefits (net costs) to the water contractors, due mainly to restricted Tunnels conveyance capacity or restrictive operating rules.

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[195] CM 2 facilities for Yolo Bypass Fisheries Enhancement are just 4.7 percent of combined costs of Conservation Measures 1 and 2. These facilities include: Clifton Court Forebay, Banks Pumping Plant, Skinner Fish Protective Facility, Barker Slough Pumping Plant, North Bay Aqueduct, New State Water Project diversions at the North Delta Intakes (including fish screens), the Twin Tunnels and related conveyance facilities (pumps, surge towers, forebays, afterbays, etc.), and temporary barriers in the Delta. See also Bay Delta Conservation Plan, Chapter 4, *Covered Actions,* Section 4.2.

[196] Bay Delta Conservation Plan, Chapter 8, *Implementation Costs and Funding Sources*, Table 8-37, pp. 8-65 and 8-66.

[197] BDCP calls for two separate outflow decisions in the Decision Tree process, but the economic analysis evaluates only the two outcomes where BDCP either completely "wins" or "loses" because this approach brackets all possible outcomes of the process. "Winning" would result in lower Delta outflow results with higher exports. "Losing" would result in higher Delta outflows and lower exports. Winning one and losing another flow decision is likely between these two poles of the range of outcomes.

Figure 10

Table 9.A-2. Summary of State and Federal Water Contractor Economic Benefits and Costs ($ millions)

Alternative or Scenario Description			Total Benefits and Costs[a, b]		
Alternative or Scenario	Facility Size (cfs)	Average Annual Water Deliveries (MAF)	Total Benefits[c]	Total Costs[d]	Net Benefits
BDCP Proposed Action High-Outflow Scenario	9,000	4.705	$18,011	$13,472	$4,540
BDCP Proposed Action Low-Outflow Scenario[e]	9,000	5.591	$18,826	$13,487	$5,339
A: W Canal 15,000 cfs	15,000	5.009	$23,187	$11,110	$12,076
B: Tunnels 6,000 cfs	6,000	4.487	$14,445	$12,347	$2,098
C: Tunnels 15,000 cfs	15,000	5.009	$23,187	$15,641	$7,545
D: Tunnels: 3,000 cfs	3,000	4.188	$8,923	$10,240	-$1,317
E: Isolated 15,000 cfs	15,000	3.399	-$8,697	$15,711	-$24,407
F: Through Delta	N/A	4.172	$12,060	$5,233	$6,826
G: Less Tidal Restoration	9,000	4.705	$18,011	$13,432	$4,579
H: More Restoration	9,000	4.705	$18,011	$13,505	$4,506
I: Fixed Spring Outflow	9,000	4.338	$13,417	$13,472	-$55
Existing Conveyance High-Outflow Scenario	N/A	3.446			
Existing Conveyance Low-Outflow Scenario	N/A	3.889			

Notes:
[a] Construction is assumed to begin in 2015. BDCP operations are assumed to begin in 2025.
[b] All values are in 2012 $ (millions), and are discounted to present value using 3% real discount rate.
[c] Benefits are calculated out to year 2075.
[d] Costs are calculated out to year 2075.
[e] Benefits for the BDCP Proposed Action Low-Outflow Scenario are calculated relative to the Existing Conveyance Low-Outflow Scenario, which assumes Scenario 6 operations, no Fall X2, no north Delta diversions.
cfs = cubic feet per second; MAF = million acre-feet

The BDCP economic analysis compares the nine alternatives (identified in Chapter 9) to the BDCP Proposed Action High Outflow Scenario as well as to an "Existing Conditions High Outflow Scenario." The "Existing Conditions" scenarios argue that the Twin Tunnels' benefits lie in supposedly preserving existing export levels. Principal author Professor David Sunding likens this benefit to a homeowner investing in his or her home's foundation to shore up its overall seismic

strength. It may generate no additional usable space of value, but is intended to protect the home's investment value against earthquake damage for the long term.[198]

BDCP Director Jerry Meral also stated to the Water Association of Kern County on July 23, 2013, that "Protecting our 5.5 million acre-feet of exports has got to be our number one priority."[199] His statement indicates that, in the absence of additional storage to create new yield (another issue unto itself), the Twin Tunnels yields very little, if any, "new" water over existing Delta exports. Thus, the cost of *incremental water preserved* is the "baseline" against which the Twin Tunnels' cost is measured in the BDCP economic analysis.

The labeling in Table 9.A-2 of the preservation scenarios as "existing" for future of Delta exports without Twin Tunnels does not match recent experience with Delta export pumping, and misleads readers. Since Water Rights Decision 1641 took effect in 2000 and the biological opinions by NMFS and US Fish and Wildlife Service took effect in 2009, annual south-of-Delta exports have averaged 5.4 million acre-feet. What is going on with the Twin Tunnels' "existing scenarios"?

Unlike Professor Sunding's analogy to replacing the foundation of a house, BDCP's economic analysis describes another rationale for assuming that the future of Delta exports without the Twin Tunnels will be much lower than in the recent past.[200]

A reasonable translation of this explanation is that in the next few years, and in the event that the Twin Tunnels project is not permitted, built and operated, BDCP assumes the fishery agencies and the State Water Resources Control Board will take concrete steps to reduce exports to protect public trust resources in the estuary and shore up recovery of listed species in the Delta watershed. The proponents of BDCP are essentially positing a bet against their ability to prevent estuarine protection flows in order to provide a large increment of "preserved" export levels that could help justify the Twin Tunnels project.

This "bet" is highly speculative. In the event there is no Twin Tunnels project, it is equally, if not more, plausible that in the long-term a "without Twin Tunnels" future entails continuation of export restrictions contained in the Delta smelt and salmonid biological opinions from the US Fish and Wildlife Service and the National Marine Fisheries Service. According to the State Water Resources Control Board, these biological opinions establish export limitations that would keep the long-term average south-of-Delta exports to about 5.1 million acre-feet annually.[201] The BDCP environmental impact report/statement (EIR/S) states that the average annual water cost to Delta exports of the 2009 biological opinions is about 703,000 acre-feet.[202] Subtracting this increment from the Dayflow average south of Delta exports since 2000 yields a biological opinion range of Delta exports of 4.66 to 5.1 million acre-feet for a "without Twin Tunnels" scenario.

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[198] Maven's Notebook, "Dr. Sunding makes his case for the BDCP to Metropolitan's Special Committee on the Bay-Delta," accessed online July 29, 2013, at http://mavensnotebook.com/2013/07/29/dr-sunding-makes-his-case-for-the-bdcp-to-metropolitans-special-committee-on-the-bay-delta/.

[199] Video of Meral's remarks to the Water Association of Kern County on July 23, 2013, were accessible online at http://baydeltaconservationplan.com/News/News/13-07-31/Natural_Resources_Deputy_Secretary_Provides_Update_on_BDCP_to_Water_Association_of_Kern_County.aspx.

[200] *BDCP*, *op. cit.*, Appendix 9.A, p. 9.A-1, lines 35-40, and p. 9.A-2, lines 1-9.

[201] State Water Resources Control Board, *Comments on the Second Administrative Draft Environmental Impact Report/Environmental Impact Statement for the Bay Delta Conservation Plan*, July 5, 2013, Attachment 2.

[202] Admin Draft *BDCP Environmental Impact Report/Statement,* 2013, Chapter 5, p. 5-52.

What is the most realistic amount of exports that will be preserved in order to measure its value appropriately? Answering this question depends on what future actions will be taken about the Delta's health by the fishery agencies and the State Water Resources Control Board without the Twin Tunnels project in place.[203] This results in tremendous uncertainty about benefits and financial strength of BDCP. It also means great instability in the net benefits to be expected for Applicants and their agricultural and urban customers. ***This instability is fatal to the confidence assignable to BDCP funding assurances.***

Moreover, we suspect BDCP officials foment confusion about Twin Tunnels export activity. As we describe below in Section VII, actual usage of the Tunnels for cross-Delta water transfer market activity would likely increase exports in drier and drought years. The market for cross-Delta transfers doesn't materialize unless contractual allocations go below 50 percent of Table A amounts for State Water Project contractors and 40 percent of contract amounts for CVP contractors. BDCP claims they did not model water transfer behavior, so it appears to us the Delivery volumes in Figure 10 could be understated because water market transfer activity using Twin Tunnels capacity is omitted. They appear to be talking strictly about contractual deliveries.

B. BDCP's Costs Are Higher Than Alternative and More Reliable Supplies

Compared to other sources of potential new water supply in California, the Twin Tunnels project ranges from the high end of these alternative sources to being infeasible altogether, depending on financing assumptions used in the BDCP analysis.

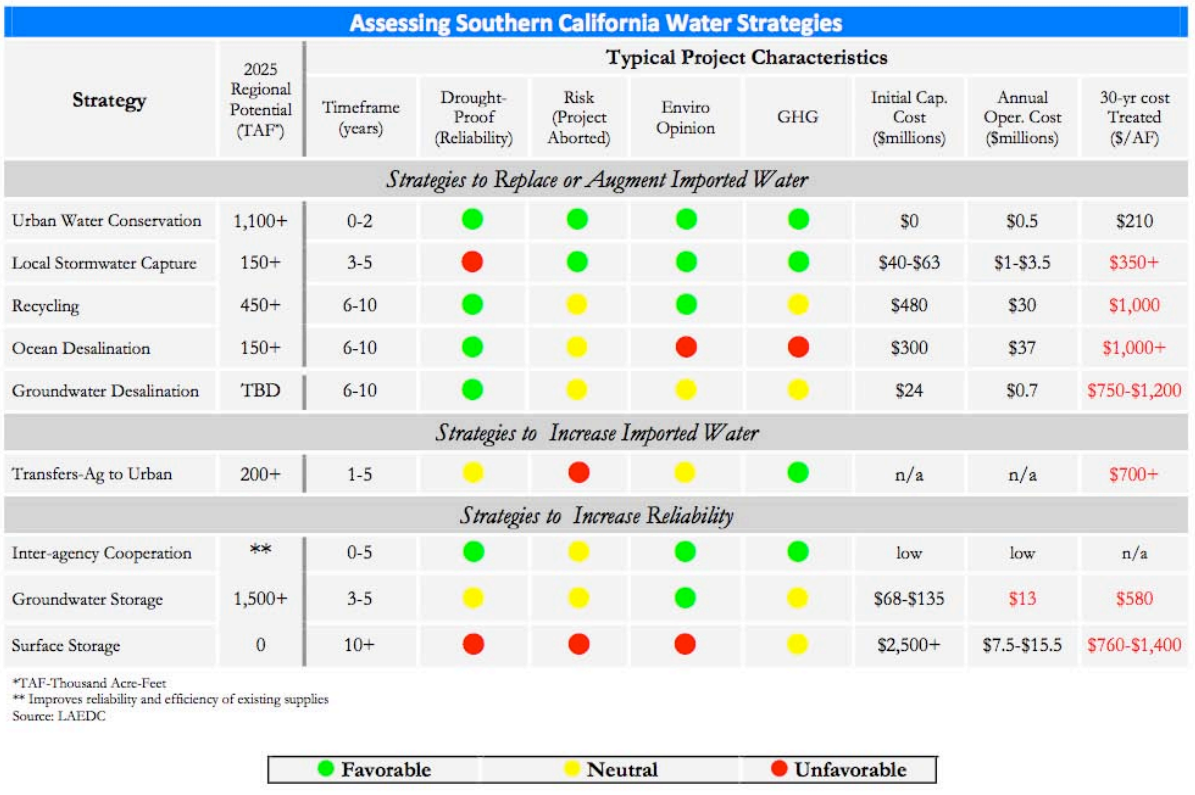
To understand whether BDCP's proposed action is a good investment, its cost must be compared with those of other potential sources of water supply. Such alternatives include the take alternatives in the BDCP economic analysis, as well as alternative forms of supply such as recycling, desalination, storm water recovery, improvement of existing Delta levees, and such. In order to compare apples to apples, incremental cost estimates for each alternative are needed to make such a comparison possible.

EWC's analysis in **Attachment 2** to this comment letter also shows that several moderate and low-export Twin Tunnels project scenarios become infeasible if lower and very plausible estimates of "preserved" export levels are used. If the existing modeled water cost of the biological opinions is subtracted from average south-of-Delta exports the last 15 years or so, the future without Twin Tunnels' exports could average about 4.66 million acre-feet. This "preserves" about 45,000 acre-feet worth of exports. ***At that reduced level of "supply preservation" the incremental cost of Twin Tunnels water skyrockets from $723 to over $20,200 per acre-foot.*** Other scenarios fail to preserve exports and become infeasible as a result (that is, they have negative incremental costs). In **Table A2-1 in Attachment 2**, the low outflow (that is, high average exports of 5.591 million acre-feet per year) without-Twin-Tunnels scenario would have an annualized cost per acre-foot of about $979. This is nearly twice the per unit cost of water from the Twin Tunnels project using BDCP assumptions for future exports.

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[203] Rodney T. Smith, *Hydrowonk Blog*, posted October 9, 2013. Dr. Smith's serial examination of BDCP economics, yield, and finances are essential reading for those interested in these BDCP issues, whether one agrees or not. His blog posts on BDCP commenced July 30, 2013 and continued through October 9, 2013. Regarding these baseline water supply issues, Dr. Smith observed, "None argue that the no tunnel scenario would yield less water than projected by DWR. All argue that there will be significantly more water than projected by DWR. If this proves the case, the annual cost of BDCP water will easily exceed $1,000/AF (inflation adjusted)." Accessible online 11 April 2014 at http://hydrowonk.com/blog/2013/10/09/hydrowonks-take-on-the-bdcp/.

Figure 11



Assessing Southern California Water Strategies

Strategy	2025 Regional Potential (TAF*)	Typical Project Characteristics							
		Timeframe (years)	Drought-Proof (Reliability)	Risk (Project Aborted)	Enviro Opinion	GHG	Initial Cap. Cost ($millions)	Annual Oper. Cost ($millions)	30-yr cost Treated ($/AF)
Strategies to Replace or Augment Imported Water									
Urban Water Conservation	1,100+	0-2	●	●	●	●	$0	$0.5	$210
Local Stormwater Capture	150+	3-5	●	●	●	●	$40-$63	$1-$3.5	$350+
Recycling	450+	6-10	●	●	●	●	$480	$30	$1,000
Ocean Desalination	150+	6-10	●	●	●	●	$300	$37	$1,000+
Groundwater Desalination	TBD	6-10	●	●	●	●	$24	$0.7	$750-$1,200
Strategies to Increase Imported Water									
Transfers-Ag to Urban	200+	1-5	●	●	●	●	n/a	n/a	$700+
Strategies to Increase Reliability									
Inter-agency Cooperation	**	0-5	●	●	●	●	low	low	n/a
Groundwater Storage	1,500+	3-5	●	●	●	●	$68-$135	$13	$580
Surface Storage	0	10+	●	●	●	●	$2,500+	$7.5-$15.5	$760-$1,400

*TAF-Thousand Acre-Feet
** Improves reliability and efficiency of existing supplies
Source: LAEDC

● Favorable ● Neutral ● Unfavorable

LAEDC Consulting Practice

How do these incremental water costs of the proposed Twin Tunnels project fit in with the cost of other alternative sources of water for California? Figure 11 draws on cost data from recycling and desalination projects in southern California summarized by the Los Angeles Economic Development Corporation (LACEDC).[204] Recycling project costs range between $210 for urban water conservation supplies to $1400 per acre-foot for new surface storage supplies. Twin Tunnels water would fall within this range ($530 to $715 per acre-foot) if BDCP assumptions about future Delta exports are to be believed.

But if future Delta exports without the Twin Tunnels were to follow the status quo, the range of "status quo" Delta exports yields an annualized water cost of $970 to $20,000 per acre-foot for the

[204] Los Angeles County Economic Development Corporation, *Where Will We Get the Water? Assessing Southern California's Future Water Strategies*, 2008. Accessible online 13 August 2013 at http://laedc.org/reports/WhereWillWeGettheWater.pdf.

Twin Tunnels project. This would move Twin Tunnels' relative affordability to the high end of the range of new water supplies, and even well beyond.

C. BDCP's Affordability Analysis Fails to Support Financial Assurances

The BDCP analysis of water affordability from the Twin Tunnels project is deeply flawed and fails to support the demand-side basis of financial assurances needed to make statutory findings for issuance of incidental take permits. The fishery agencies should reject BDCP incidental take application for lack of adequate funding assurances.

The questions "who pays?" and "how affordable is Twin Tunnels water?" are inadequately addressed by the BDCP economic analysis. The poor quality of the analysis undermines the credibility of BDCP's claims for offering adequate funding assurances to the fishery agencies.

Currently, agricultural water contractors pay anywhere from $7 to $112 an acre-foot in the Central Valley Project, according to Bureau cost allocation and repayment data online.[205] The average equivalent unit cost of State Water Project water to San Joaquin Valley water contractors (most of whom are agricultural) is about $52 an acre-foot in 2012. ***The new water from the Twin Tunnels project is on its own terms a very expensive water supply for growers in San Joaquin Valley agricultural water and irrigation districts.***

Many aspects of the financing and governance plans for the Bay Delta Conservation Plan are still in discussion behind the scenes.

The exorbitant cost of the Twin Tunnels in the Bay Delta Conservation Plan must be part of the fishery agencies' analysis of whether BDCP meets the funding assurance criterion of issuance. At this stage, the precise mechanisms by which the Twin Tunnels will be financed are unclear.[206] Chapter 8 states that the state and federal water contractors will be the sole funders of all water facilities and operations (Conservation Measures 1 and 2).[207] For what ensues here, the analysis assumes that the SWP Applicants issue revenue bonds to raise their share of needed capital. Chapter 8 notes too that while the Twin Tunnels project could be financed with general obligation bonds (which relies on the full faith and credit of all taxpayers in a jurisdiction, or statewide, if issued by the state of California) or revenue bonds, the latter are believed to be the more likely form of financing employed to raise capital for constructing the facilities for Conservation Measures 1 and 2 of BDCP. Because they are backed solely by revenues from use of the facilities, they carry a higher interest rate compared with general obligation bonds (which would be backed by the full faith and credit of the State of California). This results in higher aggregate interest costs for the Twin Tunnels investment.

BDCP Chapter 8 asserts the affordability of the Twin Tunnels project to the ratepayers of the urban and agricultural agencies without demonstrating it:

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[205] US Bureau of Reclamation Rate Books, 2013 Schedule A-1. Accessible online 17 July 2013 at http://www.usbr.gov/mp/cvpwaterrates/ratebooks/index.html.

[206] San Diego County Water Authority General Manager Maureen Stapleton wrote to BDCP director Gerald Meral in August 2012 that the project "is anticipated to be financed through project revenues," meaning revenue bonds. Letter of Maureen Stapleton, General Manager, San Diego County Water Authority, to Gerald Meral, Deputy Secretary California Natural Resources Agency, August 28, 2012, p. 3. Letter attached to this memorandum.

[207] BDCP, Chapter 8, Table 8-41, "Summary of Estimated Funding by Entity, Sources, and Plan Component," p. 8-74.

- Total personal income of all counties integrated into the state and federal water systems comes to $1.1 trillion and BDCP annual costs to ratepayers represents about 1/1000th of this total personal income. This, claims Chapter 8, is "far below the cost thresholds typically used for evaluating ability to pay."[208]

- Per capita costs for BDCP water conveyance facilities compare favorably with those of other large-scale water projects in California, at $580 per person (assuming a benefiting population of 25 million).[209]

These rationales are weak at best.

Concerning the first point, total personal income is an aggregated measure of income. It does not take account of the distribution of income amongst the households in a region or jurisdiction, and it fails to take account of the costs those households already face for other goods and services they purchase in the local and regional economy. Using such a rule of thumb of BDCP financing costs (i.e., "1/1000th of total personal income") is woefully inadequate measure of affordability when it comes to a project the scale of the Twin Tunnels and BDCP.

Water affordability analysis must identify and justify criteria for a reasonable cost of a particular good, such as water, and a reasonable portion of a family or household budget in which the cost of water would be thereby recognized as "affordable." (This approach is typically employed in housing affordability analysis.) Chapter 8 analysis provides no such rationale, and does not offer any reasoned analysis as to why "1/1000th of total personal income" represents a reasonable criterion. A proper economic analysis of affordability would identify what people pay now for water in these same counties, evaluate it in relation to their disposable income, and evaluate how a change in the price might affect their demand for water consumption. No such analysis is provided by the Applicants in the BDCP economic analysis.

Household income affects water consumption. Increasing income is often correlated with rising demand for water usage:

> The *intuition* for this relation is that wealthier individuals have a less restrictive budget, which allows them to use water more intensively in each of its uses, and water can be used within the household in new ways [such as installing lawn sprinklers]. As incomes grow, *holding other factors constant*, household water consumption will likely increase.[210]

This idea is the *income elasticity of demand* for water. It is a positive expression: the more wealth one has, the more water one is likely to use. It is also true that if the price of water rises, people usually respond by consuming *less* water, regardless of their income. This idea, the *price elasticity of demand*, indicates that *price* and demand for water are negatively related: the higher the price of water goes, the less of it one is likely to consume, subject to biophysical limits of our need for water.

The BDCP economic analysis acknowledges the price elasticity of demand for water in its discussion of the benefits of the Twin Tunnels' supposed impact on water supply reliability. But it is unclear, even doubtful, that this concept was applied in BDCP's economic analysis. As supplies decrease,

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[208] BDCP, Chapter 8, p. 8-99.

[209] BDCP, Chapter 8, Table 8-53, p. 8-101.

[210] BDCP, Appendix 9.A, page 9.A-16. Emphasis added.

operating costs of suppliers remain relatively fixed. Water rates would have to rise for the supplier to avoid a fiscal deficit. But as water rates rise, demand decreases, so water agency revenues often decrease, a vicious circle or negative feedback loop for the agency.

The BDCP economic analysis actually provides an entire page listing price elasticities of water demand for urban water agencies in California that may commit to paying for Twin Tunnels water.[211] Three are from the Bay Area (Zone 7, Alameda County Water District, and Santa Clara Valley Water District). Their price elasticities are all under -0.2, meaning that for a unit change in the price of water, demand would fall 20 percent (again, the negative sign means that price and demand are inversely related). Generally, price elasticities are higher among southern California water agencies, ranging from -0.146 in San Marino to -0.324 in the city of Fullerton (Orange County). The diversity of these agencies' price elasticities likely reflects the income diversity of their customer bases: the higher the incomes in different customer bases, the lower their price elasticity of demand (and therefore the more indifferent wealthier communities may be to cost-of-water price signals).

The Environmental Water Caucus would like to know: why are there no analogous price elasticities of demand for the agricultural water agencies' areas (or some other appropriate elasticity of demand with respect to water that is applicable in their regions)? Nothing at all similar for agricultural water agencies is provided in the BDCP economic analysis nor anywhere else in BDCP Chapters 8 and 9, although agricultural price elasticities of demand are surely well studied. These elasticities would be essential for helping the fishery agencies evaluate how demand for water would change among both agricultural and urban water users, given the incremental costs of Twin Tunnels water. This test must be conducted, yet it has not been provided in BDCP economic analysis.

Similarly, the focus on total personal income using a fractional ratio as the basis for judging affordability of Twin Tunnels stands out at best as odd, at worst as highly inadequate for evaluation of financial assurances BDCP hopes to provide to the fishery agencies. It neglects the effects of the price of water on demand in urban and agricultural water use sectors, and is therefore inadequate economic justification and analytical support to the contention by BDCP that Twin Tunnels water would be affordable to Applicants' customer bases. ***The BDCP economic analysis should be rejected by the fishery agencies as a supposed "assurance" of the financial strength of BDCP.***

As noted above, BDCP Chapter 8 also argues that per capita allocation of the capital costs of BDCP is a valid and meaningful approach in comparison with other per capita costs of other major water projects.

There are large problems with such a comparison. First, customers don't just pay for capital costs. They also pay revenues through their water bills to cover operating and maintenance costs and interest on bonded indebtedness to pay off capital projects. (That is an advantage in economic analysis of using an annualized cost that takes account of interest rate, term, and principal, analogous to calculating payments on a mortgage.) Customers also pay more through their water bills when there are capital cost over-runs. At least one of the projects listed in BDCP Chapter 8, a locally-built project called the Coastal Branch of the California Aqueduct to Santa Barbara County, suffered cost overruns and other undisclosed costs. The construction cost overrun was from $270 million to $600 million at completion. The remainder of previously undisclosed costs were interest, operations, maintenance and energy amounting to a final total of $1.6 billion. The costs of these

[211] BDCP, Appendix 9.A, Table 9.A-4, page 9.A-32.

overruns and extra costs are still being paid by Santa Barbara County residents between Santa Maria and Carpinteria.[212]

Second, the comparison of per capita costs of major capital water projects is far too blunt an instrument of analysis to be meaningful. It ignores the reality of how any given project is actually paid for by most consumers of water: through their monthly or bi-monthly water bills. It ignores whether their consumption is metered. It ignores a multitude of factors that figure into how much water households and businesses consume across different regions and how much income each household can put to paying extra for water.

Finally, the per capita cost analysis does not indicate over what time period the repayment of per capita cost would be required.

Thus, BDCP's "business case" to the fishery agencies is poor indeed. ***These are significant reasons to doubt the funding assurances currently provided in BDCP. If they are provided as part of the actual BDCP application for incidental take permits, they should be rejected by the fishery agencies.***

D. Lack of "Step-Up" Provisions in BDCP Financing Plan

The Twin Tunnels financing plan remains highly uncertain and fails to meet the requirements of funding assurances needed to make statutory findings for issuance of incidental take permits.

The final component of evaluating the "business case" supporting BDCP's claim of funding assurances to the fishery agencies is the question of who "steps up" to bail out the Twin Tunnels project if Applicant agencies and their customers decline to participate, or default after it is completed and goes into operation. Answers to this question are crucial for all involved in the decision whether to issue incidental take permits: the Applicants (including the state and federal governments, and the major water contractors supporting BDCP) as well as the fishery agencies responsible for permit issuance.

1. State Water Project Contractors

One approach to funding assurance that addresses the issue of what occurs in the event the Twin Tunnels project fails was provided in a 2012 letter by the San Diego County Water Authority (SDCWA) to then-BDCP director Jerry Meral.[213] SDCWA is the largest customer for imported water from the Metropolitan Water District of Southern California (MWD), which is in turn the largest SWP contractor. SDCWA in 1991 took 95 percent of its water from MWD, but now takes only about 45 percent.

SDCWA argued to Meral that MWD is struggling fiscally. MWD water sales declined 30 percent between 2008 and 2012, and are projected to level off over time. As can be seen from Figure 12, MWD's water rates were in the vicinity of $750 in 2012 and are projected to climb higher in the future.

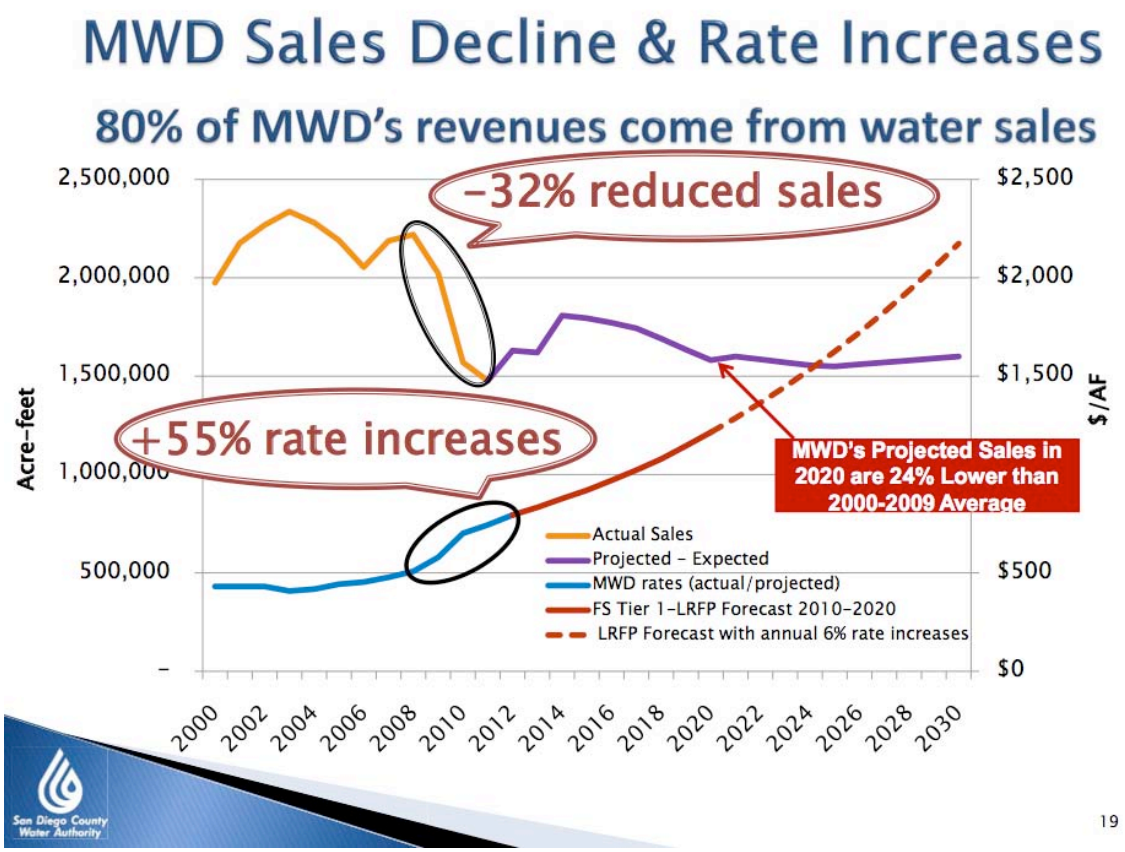
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[212] California Water Impact Network, *Why We Cannot Afford the Proposed Peripheral Canal/Tunnel: The Santa Barbara County Experience*, July 26, 2012. Accessible online at https://www.c-win.org/content/c-win-press-release-report-documents-huge-cost-overruns-santa-barbara%E2%80%99s-state-water.html.

[213] Letter of Maureen A. Stapleton, General Manager of San Diego County Water Authority, to Dr. Gerald Meral, Deputy Secretary of the California Natural Resources Agency, August 28, 2012, 8 pages. Hereafter cited as "Stapleton letter."

A 2011 study of the 2010 urban water management plans of MWD's 11 largest member agencies found that by 2035 only three agencies plan to increase the share of their water supply obtained from imports by MWD.[214] Their increased shares of imports would be very small (1 to 5 percent). West Basin Municipal Water District, and the cities of Long Beach and Los Angeles plan reductions in both the share of imported water from MWD and the absolute amounts of those imports as well. Together their absolute reductions are projected to total 141,300 acre-feet per year.[215]

Figure 12



Analysis of Metropolitan Water District water sales and actual and projected rate increases. Source: San Diego County Water Authority, *What We Need in a Bay-Delta Fix: A Perspective From MWD's Largest Customer*, May 11, 2011, slide 19. Accessible online 15 July 2013 at http://www.slideshare.net/waterauthority/baydelta.

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[214] Central Basin Municipal Water District, Three Valleys Municipal Water District, and Eastern Municipal Water District.

[215] Phillips, C. 2013. *Imported vs. Local Water Supplies: The Planning Decisions Facing Southern California Water Agencies,* Goldman School of Public Policy, University of California, Berkeley, August 3, 2011. Central Basin Municipal Water District plans no increase in the absolute amount of its MWD imports. Accessible online 15 July 2013 at http://switchboard.nrdc.org/blogs/bnelson/Local%20vs%20Imported_Final%208-4-11.pdf.

For the eleven largest MWD member agencies, they project demand growth of just 103,775 acre-feet by 2035 an average of under 400 acre-feet per member agency per year.[216]

The City of Santa Monica has vowed to become completely free of imports from MWD by 2020 while simultaneously reducing its current rate of imports from 85 percent in to 33 percent in 2012. In 1995, the City had to close five drinking water wells and replace the supplies with imports from MWD. In 2012, the City completed a water treatment plant that accounts for the recent reduction in its imports.

As a consequence of these and other actions by local water agencies in urban southern California, demand for MWD imports has weakened significantly. MWD imports include water not only from the State Water Project exporting from the Delta but Colorado River Aqueduct imports as well.

The weakening of demand for MWD imports reflects the flexibility and consumer sovereignty that MWD member agencies (including San Diego County Water Authority) exercise and enjoy. This consumer sovereignty enables them to consider and act on developing alternative local supplies rather than import costly water from MWD for which they may prefer not to pay.[217] (Many of these supply alternatives are likely to be more drought-resilient than the Twin Tunnels, which is dependent on snowpack, reservoir storage, and river runoff.)

In this fashion, MWD's high water rates and policy of allowing member agencies to opt out of taking imports are stimulating the very local and regional water self-sufficiency mandated in the Delta Reform Act of 2009.[218]

This same consumer sovereignty will make it difficult for MWD to cobble together adequate financial assurances or guarantees.

SDCWA informed Meral in August 2012 that Metropolitan Water District's member agencies are not required to buy water from MWD because they have not and "will not" sign contracts that require member agencies to make regular fixed purchases from MWD whether or not they take water. (This type of contract is known as "take or pay.") SDCWA draws out the political and financial implications of MWD supporting a project for which it cannot assure repayment of the revenue bonds:

> ...because the project is anticipated to be financed through project revenues, we are informed that bond underwriters are expected to require a 'step up' provision by which each BDCP participant in BDCP-related bonds pledges to assume the obligations of defaulting participants.[ ] [I]t is conceivable that some

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[216] This is worked out as 103,775 acre-feet divided by a 25 year planning horizon divided by 11 member agencies. This yields an average of about 377 acre-feet per member agency per year, rounded up to 400.

[217] Maven's Notebook, Assembly oversight hearing on the funding structure and economic impacts of the Bay Delta Conservation Plan (part 3): San Diego County Water Authority & Contra Costa Water District share their concerns, February 21, 2014. See especially remarks of Dennis Cushman, Assistant General Manager of San Diego County Water Authority.

[218] California Water Code Section 85021, stating: "The policy of the State of California is to reduce reliance on the Delta in meeting California's future water supply needs through a statewide strategy of investing in improved regional supplies, conservation, and water use efficiency. Each region that depends on water from the Delta watershed shall improve its regional self-reliance for water through investment in water use efficiency, water recycling, advanced water technologies, local and regional water supply projects, and improved regional coordination of local and regional water supply efforts."

> of the BDCP participants may default, which would cause remaining participants, including MWD, to assume a greater portion of the debt. It is important that Chapter 8 analyze the possible effects of the 'step up' provisions on MWD and the other participants in the BDCP.[219]

The BDCP economic analysis has so far not provided that analysis. If remaining participants must step up, that means their costs of Twin Tunnels project water will rise in order to meet repayment obligations to bondholders. The lack of such assurances at present means that BDCP underestimates the costs and affordability of its Twin Tunnels project.

In 2011, SDCWA pledged to support BDCP by committing (in a Powerpoint presentation and later in a 2013 media release[220] and in their official comments on BDCP, dated May 30, 2014[221]) to a firm, long-term contract to pay for its share of water and facilities, so long as other MWD member agencies do too.[222] Property taxes have been suggested as "the ultimate security" for BDCP repayment obligations of contractors, but property tax increases would probably require voter approval. SDCWA recommends that Meral include in BDCP "a careful legal analysis of MWD taxing authority...if taxes are contemplated as additional back-up security for project [bonded] debt." SDCWA concluded bluntly that:

> At a minimum, state water contractors that are wholesale water agencies must demonstrate that their customers—the member agencies or units that buy their water and provide their revenues—have take-or-pay contracts or other enforceable commitments to pay the fixed costs of the project commensurate with the term of the BDCP obligation [i.e., 50 years].[223]

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[219] Stapleton letter, *op. cit.*, p. 3.

[220] San Diego County Water Authority, "Water Authority Seeks Right-Sized, Cost-Effective Bay-Delta Plan," July 25, 2013. Accessible online 13 August 2013 at http://www.sdcwa.org/water-authority-seeks-right-sized-cost-effective-bay-delta-plan.

[221] Letter of Maureen A. Stapleton, General Manager, San Diego County Water Authority to Ryan Wulff, National Marine Fisheries Service, *Re: Draft EIR/EIS for the Proposed Bay Delta Conservation Plan, Alameda, Contra Costa, Sacramento, Solano, and Yolo Counties*, May 30, 2014, 19 pages plus attachments. Accessible online 8 June 2014 at http://www.sdcwa.org/sites/default/files/files/news-center/top-issues/05-30-14%20BDCP%20Comment%20Ltr.pdf

[222] San Diego County Water Authority, *What We Need in a Bay-Delta Fix: A Perspective by MWD's Largest Customer*, May 11, 2011, slide 25. Accessible online 15 July 2013 at http://www.slideshare.net/waterauthority/baydelta.

[223] Stapleton, *op. cit.*, note 16, p. 4. Metropolitan Water District has 26 member agencies, 12 of whom serve as wholesalers to another 251 cities and communities in southern California. MWD contracts for about 50 percent of State Water Project's total Table A amount. Kern County Water Agency has 13 "member units" in Kern County region, and contracts with the State Water Project for about 25 percent of the total Table A amount. See also Stapleton's letter of May 30, 2014, op. cit., to BDCP; and SDCWA's News Release, "Water Authority Seeks Clarity About Bay-Delta Financing Plan," June 3, 2014. Accessible online 8 June 2014 at http://www.sdcwa.org/water-authority-seeks-clarity-about-bay-delta-financing-plan where it states: "Since MWD derives more than 80 percent of all its revenues from water sales, a decreasing sales base over the long term would force some MWD member agencies to shoulder more of the cost of Bay-Delta upgrades than expected. The Water Authority has repeatedly called for MWD member agencies to provide firm financial commitments to demonstrate their need for the project and pay their fair share of MWD's fixed costs related to the Bay-Delta, but they have refused to do so."

Without such a "due diligence" analysis of BDCP funding, wrote SDCWA, the plan "faces a potential cascading collapse of funding."

BDCP's current economic analysis continues to be silent on this issue, despite SDCWA's warning 22 months ago. Chapter 8 does include a section on bond financing, but it is merely introductory.[224]

Whether revenue bonds are issued by the state or by highly rated water contractors, the problem of repayment arrangements remains unresolved at least until further releases of information from BDCP are available. How would the state or the bond-issuing entity make state water contractors and their member agencies commit to "take-or-pay" BDCP financing given the project's exorbitant cost and the relative competitiveness of other local supply alternatives?

2. Central Valley Project Contractors

Important questions surround the ability and willingness to pay for the Twin Tunnels project of Central Valley Project water contractors. Agricultural water agencies make up about 90+ percent of both cost allocations and water deliveries within the Central Valley Project. Do CVP contractors currently repay all of the costs of existing CVP facilities? Are they on schedule to do so? If not, how are shortfalls defrayed, and what do they still owe?

Would congressional action be needed to authorize the Bureau of Reclamation to finance its share of BDCP capital costs? What is the existing financial condition of CVP agricultural contractors to afford and support BDCP financing through agricultural water rates? BDCP's economic analysis is silent on these and other such matters.

Presently, CVP water contractors lag on repaying the costs of existing CVP facilities, according to a March 2013 review by the US Department of the Interior, Office of Inspector General (IG).[225] The IG found:

- The current rate-setting process contributes to repayment uncertainty.[226]
- Contract provisions limit repayment of project costs.[227]
- By 2030, when CVP capital facilities are required by Congress to be paid off, repayment could be short by between $330 million to $390 million.[228]

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[224] This section states that the State Water Project is a highly rated financial risk, due in part to the fiscal strength of its water contractors (the largest of whom are Metropolitan Water District and Kern County Water Agency). It provides a highly simplified example of four bond issues that could finance Conservation Measure 1 facilities (i.e., Twin Tunnels).[172] These issues could finance $15.575 billion based on interest rates ranging from 6.132 to 6.135 percent. The example does not provide any estimate of total interest costs per issue (and per acre-foot for that matter) on the financed amount at these rates.[173] ***Total interest cost fully amortized over 40 years given these bond terms would come to about $26.3 billion, bringing BDCP's total costs to $42 billion.***

[225] US Department of the Interior, Office of Inspector General, *Central Valley Project, California: Repayment Status and Payoff*, Report No. WR-EV-BOR-0003-2012, March 2013. Hereafter, DOI, *CVP Repayment Status*. Accessible online 15 July 2013 at http://www.doi.gov/oig/reports/upload/WR-EV-BOR-0003-2012Public.pdf.

[226] DOI, *CVP Repayment Status*, p. 4.

[227] *Ibid.*, p. 5.

[228] *Ibid.*, pp. 6-7.

- Municipal and industrial contractors face an annual operating and maintenance deficit of about $55 million annually by 2030 as well.[229]
- Power customers "will pay any costs above the irrigation contractors' ability to pay," meaning that when irrigation revenues fail to cover costs (such as when actual deliveries are less than projected deliveries), revenues from power sales within the CVP are used to reduce or eliminate those deficits.[230]

A 2008 study for the Delta Vision Blue Ribbon Task Force found that nearly $1.3 billion is owed by CVP contractors for the capital facilities of the project. Of this amount, San Joaquin Valley and Sacramento contractors have together repaid about 21.5 percent of this cost.

Repayment of CVP costs by the contractors is shifting, however. Just five years ago, San Joaquin Valley irrigation contractors had repaid just 19.4 percent of their allocated costs of $955 million, but within five years, Bureau accounting records indicate that collectively they have now repaid nearly half of their project costs (48.3 percent) even though their allocated capital costs rose to just over $1 billion. The surge in repayments was led by Friant-Kern and Madera Canal-area contractors, neither of whom would benefit directly from Twin Tunnels imports.

By contrast, CVP irrigation contractors on the west side of the San Joaquin Valley—who are among BDCP's Applicants and most ardent supporters—continue to lag on repayment of their existing allocated CVP costs. The irrigators of the Delta-Mendota Canal and Pool units, the San Luis unit (both Fresno and Tracy), and the Cross Valley Canal in Kern County all have repaid less than 27 percent of allocated project costs, though facilities like the Delta Mendota Canal and the San Luis Canal have existed since the 1950s and 1960s. This appears to be the case despite the fact that irrigation contractors with these CVP units by law pay no interest on their contracts (while municipal and industrial contractors do).

Along the San Luis Canal where Westlands Water District is the primary irrigation contractor, just 22.7 percent of the nearly $460 million in allocated capital costs for the Canal unit has been repaid, leaving about 77 percent that must be repaid by 2030 under congressional repayment requirements, now just 16 years away. This amounts to about $20 million per year between now and 2030.[231]

Furthermore, unlike urban water agencies whose landowners can be held financially responsible through taxes and liens in the event of BDCP bond default, agricultural water agency customers will apparently not be held responsible. Westlands Water District's manager has stated:

> The security on the bonds is the [Westlands] district's revenue, *not* the landowner's land. In a worst case,

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[229] *Ibid.*, p. 7

[230] Thus, while M&I contractors provide only a slight subsidy to agricultural contractors, the CVP is structured so that hydroelectric power revenues are used to defray operating deficits in the accounts of each irrigation contractor. *Ibid*., p. 7; see also Entrix, Inc., *Overview on Central Valley Project Financing, Cost Allocation, and Repayment Issues*, provided to the Delta Vision Blue Ribbon Task Force, September 18, 2008, p. 11. Accessible online 15 July 2013 at http://deltavision.ca.gov/ConsultantReports/CVP_Financing_and_Repayment_Summary_9-18-08.pdf. The power subsidy to irrigation contractors is confirmed on page 11 of this document.

[231] Entrix, Inc., *op. cit.*, note 34, Table 4, p. 17; US Department of Interior, Bureau of Reclamation, Mid-Pacific Region Office, "Schedule of Construction Costs Allocation by Contractor," Schedule A-2Bb, December 2012.

we file for bankruptcy. That's what the District could do. The landowners' land is not security.[232]

The Plan does not disclose who will be responsible for paying off the revenue bonds if Westlands and other water agencies default on their bonds because they cannot make their payments.

Lack of a financing plan means the Bay Delta Conservation Plan and the project description in its EIR/EIS are incomplete, cannot deliver funding assurances to the fishery agencies, and therefore cannot be legally meet the statutory findings the fishery services must make under Section 10 of the federal Endangered Species Act, and fulfill disclosure requirements of the California Environmental Quality Act and National Environmental Policy Act.

[232] Transcript of January 14, 2014, meeting of Westlands Water District Board of Directors, page 7. Accessible online 8 June 2014 at http://www.c-win.org/webfm_send/434.

V. BDCP fails to provide governance and implementation support for compliance with its long-term funding and ecological assurances.

There are numerous questions raised by BDCP's implementation plan and governance structure. Few of these questions are adequately answered at this time. Some questions have to do with funding of the Twin Tunnels projects and the habitat restoration and other conservation measures included in the Bay Delta Conservation Plan.

Other questions, though, have also to do with basic rules of decision-making and due process that are neglected in Chapters 6 and 7 of the BDCP, and in a July 2013 draft of the Implementing Agreement obtained from the US Fish and Wildlife Service this spring.

Questions bear on whether iron-clad assurances are in place prior to approval of the BDCP and issuance of incidental take permits by the fishery agencies. Other questions bear on the ***how*** of implementing BDCP. There is little about the questions and how they are answered by BDCP at present that inspire confidence and trust. Now is the time for the fishery agencies to insist on more answers from the BDCP Applicants. ***After signing the Implementing Agreement and issuing the incidental take permits, it will be too late.***

A. Ecological assurances are unsupported by governance in the Bay Delta Conservation Plan.

There are many ways in which the BDCP plan for governance and implementation fails to support long-term ecological assurances. First, the Biological Goals and Objectives are severed from compliance with incidental take permit conditions, as we described in Section III. Second, the recovery requirement in the Delta Reform Act (Water Code Section 85320(b)(2)(A) means that the ecological assurances are unsupported and virtually meaningless because the Applicants will be free from being held to account by enforceable constraints on their actions. For reasons described elsewhere in these comments, the Applicants have a poor track record minimizing the ecological effects of exporting water from the Delta.

Incidental take limits have not yet been quantified. Consequently there is no quantified basis on which to issue and enforce incidental take limits, certainly nothing available for the public to evaluate and assess.

Statutory findings cannot be made by the fishery agencies in support of issuing incidental take permits, based on modeling results generated from BDCP's analytic efforts to date.

The Authorized Entity Group (AEG) is given authority to make final decisions over how the conservation measures 2 through 22 are handled (DWR and the US Bureau of Reclamation plan to retain full ownership and management responsibility and control over their respective water project operational activities). AEG's responsibilities include:

- Oversight and management of funding and resources.
- Contracting out for services.
- ***Oversight and administration of all conservation measures.***
- ***Implementation of outreach, compliance monitoring, and reporting requirements.***
- BDCP's Annual Work Plan and Budget.

The Environmental Water Caucus is deeply concerned that the water project operators and their contractors will be responsible for administering all of the non-water project conservation

measures. ***If this means all taxpayer funding for habitat restoration will be controlled by the Implementing Office subject to AEG oversight, we view this as a non-starter.*** BDCP is saying it will depend for much of its habitat restoration and other conservation measure funding on voter-approved bond funds. These funds, should voters approve them, represent over 52 percent of the $7.3 total estimated funds needed for conservation measures 2 through 22.[233] BDCP's Implementation Office and Authorized Entity Group should not be entrusted with direct control over this much in taxpayer funds. ***The contractors claim they would put up just 10 percent of the funds for habitat restoration and other conservation measures, but would apparently exercise full control over how all $7.3 billion in funding for conservation measures 2 through 22 would be managed. We believe this represents an inherent conflict of interest, perhaps even a gift of public funds.*** The same AEG members oversee water project operations closely (if not through formal AEG actions, then through daily interaction over water allocations, deliveries, and many other project-related issues) and yet would be making final decisions about implementation of habitat restoration conservation measures as well. The metaphor of the fox guarding the chicken coop comes all too easily to mind.

We have identical concerns about the Authorized Entity Group having final say over compliance monitoring and reporting requirements. As we have noted elsewhere in these comments, these requirements have been poorly specified. Effectiveness monitoring is left out of this list as well, though it is incorporated into BDCP's appendix concerning research, monitoring and adaptive management. This implies all too loudly that BDCP Applicants likely care little whether habitat restoration projects and projects of other conservation measures effectively or not.

B. It is impossible for a project/plan the scale of BDCP to adhere to both the "No Surprises Rule" and operate an effective adaptive management program.

The problem of the large role given BDCP's adaptive management program comes into greater focus when the governance of the program is described.

As a cadre of professional scientists, the BDCP Adaptive Management Team would be charged with framing hypotheses relevant to BDCP research needs, conducting the research, and presenting results and recommendations to the Implementation Office's Science Manager. (These recommendations may address a change in how a biological goal or objective is achieved, or may even attempt to recommend a change to a biological goal or objective.) The Team is to operate, according to BDCP's governance rules, on a consensus basis.[234] But if the Adaptive Management Team fails to reach consensus on its recommendations, what then?

The Authorized Entity Group and the Permit Oversight Group[235] are given "joint" responsibility for making the final decision on the matter posed by the Adaptive Management Team. This joint responsibility goes undefined in both BDCP and the July 2013 Implementing Agreement.

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[233] BDCP, Chapter 8, *Implementation Costs and Funding Sources*, Table 8-37, p. 8-65 to 8-66.

[234] BDCP, Chapter 7, *Implementation Structure*, Table 7-1.

[235] Membership of the Authorized Entity Group consists of four individuals representing the California Department of Water Resources, the US Bureau of Reclamation, state water contractors, and federal water contractors. Membership of the Permit Oversight Group consists of three individuals representing the US Fish and Wildlife Service ,the National Marine Fisheries Service, and the California Department of Fish and Wildlife.

Questions: How will votes be handled when all members of the joint AEG/POG are present? By what quorum rules will they operate? Will decisions arrived at by rule of majority, super-majority, or consensus? Will these groups have alternates representing each agency so that no agency is excluded from making decisions when needed?

We note that this "AEG/POG" joint role crops up a lot (as shown in Table 7-1 of BDCP), when it comes "to deciding the matter" under adaptive management and monitoring. There would be seven members of this "joint" body: Four representing water agencies, three representing fishery agency regulators. ***This is an unacceptable and inequitable allocation of voting power when it comes to achieving the co-equal goals of both BDCP and the Delta Reform Act. It gives greater weight to water project operations and deliveries than to protection and restoration of the Delta ecosystem and recovery of listed species*** as called for in California Water Code Section 85320 (see discussion in Section VI on this law). We recognize, however cynically, that it is consistent with the overall thrust of the Bay Delta Conservation Plan and its likely outcomes. It is also consistent, alas, with "No Surprises" policy.

Moreover, we believe that this allocation of power within BDCP's implementing structure reflects a compelling need for the Applicants (as reflected in the membership of the AEG) to privilege the No Surprises rule over adaptive management. Achieving biological goals and objectives on behalf of the covered and listed species within BDCP will have a lower priority, given this institutional design, consistent with the statement in the Biological Goals and Objectives we cited in Section III.

The No Surprises rule is central to the adaptive management role within BDCP. Nowhere is this clearer than in the May 2014 draft implementing agreement for BDCP. As part of their deliberations, states the agreement, "the Authorized Entity Group and the Permit Oversight Group shall adhere to the following "legal, policy, and regulatory principles":

- The scope and nature of a proposed adaptive response 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 or Associated Federal Actions and Plan implementation or to better achieve the biological objectives.*

- The proposed adaptive management action must be consistent with the legal authority of the entity responsible for effectuating the action.

- The Adaptive Management process will be used to help ensure that Conservation Measures are in conformity with the ESA and NCCPA permit issuance criteria throughout the course of Plan implementation. Changes will be limited to those actions reasonably likely to ensure that (1) the impacts (or levels of impacts) of a Covered Activity or Associated Federal Action on Covered Species that were not previously considered or known are adequately addressed or (2) a Conservation Measure or suite of Conservation Measures that are less than effective, particularly with respect to effectiveness at advancing the biological goals and objectives, are modified, replaced or supplemented to produce the expected biological benefit.

- The strength of the scientific evidence linking the proposed change to a Conservation Measure and to the ability of the Plan 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 achieved, adaptive responses should favor changes that minimize impacts to water supply or reliability.

- Prior to any decision to change a Conservation Measure in a manner that would potentially result in the modification of water supplies consistent with Section [10.3.7], non-operational

> alternatives will be considered and, if such alternatives are rejected, the Adaptive Management Team will provide an explanation provided [*sic*] as to why they were not sufficient to address the effects of the Covered Activity, or Associated Federal Action, or achieve the biological objective(s) of the Plan.[236]

Thus, adaptive management to achieve biological goals and objectives will be subservient to the No Surprises rule's protection of "no net loss to exports" (see our discussion of Real-Time Operations, Section III, above) carries into BDCP implementation. ***This conflicts utterly with the Delta Reform Act's vaunted "co-equal goals."*** Their co-equal stature would be honored in the breach by how voting power is allocated within BDCP's implementation structure. ***Once the ink is dry on BDCP's incidental take permits and the implementing agreement, the burden of proof of any BDCP and/or Twin Tunnels project harm to covered species lies with the scientists and the regulators—for the next 50 years.*** Any case regulators and adaptive management team attempts to build on behalf of some change to either biological goals and objectives or to any conservation measure must be compelling, iron-clad, bullet-proof. And, in the context of BDCP governance, the Authorized Entity Group may still veto it.

Put another way, the No Surprises rule reverses the relationship between the Applicants and the fishery agencies, once the incidental take permits are issued: "No Surprises" places the burden of proof on the fishery agencies to conduct scientific research to support changes in BDCP, or suspension or revocation of its permits.

As we have already commented, there are numerous reasons why this habitat conservation plan is a bad deal for the fishery agencies and the people of California and the United States of America. BDCP modeling results indicate its "conservation strategy" will perform poorly when measured against existing environmental, economic, and fiscal conditions and criteria. ***BDCP proposes to stack the deck of its governance in favor of water operations in flagrant violation of the Delta Reform Act's co-equal goals and the state and federal endangered species acts. BDCP's governance program cannot and will not support and sustain the ecological assurances to the fishery agencies that would adaptively manage the conservation strategy as a whole to achieve its biological goals and objectives, and not appreciably reduce the likelihood of the survival and recovery of listed species.***

C. The Bureau of Reclamation's exclusion from BDCP complicates BDCP's ability to provide and sustain ecological and funding assurances.

We note that the No Surprises rule does not apply to federal agencies like the Bureau of Reclamation because federal agencies are ineligible to participate in habitat conservation plans under Section 10 of the federal ESA.[237] The Bureau must instead provide a biological assessment under Section 7 of the ESA as part of consultation with federal fishery agencies. The EIR/EIS is also intended to "inform a biological assessment that Reclamation will submit to the US Fish and Wildlife Service

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[236] *Draft Implementing Agreement for the Bay Delta Conservation Plan*, by and among the US Bureau of Reclamation, US Fish and Wildlife Service, National Marine Fisheries Service, California Department o fWater Resources, California Department of Fish and Wildlife, and State Water Project/Central Valley Project Contractors, Draft, released May 2014, Section 10.3.5.1.2, p. 35. Emphasis added. Hereafter cited as "*Draft 2014 Implementing Agreement.*"

[237] *Draft Implementing Agreement for the Bay Delta Conservation Plan*, by and among the US Bureau of Reclamation, US Fish and Wildlife Service, National Marine Fisheries Service, California Department o fWater Resources, California Department of Fish and Wildlife, and State Water Project/Central Valley Project Contractors, Draft, July 2013, Section 13.3.2, p. 42. Hereafter cited as "*Draft 2013 Implementing Agreement.*"

[USFWS] and the National Marine Fisheries Service [NMFS] to support an ESA Section 7 consultation."[238]

This asymmetry among the water project owners (i.e., DWR can participate in BDCP directly because it is a non-federal agency) poses an implementation challenge to the Applicants. Federal water contractors cannot obtain the same "no surprises" regulatory stability that the state axis of water agencies may enjoy under BDCP and Section 10 of the ESA. Instead, BDCP signatories will include officials of the Department of Water Resources, the California Department of Fish and Wildlife, NMFS and USFWS. The Bureau, according to BDCP officials will execute two new memoranda of understanding (MOUs) that they say will also receive public review, but when these documents will be available, and for how long, has not yet been announced. According to BDCP officials the two MOUs will address the Bureau's "commitment to the BDCP as a whole" to be co-signed by DWR officials at a minimum, and the second will address operation of the Twin Tunnels project and will presumably include wheeling arrangements as BDCP's Chapter 7 anticipates.[239]

Still, without the Bureau staking itself to funding, operational, and ecological management commitments that all other BDCP Applicants sign onto in the Implementing Agreement, overall assurances are structurally weakened, subject to near-term and long-term vagaries and uncertainties of congressional policies (like the Anti-Deficiency Act) and politics.

D. Financial assurances are unsupported in the Bay Delta Conservation Plan.

As noted previously, the funding plan for BDCP is incomplete and poorly specified. This unfinished business also is reflected in the draft July 2013 Implementing Agreement.[240] Preliminary review of the May 30, 2014, draft Implementing Agreement indicates that while the Funding section is now populated with words, the verbiage says little new from what is presented in Chapter 8 of BDCP. However, the new verbiage on on funding contains two disconcerting passages:

> In the event of a shortfall in State or federal funding, a Fish and Wildlife Agency(ies) shall not suspend or revoke the State and/or Federal Permits or invalidate Reclamation';s take statement if the shortfall in funding is determined to be likely to have no more than a minimal effect on the capacity of the Plan to advance the biological goals and objectives.[241] (p. 47)

> "Actions that may be considered to address such shortfalls include adjusting the scope of the Plan in proportion to the public funding shortfall.[242] (p. 48)

This draft continues to provides no insight into ***how*** BDCP will be financed, which water contractors will definitely participate.

The federal Endangered Species Act requires that habitat conservation plans specify that the "applicant will ensure adequate funding for the plan will be provided" for conservation actions that minimize and mitigate impacts on species covered by the plan. At a minimum this means that BDCP:

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[238] BDCP EIR/EIS, Chapter 1, *Introduction*, p. 1-18, lines 3-5.

[239] Personal notes of Tim Stroshane from California Department of Water Resources conference call, May 28, 2014.

[240] *Draft 2013 Implementing Agreement.*, Section 12, *Funding*, pp. 38-40. Placeholders for obligations of the Authorized Entities and the fishery agencies contain no descriptions of funding.

[241] *Draft Implementing Agreement*, released May 30, 2014, p. 47.

[242] *Ibid.*, p. 48.

- Must ensure funding over the lifetime of the permit.
- Cannot rely on federal funding to "ensure" funding of the plan in light of the "Anti-Deficiency Act and the availability of appropriate funds."
- Must provide "remedies for failure to meet funding obligations by signatory measures".
- "Cannot rely on speculative future actions of others" for funding, which would include voter approval of bond funds. And
- Must be backed by a guarantee by the applicant to ensure funding for all plan elements.

BDCP fails to meet any of these criteria as reflected in case law on habitat conservation plan funding assurances.[243]

BDCP's analysis of supply and demand for Twin Tunnels water deliveries is grossly inadequate. Demand has not been demonstrated to exist for continuing imports from the Delta by Metropolitan Water District customers, as noted above. And the junior water rights of the state and federal water projects generally will not be improved in their priority position by obtaining new points of diversion on the lower Sacramento River at this late date. State and federal water supply reliability in the Delta will continue to be poor over the long haul, which will dampen sales and demand, which will in turn reduce the financial strength and capacity of the State Water Project in the long run, which could undermine their ability and willingness to continue funding implementation of the Bay Delta Conservation Plan. As discussed above, the largest CVP contractor already has plans to declare bankruptcy if that district cannot make payments, in order to avoid any liabilities for its landowners. This is an irresponsible exit strategy.

For lack of a financing plan, statutory findings about funding assurances cannot be reasonably made by the fishery agencies in support of issuing incidental take permits.

E. Will the State of California contract away its fiduciary responsibility to enforce the Public Trust Doctrine if one of its public trust agencies, the Department of Fish and Wildlife, signs the Implementing Agreement for BDCP and issues incidental take permits with a term of 50 years?

Local cities and counties are not allowed to contract away their police powers, including in matters of land use and subdivision in regulating new development. The State of California has fiduciary responsibility to protect the public trust.[244] We are concerned that the State of California may tie its hands illegally and unnecessarily when it comes to enforcing the protection of public trust resources in the Delta, some of which are fish and wildlife.

The California Department of Fish and Wildlife is responsible for at least a portion of the state's obligation to protect the public trust. The State Water Resources Control Board is also an agency of the State of California that is charged with protecting the public trust through its regulation of water rights and water quality. We understand that the State Water Board is not to be a signatory to the Bay Delta Conservation Plan Implementing Agreement, but we remain deeply concerned that even one state agency possibly signing away its authority to protect the public trust beyond the confines of BDCP might be signing it away for any and all others with current public trust responsibility. The BDCP and its EIR/EIS should address this matter squarely.

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[243] 16 USC 1539(a)(2)(B(iii); *National Wildlife Federation v. Babbitt*, 128 F.Supp.2d 1274, 1294-95 (E.D. Cal., 2000); *Southwest Center for Biological Diversity v. Bartel,* 470 F.Supp.2d 1118, 1155 (S.D. Cal., 2006); and *HCP Handbook*, pp. 3-33 to 3-34.

[244] *National Audubon Society v. Superior Court of Alpine County,* 658 P.2d 709 (Cal. 1983).

F. The Stakeholder Council as presently proposed excludes representatives of environmental justice communities.

BDCP's governance structure includes a "stakeholder council." This entity "will be formed to provide opportunities for interested parties to consider, discuss, and provide input on matters related to" BDCP implementation.

It appears to our member groups that the stakeholder council is to serve as a forum to help the BDCP implementation office gauge how it is perceived by "interested parties" like local elected and appointed officials, state, federal, and regional agencies (Delta-focused and the Central Valley Flood Protection Board), the counties, three "local government" seats, and the lay public. It also appears to us that the stakeholder council will "develop its own process to consider and provide input regarding the various aspects of BDCP implementation" and an opportunity to get and disseminate information about BDCP activities to their constituencies. It provides three seats for "conservation groups with expertise in fish and wildlife management, and or the management of aquatic habitats and other natural lands."[245]

This structure excludes representatives of environmental justice communities. It should be clear from our comments, and from Attachment 1, that BDCP poses important environmental justice issues for this community, including access to public arenas about water and fish in the Delta (i.e., public participation and information), subsistence fishing and public health, recreating, jobs, agricultural employment, and housing. If BDCP continues, the Stakeholder Council needs to reach out to include EJ communities of the Plan Area.

G. The meetings of both the Authorized Entity Group and the Permit Oversight Group must comply with the Brown Act.

The "current thinking" of BDCP officials appears to us to limit as much as possible public access to the affairs of the Authorized Entity Group and the BDCP Implementation Office. This retrenchment, is reflected in language changes to the draft IAs from July 2013 to May 2014. The July 2013 Draft Implementing Agreement of BDCP states:

> The Authorized Entity Group will meet on a schedule of its own choosing, but at a minimum on a quarterly basis. [It] may also be convened by the Program Manager, as needed, to review issues that arise during the implementation of the Plan, including proposed amendments to the Annual Work Plan and Budget. The Authorized Entity Group will also meet with the Permit Oversight Group…, at least on a quarterly basis to review Plan implementation issues, including those related to the adaptive management and monitoring program and the restoration and preservation of habitat.
>
> The Authorized Entity Group will institute procedures with respect to public notice of and access to its meetings with the Permit Oversight Group. The date, time, and location of the meetings will be posted on the BDCP web site at least 10 days prior to such meeting. The meetings will be held at locations within the City of Sacramento or the legal Delta. All meetings will be open to the public.[246]

The May 2014 draft Implementing Agreement retains the first paragraph in its entirety, but amends the second so that the AEG ***reduces its obligations to the public*** from "All meetings will be open to the public" to merely informing the public via the BDCP web site of what decisions the AEG has made after the fact.:

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[245] *Ibid.*, Section 14.6.2, p. 56.

[246] *Draft Implementing Agreement*, July 2013, Section 14.3.3, p. 52.

> The Authorized Entity Group shall have the responsibility to inform the public of its deliberations and decisions. As such, the Program Manager will ensure that the public receives notice of upcoming meetings of the Authorized Entity Group, that meeting agendas are posted prior to such meetings, and that any decisions of the Authorized Entity Group are made available through the BDCP web site. *On a periodic basis, the Authorized Entity Group will hold meetings that are open to the public.* The Authorized Entity Group will institute procedures with respect to public notice of and access to these meetings and to any public meetings it holds with the Permit Oversight Group. The date, time, and location of the meetings will be posted on the BDCP website at least ten (10) days prior to such meetings. The meetings will be held at locations within the City of Sacramento or the legal Delta.[247]

This is woefully insufficient for promoting meaningful informed public participation about Delta and BDCP affairs. ***All AEG should be publicly accessible and subject to California's Brown Act, which establishes standards for open meeting practices by all public agencies in California.*** After all, BDCP and its Applicants hope to receive and/or coordinate habitat restoration and other conservation measures with billions of dollars of taxpayer funds that will directly affect the management of water exports from the Delta, a matter affecting nearly every part of California. ***At a minimum, the Implementing Agreement and the BDCP must commit to rigorous compliance with the provisions and practices of open government called for in the Brown Act.***[248]

The Applicants should also commit to having the Implementing Office create and maintain a state-of-the-art web site that facilitates the public's access to information, including real-time data, reports, etc., unlike tight-lipped web sites run by several prospective BDCP applicants. ***Expanding the State Water Project's already domineering and paternalistic presence in the Delta means the Applicants wanting to do so must undertake greater responsibility and responsiveness to the public for its management and accountability, not less.***

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[247] Draft Implementing Agreement, released May 30, 2014, Section 15.3.3, *Meetings of the Authorized Entity Group*, p. 60.

[248] The Brown Act is contained in section 54950 *et seq*. of the Government Code.

VI. BDCP is contrary to law

BDCP's draft July 2013 Implementing Agreement says (twice) that "all activities undertaken pursuant to this Agreement, the BDCP, or the Permits must be in compliance with all applicable local, state and federal laws and regulations."[249] The May 2014 Implementing Agreement contains this identical provision.[250] This section of EWC's comments describes the many ways that BDCP fails to comply with many other applicable laws and regulations.

The Bay Delta Conservation Plan and its Project Objectives and Purpose and Need for BDCP do not comply with existing state or federal law. The EWC documents these failures to comply with established law in this section and the following section where compliance deficiencies are itemized with respect to the National Environmental Policy Act and the California Environmental Quality Act.

The purposes of the proposed actions are to achieve the following.

1. Consider the applications for incidental take permits[6] for the covered species that authorize take related to the actions listed below.
   a. The operation of existing SWP Delta facilities.
   b. The construction and operation of facilities and/or improvements for the movement of water entering the Delta from the Sacramento Valley watershed to the existing SWP and CVP pumping plants located in the southern Delta.
   c. The implementation of any conservation actions that have the potential to result in take of species that are or may become listed under the ESA, pursuant to the ESA at section 10(a)(1)(B) and its implementing regulations and policies.
2. Improve the ecosystem of the Delta by implementing the actions listed below.
   a. Providing for the conservation and management of covered species through actions within the BDCP Planning Area that will contribute to the recovery of the species.
   b. Protecting, restoring, and enhancing certain aquatic, riparian, and associated terrestrial natural communities and ecosystems.
   c. Reducing the adverse effects on certain listed species due to diverting water.
3. Restore and protect the ability of the SWP and CVP to deliver up to full contract amounts, when hydrologic conditions result in the availability of sufficient water, consistent with the requirements of state and federal law and the terms and conditions of water delivery contracts held by SWP contractors and certain members of San Luis Delta Mendota Water Authority, and other existing applicable agreements.

The above Purpose Statement reflects the intent to advance the coequal goals set forth in the Sacramento–San Joaquin Delta Reform Act of 2009 of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The above phrase—*restore and protect the ability of the SWP and CVP to deliver up to full contract amounts*—is related to the upper limit of legal CVP and SWP contractual water amounts and delineates an upper bound for development of EIR/EIS alternatives, not a target. It is not intended to imply that increased quantities of water will be delivered under the BDCP. As indicated by the "up to full contract amounts" phrase, alternatives need not be capable of delivering full contract amounts on average in order to meet the project purposes. Alternatives that depict design capacities or operational parameters that would result in deliveries of less than full contract amounts are consistent with this purpose.

[249] *Draft 2013 Implementing Agreement*, Sections 23.6 and 23.22. It will be essential to retain one or both of these clauses in the final version.

[250] *Draft 2014 Implementing Agreement*, Section 24.5, p. 89. Section 24.20, p. 92, also states "This Agreement will be governed by and construed in accordance with the laws of the United States and the State of California."

Source: BDCP Draft Environmental Impact Statement/Report, Chapter 2, *Project Objectives and Purpose and Need,* pp. 2-4 to 2.5.

The CEQA-oriented Purpose Statement is similar.[251]

Our comments in this section focus on many ways in which BDCP violates the Delta Reform Act of 2009, the California Water Code, the federal Clean Water Act and the California Porter-Cologne Water Quality Control Act, the federal Endangered Species Act, the California Constitution's ban on waste and unreasonable use and unreasonable method of diversion of water, and the Public Trust Doctrine. We make a case for excluding the Bay Delta Conservation Plan from the Delta Plan. The Purpose and Need statement, intended to comply with National Environmental Policy Act requirements, is excerpted here; in Section VII we describe how the omission of the Twin Tunnels' role in expanding California's cross-Delta water transfer market from the EIR/EIS's purpose and need violates both CEQA and NEPA. And we recommend BDCP's Implementation Office come under the Brown Act to ensure public access and well-noticed open meetings, in Section VI.

A. BDCP is contrary to the Delta Reform Act.

BDCP Applicants construe their responsibilities under the Delta Reform Act of 2009 far too narrowly. That analysis focuses almost entirely on Water Code Section 85320, which sets out special findings the California Department of Fish and Wildlife must make, and briefly describes an appeal process to the Delta Stewardship Council.[252] There are numerous other sections with which BDCP must also comply, and which are ignored in the limited policy analysis provided by BDCP in the EIR/EIS and its appendices.

1. BDCP and its environmental impact report and statement fail to properly consider what it will take to recover Delta ecosystems and restore fisheries.

California Water Code Section 85320 lays out a process through which BDCP must go before the California Department of Fish and Wildlife prior to receiving approval of its natural communities conservation plan and incidental take permit application package and issuance of incidental take permits. Section 85320(b)(2) lists among the special findings CDFW must make:

> (A) *A reasonable range of flow criteria, rates of diversion, and other operational criteria* required to satisfy the criteria for approval of a natural community conservation plan as provided in subdivision (a) of Section 2820 of the Fish and Game Code, *and other operational requirements and flows necessary for recovering the Delta ecosystem and restoring fisheries under a reasonable range of hydrologic conditions, which will identify the remaining water available for export and other beneficial uses.*[253]

BDCP cannot demonstrate compliance with, and the Department of Fish and Wildlife will be unable to sustain, this required finding without abusing its discretion to interpret this law.

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[251] BDCP Draft Environmental Impact Statement/Report, Chapter 2, *Project Objectives and Purpose and Need,* pp. 2-2, lines 21-35; 2-3, lines 1-38; and 2-4, lines 1-6. Hereafter cited as "EIR/EIS."

[252] This narrow treatment is exemplified in EIR/EIS, Appendix 3A, *Identification of Water Conveyance Alternatives, Conservation Measure 1*, Table 3A-15, p. 3A-149. It erroneously assumes that hydrologic conditions, flow criteria, diversion rates, and conveyance designs are the universe of appropriate selection criteria for "a reasonable range of alternatives" for BDCP.

[253] Emphasis added.

BDCP modeling results show decreased salmonid survival rates, increased Delta smelt entrainment risk (including at the North Delta intakes), eastward migration of X2, reduced Delta outflow, and longer residence times of water passing through the Delta. The trend of each of these indicators is away from the criterion in Water Code Section 85320(b)(2)(A), which calls for flows necessary for recovering the Delta ecosystem and restoring fisheries under a reasonable range of hydrologic conditions.

The BDCP fails to identify the amount of flow necessary for recovering the Delta ecosystem and restoring fish populations, and *only then* identify the *remaining* amount of water for export and other beneficial uses. For example, if the amount of flow required to recover the Delta ecosystem and restore fisheries corresponds to at least the amount identified in the SWRCB's August 2010 flow criteria report, along with corresponding levels for other areas of the system, then the EIR/EIS must include an alternative that reserves such flows for instream purposes and *then* identifies remaining water for exports and other beneficial uses. (Alternatively, the EIR/EIS could itself analyze the amount of flow that would recover the Delta and restore fish populations through new alternatives that provide additional in-Delta flows over and above what the SWRCB recommended.) Without a single alternative assessing the flows needed to "[recover] the Delta ecosystem and [restore] fisheries" first and foremost, the BDCP fails to meet the requirements of the Delta Reform Act.

Moreover, only *one* alternative, Alternative 8, approximates "other operational requirements and flows necessary for recovering the Delta ecosystem and restoring fisheries." This is the only alternative that gestures toward complying with the additional provision of this section that after "identifying the flows necessary for recovering the Delta ecosystem and restoring fisheries…" then identifies "the remaining water available for export and other beneficial uses." Alternative 8 indicates that once public trust flows needed to recover the Delta and restore fisheries are supplied, there will only be on average about 3.1 million acre-feet of exports available for "export and other beneficial uses." Even so, the EIR/EIS evaluation of Alternative 8 analyzes neither quantitatively nor qualitatively whether the Delta ecosystem will recover and fisheries will be restored to the point of meeting the goal of ecosystem recovery in the Delta. Moreover, it will also construct a Twin Tunnels Project on the scale of Alternative 4 with all the attendant hydrodynamic problems associated with that alternative. In salmonids' case, federal and state statutory abundance doubling goals should be the standard against which Water Code Section 35820(b)(2)(A) should be evaluated, but the EIR/EIS fails to provide that evaluation.[254]

2. BDCP and its environmental impact report and statement fail to properly comply with the Delta Reform Act's co-equal goals.

The Delta Reform Act's "co-equal goals" are defined as:

> the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.[255]

The Bay Delta Conservation Plan fails to protect, restore, and enhance Delta ecosystems through recovery and survival of listed species, as we have described above in our comments in Section III above..

[254] We refer here to the Central Valley Project Improvement Act of 1992, Section 3406(b)(1), and California Fish and Game Code Section 6902(a).

[255] California Water Code Section 85054.

Thus, the Bay Delta Conservation Plan also fails to "improve the water conveyance system," as required by Water Code Sections 85020(f). This section does not set forth criteria or standards by which improvements to the conveyance system of the Delta are to be judged. But when viewed from the standpoint of the supposedly co-equal goals of the Delta Reform Act, the Twin Tunnels project unbalances the coequal goals. It fails (as do most of CMs 2 through 22) to protect, restore and enhance the Delta ecosystem. Thus, its proposed conveyance system, the Twin Tunnels project, cannot be found to "improve the water conveyance system" over what exists in the Delta now. And its hoped-for water supply reliability may fall short because California's climate is likely to yield fewer wet and above normal years on which Twin Tunnels water supply reliability claims depend.

The BDCP also fails to comply with California Water Code Section 85020(g) which states:

> "The policy of the State of California is to achieve the following objectives that the Legislature declares are inherent in the coequal goals for management of the Delta:
> ...(g) Reduce risks to people, property, and state interests in the Delta by effective emergency preparedness, appropriate land uses, and investments in flood protection."

The BDCP does not comply with WC Section 85020(g) because it does not consider any Delta levee improvements in its project purpose/objectives, nor among the other measures of its conservation strategy. In fact, BDCP's EIR/EIS affirmatively excludes Delta levee improvements in its analysis of cumulative impacts (see Section VII below). It only considers new Delta conveyance as a means of reducing future impacts to water deliveries from sea level rise and seismic or other levee failure. It does not consider Delta levee improvements as a means of reducing flood risk not only to water conveyance , but also to the people, places and infrastructure of the Delta.

The omission of Delta levee improvements flies in the face of the Delta Protection Commission's Economic Sustainability Plan that states that levees can be brought up to the PL 84-99 standard to reduce the probability of catastrophic levee failure for $2 to $4 billion. To be consistent with Water Code Section 85020(g), BDCP would have to include a goal (and implementing conservation measures and funding assurances) to improve critical Delta levees for both ecosystem restoration and water supply reliability.

3. BDCP and its environmental impact report and statement fail to comply with Water Code Section 85021

It is state policy to reduce reliance on diversions from the Delta (Water Code Section 85021[256]). However, the project objectives and purpose call for "full contract deliveries" to CVP and SWP contractors. According to USEPA[257], that volume of water is 7.43 million acre-feet, nearly a million acre-feet more than the maximum amount of water ever diverted from the Delta in a single year. This BDCP outcome would increase, not reduce, reliance on the Delta for imported water. While the federal purpose clarifies that alternatives providing less than full contract deliveries is acceptable, the objective/purpose to work toward meeting full CVP and SWP contract deliveries is clearly an attempt to increase Delta diversions, not reduce them. This is a fundamental flaw in the BDCP EIR/EIS.

Figure 5.B.4-4, cited above, Section III, shows BDCP modeling results that show the state and federal export pumps will increase reliance on the Delta in wet and above normal years. It should also be

[256] See footnote 217, above.

[257] See June 2010 letter from USEPA to USBR, NMFS and USFWS. Accessed at http://www.c-win.org/webfm_send/150

noted that in drought years, the Bureau and DWR habitually petition the State Water Resources Control Board to have Delta water quality standards waived on vague grounds of protecting "health and safety" for their contractors. The Board has yet to refuse these requests, in defiance of legal due process, and there is no reason to think that they would if a Twin Tunnels system is constructed and operated in a manner vastly different that what is modeled in BDCP and the EIR/EIS. In any event, BDCP modeling and expected reliance on "real-time operations" will continue and expand reliance on the Delta for exports.

By definition of the project's purpose, need, and design of each of the alternatives, BDCP violates California Water Code Section 85021, which requires reduced reliance on the Delta for future water supplies among those already depending on the Delta. The project's operational goals focus on increasing reliance on the Delta for North Delta Intake diversions during wet and above normal years, while continuing emphasis on South Delta diversions for export in all other water years.[258]

BDCP Applicants fail to demonstrate in BDCP documents what they have done locally and regionally to decrease their reliance on Delta imports/exports and yet still justify each of their needs for the Twin Tunnels project, so there is no analysis provided in the EIR/EIS or in the Bay Delta Conservation Plan that shows actions by the Applicants that would counteract this apparent increase in reliance on Delta exports by BDCP.

BDCP's obsessive focus on full contract deliveries, north Delta diversions to the Twin Tunnels, and extensive habitat restoration come at exclusion of other potential actions. The coequal goals of the 2009 Delta Reform Act can be met by other activities less disruptive to the Delta such as levee improvements, increased Delta outflows and regional self-reliance for water through investment in water use efficiency, water recycling, advanced water technologies, local and regional water supply projects, and improved regional coordination of local and regional water supply efforts. But no such actions are analyzed in the EIR/EIS by the Applicants.

Finally, as we describe more fully in Section VII, an undisclosed purpose and need for the Twin Tunnels is to expand California's cross-Delta water transfer market. This transfer activity will occur typically in years when State Water Project contractual allocations are 50 percent or lower, and Central Valley Project contractual allocations are 40 percent or lower. As climate change in California unfolds, these transfer market triggers are likely to increase, solidifying increased, not decreased reliance on the Delta. This is contrary to Water Code Section 85021.

4. BDCP and its environmental impact report and statement fail to demonstrate compliance with 85086(c)(1) by eliminating consideration of the Delta flow criteria adopted by the State Water Board in August 2010.

Water Code Section 85086(c)(1) states that *"For the purpose of informing planning decisions for the Delta Plan and the Bay Delta Conservation Plan, the board shall, pursuant to its public trust obligations, develop new flow criteria for the Delta ecosystem necessary to protect public trust resources."* However, the BDCP project objectives/purpose statements do not even mention the SWRCB's 2010 "Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem." While strict compliance with the SWRCB's flow criteria is not required, it is required by the Delta Reform Act that they be used for planning purposes for BDCP, yet it is not analyzed in the EIR/EIS. BDCP only puts forward alternatives that construct habitat and generally decrease Delta outflow. But it does not consider that aquatic ecosystem restoration could be achieved by increased Delta

[258] Bay Delta Conservation Plan EIR/EIS, Chapter 5, Water Supply, Figures 5-22 (wet years) and 5-23 (dry years).

outflows. The Delta Flow Criteria report in fact pointedly states that flow and habitat are both needed to recover the Delta. ***Therefore, the BDCP project objectives and purpose are inconsistent with yet another section of the Delta Reform Act.***

The 2010 Delta Flow Criteria Report[259] was rejected as an alternative by BDCP Applicants on grounds that modeling showed that the State Water Board's flow criteria would allegedly result in widespread dead pools in and depleted deliveries from upstream reservoirs, which would violate BDCP EIR/EIS alternative screening criteria. The Board included DWR's analysis as an appendix to the Draft Delta Flow Criteria report in July 2010. Once out for public review, the modeling results (Appendix B "Water Supply Modeling" of the draft report) were roundly criticized from many quarters, because it exceeded the charge of Water Code Section 85086, had not been included for expert and public review in the informational proceedings, and had not been peer-reviewed prior to its release. In putting the water supply impact appendix forward, DWR tried hard to reframe the agenda of the Delta Flow Criteria process after the proceeding yielded results they did not like. The primary reason reservoirs would go to dead pool in their analysis was that the modeling criteria simultaneously maximized Delta inflows, outflows, and south of Delta deliveries at the expense of prudent carry-over for dry year or drought conditions. CVP and SWP operators made a related point to consulting engineer and modeler Walter Bourez when interviewed about BDCP modeling in 2013 that they would not operate the reservoirs that way; they would definitely try to optimize reservoir releases for meeting Delta water quality objectives, manage cold-water pools, while meeting senior water rights and making releases available for deliveries as best they could.[260] The approved report in August 2010 does not include DWR's suspect modeling appendix.

The point of the Delta flow criteria proceeding was to answer the question of "what flows do fish need?" ***This is needed to determine the public trust instream flow needs for the Delta. Under the public trust doctrine and Water Code Section 85320, only what flows remain after such analysis should be allocated to SWP and CVP contractors. Deletion of the DFC report as a BDCP alternative removed a scientifically informed and reasonable option from consideration, yet another disservice of this EIR/EIS.***[261]

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[259] See footnote 59 above.

[260] Of the assumptions disclosed for the impact analysis in the 2010 modeling effort by DWR, the analysis assumes "full entitlements for CVP and SWP contractors." This was and is still not a reasonable assumption, given the constraints placed on CVP and SWP Delta operations to keep their uses and diversions reasonable under the law. "Full entitlements" is also an ambiguous term; it could be interpreted as full contractual entitlements regardless of water year type, or according to water year type. It could also mean "no net loss to exports," as well. This ambiguity is neither identified nor clarified in DWR's 2010 modeling of impacts in 2010. The California Water Impact Network and the California Sportfishing Protection Alliance pointed out to the State Water Board that it was application of "full entitlements" to Delta exports and water project operations in the Delta that led to the Legislature's passage of Water Code Section 85086 and to preparation of the Delta Flow Criteria Report in the first place. Letter of Carolee Krieger and Bill Jennings to Charles Hoppin, Chair, State Water Resources Control Board, "Comment Letter - Draft Delta Flow Criteria Report," July 28, 2010, 2 pages. Accessible online 12 May 2014 at http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/comments072910/carolee_krieger.pdf.

[261] Appendix 3A, p. 3A-67, lines 40-48 to p. 3A-68, lines 1-14; and Draft Delta Flow Criteria report accessible online 4 May 2014 at http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/.

5. BDCP and its environmental impact report and statement fail to demonstrate how its Twin Tunnels complies with the Reasonable Use and Public Trust Doctrines, mentioned in Water Code Section 85023, which states that these doctrines are "particularly important and applicable in the Delta."

The EWC has located no analysis in the BDCP documents that evaluate the proposed/preferred alternative from the standpoint of its compliance with Article X, Section 2 of the California Constitution, or of its compliance with the Public Trust doctrine. Evaluation of this action is required by Water Code Section 85023 to demonstrate this compliance.

6. BDCP and its environmental impact report and statement fail to demonstrate compliance with Water Code Section 85031(a), specifically area of origin laws and doctrines that apply to the Delta.

This section of the California Water Code requires that actions contemplated under the Delta Reform Act comply with area of origins water rights statutes. BDCP fails to demonstrate through its modeling results that it complies with Water Code Sections 12200-12205 (the Delta Protection Act of 1959). Delta outflow is reported by BDCP to decrease while residence times of water in the Delta increase. In-Delta salinity levels are projected by BDCP to increase which will reduce the quality of water for in-Delta agricultural uses for irrigation and the beneficial uses enjoyed by environmental justice communities whose members rely on subsistence fishing in the Delta for a significant portion of their diet and nutrition. Reverse flows on the lower Sacramento River will increase, which may injure neighboring water right holders. And subsistence fishers may be harmed by worsening mercury and selenium concentrations contaminating fish tissues in the long term, resulting from BDCP water operations and habitat restoration activity. ***BDCP has conducted no analysis of in-Delta water demand and subsistence fishing patterns represented by these beneficial uses when it conducts its operational studies of the BDCP and the Twin Tunnels project. These uses are protected by the Delta Protection Act of 1959.***

BDCP also fails to demonstrate how the proposed Twin Tunnels project complies with county and area of origin laws.

In addition, BDCP fails to identify the role of the ***Delta common pool*** in shaping the experiences of environmental justice communities and the informal ways in which they make use of Delta habitat, fish, and other resources for their subsistence and recreation. They are beneficial users of water via the common pool and its public trust resources. The California Department of Water Resources recognizes the Delta common pool for purposes of analyzing and regulating water transfers.[262] BDCP must recognize the common pool as it contemplates its development schemes.

The Delta Protection Act of 1959 affirms area of origin water rights in the Delta. It declared that "a general law cannot be made applicable to [the] Delta and that the enactment of this law is necessary for the protection, conservation, development, control and use of the waters in the Delta for the public good."[263]

The Delta Protection Act of 1959 further states that maintenance of an adequate water supply in the Delta and provision of Delta exports to areas of water deficiency "is necessary to the peace, health, safety and welfare of the people of the State" consistent with area of origin rights of all other areas

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[262] California Department of Water Resources, *op. cit.*, footnote 27, above, p. 3.

[263] California Water Code Section 12200.

recognized in the Water Code.[264] This law requires the State Water Project and the Central Valley Project to provide salinity control and "an adequate water supply for the users of water in the Sacramento-San Joaquin Delta."[265] It further prohibits any "person, corporation, or public or private agency or the State or the United States" from diverting water from the Delta "***to which the users within said Delta are entitled.***" Moreover, "in determining the availability of water for export from the Sacramento-San Joaquin Delta ***no water shall be exported which is necessary***" to meet the Delta Protection Act's requirements.

In determining the water available for export from the Delta, the law requires that "no water shall be exported which is necessary to meet" the requirements of the Delta Protection Act.[266] Passage of the Delta Protection Act predates the water rights of the State Water Project in the Delta.

Unfortunately, this law has never been adequately enforced in the Delta because the availability of water has never been determined by the State Water Resources Control Board or its precedent agencies. Moreover, in-Delta demand for various beneficial uses of water has also never been studied, though Appellate Justice John Racanelli directed the State Water Board to do so in 1986 as part of its water quality planning role. The State Water Board has never conducted water availability analysis for its water quality control plans or its implementing water rights decisions, even though required to in the Racanelli Decision.[267]

But the State's persistent inattention to court direction does not mean the common pool protections called for in the Delta Protection Act of 1959 lack authority. The water rights and beneficial uses protected by this law protect the rights of environmental justice community subsistence anglers and community members at play on the shores and in the waters of the Delta. Appellate Justice John Racanelli long ago required the State Water Board that its public trust and Clean Water Act obligations were to protect water rights and all other beneficial uses of water whether they were the subject of water rights claims or not. This means that the beneficial uses of environmental justice communities must also be protected. ***The State has failed to fulfill its obligation to follow water quality and water rights law and now the BDCP Applicants fail to conceive of the regulatory setting and affected environment of the proposed action broadly enough to account for the importance of the Delta common pool for environmental justice communities in the Plan Area.***

7. BDCP and its environmental impact report and statement fail to demonstrate how its proposed new points of diversion for the State Water Project will comply with Water Code Section 1700, *et seq.*

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[264] California Water Code Section 12201.

[265] California Water Code Section 12202.

[266] California Water Code Section 12205.

[267] *United States v. State Water Resources Control Board* (1986) 182 Cal.App.3d 82. Justice Racanelli wrote, "In performing its dual role [of regulating water quality and water rights]...the Board is directed to consider not only the availability of unappropriated water but also *all* competing demands for water in determining what is a reasonable level of water quality protection [citation]. In addition, the Board must consider 'past, present, and probable future beneficial uses of water [citation] as well as '[water] quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area." Water quality protection is achieved in part by the Board's regulation of water rights as an implementation tool.

This section of the California Water Code addresses State Water Board regulation of changes in the point of diversion, place of use, or purpose of use. The BDCP is required by the Delta Reform Act to comply with the California Water Code.[268] The BDCP Applicants provide no analysis in either the BDCP or its EIR/EIS as to whether the proposed Twin Tunnels project and its habitat conservation plan comply with the California Water Code.

The North Delta Intakes for each of the alternatives will represent changes in the point of diversion of the State Water Project. No analysis of whether these proposed changes would potentially injure neighboring water rights holders is provided in either the water supply section or the surface water treatments of the EIS/EIR.

In addition, Conservation Measure 21, *Nonproject Diversions* contemplates actions to minimize entrainment of covered fish in smaller agricultural diversions that are unrelated to the mega-diversions of the state and federal Delta export pumps. These actions include

> 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….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.[269]

The EWC believes this "conservation measure" directly threatens in-Delta water users with loss of their diversions by harassment. "Remedial actions" contemplated by BDCP's Implementation Office would identify landowners who operate diversions identified by the technical team for CM 21 as "a high priority for remediation" who will be "invited to participate in CM21 "subject to funding availability." Such landowners, it appears, would sign "a certificate of compliance committing them to the process and terms of this conservation measure."[270]

The EWC finds this to be the height of hypocrisy for the lead BDCP Applicant, the California Department of Water Resources, to be planning to remediate nonproject diversions when DWR includes in BDCP no plans whatsoever to install fish screens at the Banks Pumping Plant—screens which were planned as part of the CalFED Record of Decision in 2000, but which were scrapped when state and federal water contractors refused to pay for them. The "nonproject diversions" targeted by BDCP are small indeed compared to the horrific salvage operations carried out at the state and federal pumping plants on a daily basis.

Conservation Measure 21 appears to be a thinly veiled program to eliminate water diversions that might otherwise assert water rights in the north Delta that could otherwise be injured by the North Delta Intakes of the Twin Tunnels project. Eliminating these nonproject diversions through a "conservation measure" in advance of obtaining the water rights permits will

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[268] California Water Code § 85031(c), which states, "Nothing in this diversion [meaning Division 35, the Delta Reform Act of 2009] supersedes, limits, or otherwise modifies the applicability of" the provisions of the California Water Code that address changing a point of diversion, a use, place or purpose of use of water, "including petitions related to any new conveyance constructed or operated" as may be approved by the California Department of Fish and Wildlife under Water Code Section 85320.

[269] Bay Delta Conservation Plan, Chapter 3, Section 3.4.21, *Conservation Measure 21 Nonproject Diversions*, p. 3.4-339, lines 20-27.

[270] BDCP, Chapter 3, *Conservation Strategy*, p. 3.4-341, lines 201-23.

facilitate the State Water Board's ability to make a finding of "no injury" to other water rights holders in the north Delta.

Similarly, conversion of privately-owned agricultural land to restored habitat under the BDCP's other restoration-focused conservation measures would also reduce or eliminate water diversions that might otherwise assert water rights in the north Delta that could otherwise be injured by BDCP's new points of diversion.

B. The Bay Delta Conservation Plan will injure other water right holders in the Delta in violation of California water law.

BDCP fails to identify other water right holders in the Plan Area, and those that would be directly and indirectly affected by North Delta diversions, installation of new flow and fish control structures. Most are right holders senior to SWP and CVP water rights in the Delta. New diversions and facilities do not improve the priority of SWP and CVP water rights.

While in recent years many Delta water rights were challenged, the vast majority were found after extensive investigation by the Delta Water Master to be robust and supported by substantial evidence.[271]

It appears to us that the only consideration of water rights injury that BDCP has undertaken is from Appendix 3A of the EIR/EIS, shown below, in relation to screening of alternatives.

BDCP asks whether alternatives would "result in impairment" (the legal term here ought to be "injury") of existing senior water rights in the Delta's watershed "who are not applicants for incidental take authorization" under BDCP. The first sentence of "results" states that BDCP alternatives "that have been consistent with the three levels of screening criteria" would not "require changes in legal rights". In the event that senior water right holders were injured, it is DWR's rights, and perhaps those of the Bureau's in the Delta, that would "require changes" to their water rights permits. This must be the case because it would have to follow California's law of water rights priorities. Moreover, the last clause of the first sentence adds, "although legal ownership may change due to sale of property."

In Figure 13, we interpret the first sentence to mean "none of the BDCP alternatives would injure legal water right holders because we would compensate them for their property as required by the 5th amendment of the US Constitution," requiring just compensation from the government when taking private property for some public use or benefit.

However, the second part of this answer, relating to why two other alternatives (including the State Water Board's 2010 Delta Flow Criteria alternative) incorrectly states that "these alternatives would result in reductions in water deliveries to Sacramento River water rights holders in order to achieve the flow and water quality objectives in these operations alternatives." ***This explanation is a distortion. It fails to acknowledge that the vast majority of Sacramento River water rights holders are senior to the rights of the Bureau on the Sacramento River. It ignores the State Water Project's even more junior priority on the Feather River and in the Delta. This explanation is only possible when reasonable alternatives are interpreted to reflect the narrow objectives and purposes BDCP (especially the California Department of Water Resources) has improperly construed from the Delta Reform Act of 2009.***

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[271] Craig M. Wilson Delta Watermaster, *Water Right Compliance and Enforcement in the Delta*, A Report to the State Water Resources Control Board and the Delta Stewardship Council, presented February 7, 2012, 9 pages. Accessible online April 28, 2014, at http://www.swrcb.ca.gov/board_info/agendas/2012/feb/020712_9_with%20report.pdf.

Figure 13

Table 3A-17. Determination of Consistency of with Legal Rights of Entities that are Not BDCP Participants

If the answer to this question is "Not Likely" or "Unknown," the alternative would be considered in the EIR/EIS. If the answers to this question are "LIKELY" or "YES," the alternative would not be considered in the EIR/EIS.	
Measures of Consistency	**Results**
Would the potential alternative result in the impairment of existing senior water rights in the Sacramento-San Joaquin Rivers watershed who are not applicants for incidental take authorization through the proposed Bay Delta Conservation Plan?	No for the range of conveyance alternatives that have been consistent with the three levels of screening criteria would not require changes in legal rights although legal ownership may change due to sale of property. However, the answer would be Likely for Second Screening Dual Conveyance Alternative 8A, which includes operations alternatives based on Scenario 7a, and Second Screening Dual Conveyance Alternative 9A, which includes operations alternatives based on the State Water Resources Control Board 2010 Flow Recommendations for Delta Ecosystem. Based upon preliminary model analyses, both of these alternatives would result in reductions in water deliveries to Sacramento River water rights holders in order to achieve the flow and water quality objectives in these operations alternatives.

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In both "results" in Table 3A-17, DWR and BDCP Applicants reveal themselves as the predators —preying on smaller water right holders as part of a conniving water grab—for new water supply that our member groups have long suspected them of being.

C. The Bay Delta Conservation Plan will degrade water quality and harm beneficial uses in the Delta in violation of the federal Clean Water Act and the California Porter-Cologne Water Quality Control Act.

The BDCP and its EIR/EIS acknowledges (even factoring in climate change effects) that residence time of water in the Delta will increase, Delta outflow will decrease, mercury and selenium in fish tissues will increase, raising public health concerns. And salinity levels will increase throughout the Delta, creating water quality havoc for boaters, agricultural irrigators, and sport- and subsistence fishing. We document these findings and concerns in Sections III and VII of this comment letter.

BDCP's stated objectives and purpose for water quality are only in relation to physical and operational improvements to the state and federal water projects in the Delta. In BDCP's view, environmental water quality and human public health are secondary to the quality of water exported by the state and federal water projects. No mention is made of improving water quality for communities whose water supplies are adversely affected.

These impacts would be adverse under NEPA.[272] They would be part and parcel of approving BDCP; to approve BDCP entails acceptance by the fishery agencies that these other significant and unavoidable, adverse effects will occur. In making such approvals, the EWC contends that making such a decision would be arbitrary and capricious of the agencies, and therefore be contrary to law under the federal Clean Water Act and the state Porter-Cologne Water Quality Control Act (see our analysis below Section VII).

D. The Bay Delta Conservation Plan will continue and promote further wasteful and unreasonable uses of water and methods of diversion of water, contrary to Article X, Section 2 of the California Constitution and California Water Code Section 100.

BDCP would be contrary to Article X, Section 2 of the California Constitution and California Water Code Section 100 because it violates:

- Various sections of the Delta Reform Act of 2009 identified here in Section VI.
- State and federal clean water legislation and regulation.
- California Water Code's no injury rule.
- Ecological and funding assurance requirements of the state and federal ESAs and state NCCPA.
- The Delta Protection Act of 1959 - the Delta's area of origin water rights.

E. ESA and NEPA violations are precluding meaningful public review.

The Twin Tunnels would divert enormous quantities of water from the Sacramento River near Clarksburg, California.[273] As a result of this massive diversion, enormous quantities of water that presently flow through the Sacramento River and sloughs to and through the Sacramento-San Joaquin Delta would not reach the Delta, and flows would be reduced in the Sacramento River and sloughs. Also, there would be adverse cumulative effects ranging from rising sea levels and reduced snowpack and runoff due to climate change to changes in upstream reservoir operations and current preservation of flows for fishery purposes all the way upstream to the Shasta, Trinity, Oroville, and Folsom reservoirs. The Twin Tunnels are identified as Alternative 4, the California Department of Water Resources (DWR)' Preferred Alternative.[274]

The Sacramento River Winter Run Chinook Salmon is listed as an endangered species under the ESA. The Central Valley Spring Run Chinook Salmon, Central Valley Steelhead, Southern Distinct Population Segment of North American Green Sturgeon, and Delta Smelt, are listed as threatened species under the ESA. The reaches of the Sacramento River, sloughs, and the Delta that would lose significant quantities of freshwater and freshwater flows through operation of the proposed Twin Tunnels are designated critical habitats for each of these five listed endangered and threatened fish species. Yet in complete disregard of these undisputed facts, no Biological Assessment has been prepared and issued by the federal Bureau of Reclamation with respect to the Twin Tunnels project. Also, no final or even draft Biological Opinion has been prepared by the National Marine Fisheries

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[272] BDCP EIR/EIS, *Executive Summary*, Table ES-9 reports several adverse water quality effects of the proposed action: WQ 11, 13, 14, and 25 We argue that they fail to find adverse effects where they should in WQ-12, and 26..

[273] Comments in this section are drawn from Letter of E. Robert Wright, Senior Counsel, Friends of the River, "Preliminary comments on fundamental BDCP Violations of the ESA," March 6, 2014. Accessible online June 4, 2014, at http://www.friendsoftheriver.org/site/DocServer/Atc_12.pdf?docID=8312.

[274] BDCP Draft EIR/EIS, page 3-3.

Service (NMFS) or U.S. Fish and Wildlife Service (USFWS) with respect to the impacts of the operation of the Twin Tunnels on the five listed species of fish or their critical habitats.

The failure to prepare Biological Assessments and Biological opinions prior to issuing the BDCP draft Plan and EIR/EIS for what in the absence of those documents deliberately causes uninformed public review is astonishing. The Ninth Circuit Court of Appeals has repeatedly held that: "Any possible effect, whether beneficial, benign, adverse or of an undetermined character, triggers the formal consultation requirement."[275] We doubt that even the ardent advocates for the Twin Tunnels who prepared the 40,000 pages of BDCP advocacy documents would contend that taking large quantities of water away from the River, sloughs, and Delta does not have "any possible effect, whether beneficial, benign, adverse or of an undetermined character."

The ESA Regulations (50 C.F.R. § 402.14(a)) require that "Each Federal agency shall review its actions *at the earliest possible time* to determine whether any action may affect listed species or critical habitat. If such a determination is made, formal consultation is required. . . ."[276] The Biological Assessments and Biological Opinions are the written documents that federal agencies must prepare during the ESA consultation process. The NEPA Regulations require that "To the fullest extent possible, agencies shall prepare draft environmental impact statements concurrently with and integrated with environmental impact analyses and related surveys and studies required by the. . . Endangered Species Act. . . ."[277]

The Biological Opinion is to determine "whether the action, taken together with cumulative effects, is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat." 50 C.F.R § 402.14(g)(4).

Consequently, against this threat of extinction, conducting the draft EIR/EIS public review and comment stage without Biological Opinions or even Biological Assessments and draft Biological Opinions, leaves the public in the dark and violates both the ESA and NEPA. Conducting the NEPA environmental draft process prior to and in a vacuum from the ESA consultation process violates the ESA command to carry out the ESA process "at the earliest possible time" and violates the NEPA command to conduct the NEPA and ESA processes "concurrently" and in an "integrated" manner.

In the absence of answers to basic questions including ESA questions about jeopardy of listed fish species and adverse modifications of designated critical habitats, the draft BDCP EIR/EIS is not sufficient for informed review by the public and the decision-makers. It will be necessary at minimum under the ESA, NEPA and CEQA for the federal and state agencies to prepare, issue, and circulate for public review a ***new draft*** EIR/EIS concurrently with and integrated with Biological Assessments and Biological Opinions.[278] Then, and only then, would the public and the decision-makers have the opportunity to engage in meaningful analysis of a preferred project alternative and informed comparison with other alternatives.

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[275] *Western Watersheds Project v. Kraayenbrink*, 620 F.3d 1187, 1210 (9th Cir. 2010). *Accord, Karuk Tribe of California v. U.S. Forest Service,* 681 F.3d 1006, 1027 (9th Cir. 2012)(en banc), *cert. denied,* 133 S.Ct. 1579 (2013); *Cal. ex rel. Lockyer v. U.S. Dept of Agric.,* 575 F.3d 999, 1018 (9th Cir. 2009).

[276] *Karuk Tribe of California v. U.S. Forest Service,* 681 F.3d 1006, 1020.

[277] 40 C.F.R. § 1502.25(a).

[278] 40 C.F.R. §§ 1502.9(a); 1502.25(a) (NEPA); 14 Code Cal. Regs. §§ 15065(a)(1); 15088.5(a)(CEQA).

F. The Bay Delta Conservation Plan violates the Public Trust Doctrine.

BDCP would further divert and degrade the Delta common pool thereby violating the rights of environmental justice communities to continue fishing in locations that would be altered and enclosed by BDCP facilities and restoration projects. The presence of this common pool in the Delta makes it subject to regulation under the Public Trust Doctrine. The state of California has a fiduciary responsibility to protect this common pool resource in all its dimensions for the common heritage of the people of California.

The State Water Project and federal Central Valley Project are coordinated water systems. Their operations upstream of the Delta and within the Delta have contributed greatly to the demise of migratory and resident fish, and BDCP documents provide ample evidence of the likelihood that operation of the North Delta Intakes will:

- Degrade water quality by increasing residence time of water and reducing Delta outflow;
- Harm Delta smelt by reducing Delta outflow, pulling X2, the low salinity zone isohaline, further east, placing Delta smelt at greater risk of entrainment and take at the North Delta intakes, in addition to the 60 percent of years (below normal, dry, and critical years) when Delta smelt will still face entrainment risk from the south Delta export pumps.
- Reduce winter-run Chinook and spring-run salmon survival rates through the Delta by introducing the North Delta intakes along the lower Sacramento River, diverting Sacramento River flows upstream into Yolo Bypass for floodplain inundation and seasonal habitat restoration.
- Fail to control biotic and abiotic stressors on listed fish species in the Delta, including invasive nonnative bivalves, submerged aquatic vegetation, methylmercury formation from construction and restoration of habitat, and increased selenium contamination well in excess of recommended toxicity thresholds, despite upstream source control activities.

These and other effects of the Bay Delta Conservation Plan and its proposed Twin Tunnels project (described in Conservation Measure 1) would, if implemented, violate the Public Trust Doctrine.

G. The Bay Delta Conservation Plan must be excluded from the Delta Plan because of these failures.

The Bay Delta Conservation Plan must be excluded from the Delta Plan it fails to comply with:

- Water Code Section 85320 in its entirety.
- Requirements to fulfill numerous ecological and funding assurances as documented above for the Bay Delta Conservation Plan itself.
- The Delta Reform Act of 2009 provisions identified here in Section VI.
- The reasonable use doctrine framed in California's Constitution and Water Code Section 100.
- The Public Trust Doctrine.

The Bay Delta Conservation Plan calls for construction and launch of operation of the Twin Tunnels project prior to the vast majority of habitat restoration activities getting financed and undertaken. This places the cart of water development before the horse of habitat restoration.

When it comes to protecting public trust resources in the Delta, this reversal of priorities (placing water supply reliability development ahead of habitat restoration) places Delta ecosystems at great risk of collapse, not recovery; places Delta listed fish species at great risk of extinction, not restoration to once robust and sustainable populations.

VII. Specific Comments on the EIR/EIS

The Bay Delta Conservation Plan EIR/EIS is an essential component of the application package to be submitted for federal incidental take permits, together with an implementing agreement and habitat conservation plan (or natural communities conservation plan in the case of application for such a permit from the California Department of Fish and Wildlife). Without an adequate EIR/EIS, the application package is incomplete and statutory findings cannot be met, issuance of the incidental take permits may be delayed or denied.

The BDCP EIR/EIS is plagued by its length and complexity. With nine alternatives and eight operational scenarios besides the No Action Alternative, every chapter of this document is at least 100 pages long, far longer than most lay readers have the time for, and far longer than most busy professional reviewers have time to parse and analyze.

Several of the chapters have lengthy and/or numerous technical appendices containing supporting detailed analyses. Similar topics can be scattered throughout six or eight different sections or appendices or chapters of the EIR/EIS. This dispersion of information and analysis creates multiple needles in multiple haystacks, easily defeating the full disclosure of accessible information about the proposed action as required by CEQA and NEPA. The EIR/EIS's Fish and Aquatic Species Chapter 11 just by itself contains 3,055 pages—4,700 pages when four related appendices are included. Review of this in tandem with the fish related appendices of the EIR/EIS's "project description"—the Bay Delta Conservation Plan in its full entirety—runs the total page count for reviewing just for fish issues into the vicinity of 10,000. Of necessity, lay readers must be strategic if they are to gain any insight into the environmental effects of the Bay Delta Conservation Plan.

The EIR/EIS's Executive Summary and index helps to a limited degree with this, but the former is not a complete summary.[279] ***It omits summaries of the impacts and mitigation measures on the last chapters of Environmental Justice and Growth Inducement. It contains no summary of cumulative impacts in the EIR/EIS.***

In order to fulfill its paramount policy requirement under both the National Environmental Policy Act and the California Environmental Quality Act, the EIR/EIS should at a minimum be revised to include summaries at the opening of every chapter that enable readers to ascertain rapidly the key findings for impacts and mitigation measures, by alternative. The summary should also state in what sections the key analyses are located, since BDCP groups narrative content under certain alternatives because effects might be similar across alternatives. This should be identified up front in each chapter. But these documents (BDCP and its EIR/EIS), by their sheer size and complexity, still defy and defeat CEQA and NEPA requirements. Readers must be able to understand it so that public decision makers may make well-informed decisions about the Plan and its Alternatives within. The EWC had one person working nearly full-time since the documents were released in December 2013 and could not review its entirety. The BDCP documents' size, complexity, and dispersion of information make this impossible, despite the six-month-long comment period.

[279] BDCP's EIR/EIS does include a general topic index, but it is not detailed enough to make its use efficient for a reader seeking specific information—one must track down each specific index page in different files. We estimate that a complete volume, hard copy of the BDCP documents costs between $3,000 to $6,000 to print and bind.

A. The EIR/EIS and Bay Delta Conservation Plan documents are incomplete because the California Department of Water Resources has been unable to collect necessary environmental survey and geotechnical data from Delta lands directly related to habitat restoration and Conservation Measure 1 facilities.

Delta landowners have successfully resisted having to permit entry to professional scientists and engineers representing the California Department of Water Resources to conduct surveys and gather data on environmental and cultural resource conditions, and surface and subsurface geotechnical conditions.[280]

Because DWR has been unable to complete the environmental, cultural, and geotechnical studies it needs to perform an adequate project-level setting and impact analysis of all biological, cultural and geotechnical/engineering resources in the Delta, the setting and impact analyses concerning these resources are necessarily deficient from the standpoint of providing full disclosure of affected environmental conditions and project effects, whether beneficial or adverse. Therefore, the BDCP Draft EIR/EIS will need to be revised, once these data are obtained, and recirculated as a Draft EIR/EIS in order to ensure the public and relevant decision makers receive full disclosure of these resources and potential impacts of BDCP.

The BDCP Applicants' presentation in Chapter 18, *Cultural Resources*, is intended to reassure lay readers and decision makers that they have performed due diligence in their efforts to document and report on cultural resources in the EIR/EIS.

> A number of standard methods such as record searches and site visits were used to determine the types and location of known cultural resources that could be affected by BDCP alternatives. Record searches were conducted and aerial photography was used for the entire study area. In addition, *surveys were conducted in accessible areas.*[281]

But to their credit, they acknowledge that "for numerous practical reasons...not all potential cultural resources in the study area could be identified."[282] This is a fatal flaw of the EIR/EIS because it means that the BDCP Applicants fail to discharge all of their duties to identify and analyze all cultural resources under NEPA, CEQA, and state and federal cultural resource laws like the National Historic Preservation Act and the Native American Graves Protection and Repatriation Act, which

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[280] The California Department of Water Resources acknowledges that it "has been unable, despite diligent efforts, to gain access to all of the private properties within the Delta on which it would like to conduct ground surveys, Environmental Site Assessments, and engineering, biological, geotechnical, archaeological, floral and faunal studies. Although DWR has been able to conduct some of the geotechnical studies it contemplated originally [by doing them off-site in neighboring river channels], it has not been able to conduct all such studies because of the court order issued April 8, 2011. DWR has challenged that court decision and is currently seeking access to land in the Delta for the purpose of conducting the geotechnical activities through the use of eminent domain. In short, DWR has done all that is reasonably feasible under the circumstances to conduct thorough investigation of all of the BDCP alternatives." BDCP EIR/EIS, Chapter 4, Appendix 4A, *Summary of Survey Data Collection Efforts*, p. 4A-11, lines 2-10. DWR lost its challenge, however, in the appellate court. See California Court of Appeal, Third Appellate District (San Joaquin), *Property Reserve, Inc. v. The Superior Court of San Joaquin County and the California Department of Water Resources*, (2014) 224 Cal.App.4th 828.

[281] BDCP, EIR/EIS, Chapter 18, *Cultural Resources*, p. 18-1, lines 25-27.

[282] *Ibid.*, p. 18-2, lines 20-21.

they must do for the EIR/EIS to be considered adequate with respect to cultural resource characterization and analysis.

> A primary reason is the fact that, in order to evaluate whether particular sites were "historic resources" or "unique archeological resources," invasive and even destructive techniques would have had to be used. Another factor was the sheer size of the study area, which made it impossible to evaluate every potential resource within any reasonable timeframe and at any reasonable cost. Moreover, the professional cultural resource specialists concluded that reasonable samples, combined with record searches and analyses of aerial photographs, would allow them to sufficiently characterize the nature of the resources and the likely effect within the footprint of the BDCP alternatives. In addition, every effort is made to avoid and minimize effects on significant cultural resources, including historic properties and historical resources. Finally, much of the Plan Area—particularly portions that could be affected by BDCP alternatives—was not legally accessible.[citation][283]

In other words, in translation: "It's probably better that we didn't have access to particular sites because our sampling methods might have harmed the resources. The Plan Area, made up of the legal Delta, Suisun Marsh, and Yolo Bypass, was too big for us to inventory all the cultural resources therein because we didn't have enough time and enough budget to do it. So, we relied on remote sensing techniques and archival records research to try to make up for that. We promise to try to avoid and minimize harm to cultural resources in the Plan Area. But (pesky) Delta landowners wouldn't let us on the lands where the alternatives would actually go, so we don't have everything we're supposed to have to comply with CEQA and NEPA. But we tried really hard to overcome these limitations." (We note in passing that this is the first time we have heard BDCP complain about its own self-inflicted Study Area.)

In court with the Delta landowners, however, California Department of Water Resources witness related a different story in testimony during the recent *Property Reserve* case.

> 7. Environmental studies, evaluations and assessments described herein are required to gather information to assess project feasibility, investigate project design alternatives, prepare the appropriate environmental documents, obtain information to identify necessary permits and define the appropriate mitigation for project impacts. Temporary entry onto the subject properties is necessary to define the current environmental setting and to perform general environmental reconnaissance of the area, as well as biological, archaeological and hydrological assessments. Assessments are surveys that are carried out within the study area of proposed project footprints and alignments that include alternative routes and projected feature sites associated with the alignments being studied. In addition, assessments must be carried out within the proposed alignments, up to five-hundred (500) feet on either side of the center-lines of alignments studied, and within and along proposed temporary right-of-ways, access roads and construction lay-down areas studied for future project alignments.[284]

DWR's environmental manager makes a compelling case that the absence of information otherwise obtainable from on-site surveys, including of archaeological resources, is vital to DWR's objective of designing, permitting, constructing, and operating the facilities called for in Conservation 1 of BDCP. Yet the BDCP Applicants (of which DWR is the lead applicant) try to put the best face on the lack of complete cultural resources information due to the lack of access to lands along the alignments of BDCP alternatives. DWR wants it both ways, depending on the context in which it is speaking. However, ***it remains true that they need the survey information for properly designing, permitting, constructing and operating the project, which the EIR/EIS must disclose, yet does***

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[283] *Ibid.*, p. 18-2, lines 21-31.

[284] *Declaration of DWR Environmental Program Manager Derrick Adachi in Support of DWR's Petition for Right of Entry*, signed September 1, 2010, provided to the trial court in the case under penalty of perjury.

not. The EIR/EIS is fatally inadequate on these grounds, in addition to other reasons we supply in our comments.

We describe additional issues with Delta cultural resources and the conduct of this EIR/EIS below in our comments on setting and impacts issues.

B. The EIR/EIS and Bay Delta Conservation Plan documents were not noticed, let alone properly noticed to or translated for the Delta's environmental justice communities.

Federal and state laws require agencies to consider environmental justice and to prohibit discrimination in their decision making processes. Title VI of the Civil Rights Act of 1964 and related statutes require that there be no discrimination in Federally assisted programs on the basis of race, color, national origin, age, sex, or disability (religion is a protected category under the Fair Housing Act of 1968). Federal Executive Order (EO) 12898 (1994) requires Federal agencies, including the United States Bureau of Reclamation, to make environmental justice part of their mission and to develop environmental justice strategies. The Presidential Memorandum accompanying the Executive Order specifically singles out NEPA, and states that "[e]ach Federal agency must provide opportunities for effective community participation in the NEPA process, including identifying potential effects and mitigation measures in consultation with affected communities and improving the accessibility of public meetings, crucial documents, and notices."

The Bureau of Reclamation has put meager administrative resources into preparing guidance for its activities on environmental justice. The Bureau relies for cover on this issue by taking US Department of the Interior goals as its own. Interior Department Goal 1 states that "The Department will involve minority and low-income communities as we make environmental decisions and assure public access to our environmental information."

Interior Department Goal 3 states:

> The Department will use and expand its science, research, and data collection capabilities on innovative solutions to environmental justice-related issues (for example, assisting in the identification of different consumption patterns of populations who rely principally on fish and/or wildlife for subsistence).[285]

In other words, the Department of the Interior, and by extension the Bureau of Reclamation and the US Fish and Wildlife Service appear to expect to foster adaptation of environmental justice communities to federal actions. However, BDCP and its EIR/EIS take no responsibility for meeting either the first goal or the third goal in the Department's Environmental Justice plan.

The State of California has defined "environmental justice" as: "the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies." Additionally, California has enacted Government Code 11135(a), which states:

> No person in the State of California shall, on the basis of race, national origin, ethnic group identification, religion, age, sex, sexual orientation, color, genetic information, or disability, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state.[286]

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[285] "Environmental Justice" web on the Bureau of Reclamation's web site, accessible online at http://www.usbr.gov/cro/sub_ej.html.

[286] California Government Code Section 11135(a)

NEPA regulations define impacts or effects to be analyzed as including "ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative."[287]

Over 35 percent of the people directly affected by negative socio-economic and environmental impacts described in the Bay Delta Conservation Plan, and commented on herein, are members of environmental justice communities, a majority of whose first-spoken language is not English. Figure 28-1 of the EIR/EIS maps the location of census tracts whose populations have significant percentages of Hispanic/Latino population in them. They reside throughout the Delta. Figure 28-2 of the EIR/EIS shows the geographic distribution of Delta residents whose incomes are below the poverty line in 2010. These Delta-area residents include farm workers within the Delta, poor residents living in rural Delta communities and town and cities of the legal urban Delta, and subsistence fishing communities found within the legal Delta and its surrounding areas.

Impacts from BDCP are expected to include relocation from their homes, loss of jobs, inability to fish for nutrition, higher water rates as urban municipal water systems will be forced to upgrade their water treatment systems, exposure to increased water contaminants like methylmercury, selenium, salt, pesticides, and other chemical toxins when recreating at county and state parks within the Delta, and inability to navigate water ways when fishing or to reach communities in a timely fashion during the 10-year construction period.

These same residents of the Plan Area and the greater Delta region have not been made aware of the project or its potential impacts on their lives and communities.

BDCP recognized that it needed to perform outreach to environmental justice communities as early as 2008 when it was preparing for a series of public workshops throughout the Delta's communities. Unfortunately, BDCP has left few traces of what EJ outreach it may have done in its extensive archive of meetings and plan documents online and in its meeting schedule involving other stakeholders.

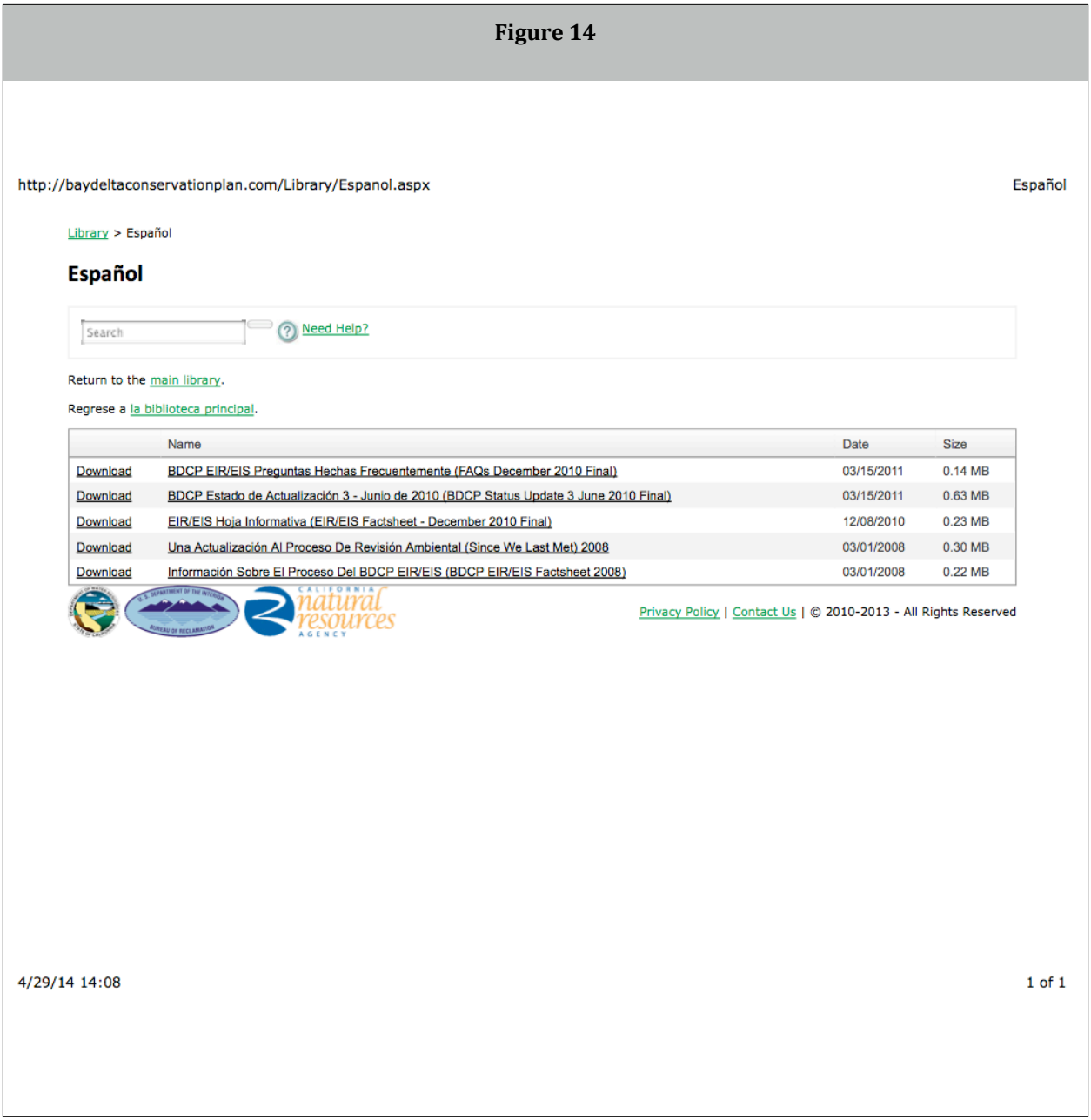
We find only these documents that have been translated into Spanish. BDCP documents, as far as we can tell, were translated into no other languages besides English and Spanish. But where there were over 40,000 pages in English, there were just 22 pages generated by BDCP in Spanish, including one web page (which printed to two pages). The pages made available in Spanish were promotional/ informational brochures. The image in Figure 14 indicates the Spanish archive of BDCP documents at www.baydeltaconservationplan.com as of April 29, 2014.

EWC member groups Restore the Delta (RTD), the Environmental Justice Coalition for Water (EJCW), and EWC consultants have researched this situation further. Our research finds that:

- Title VI of the federal Civil Rights Act of 1964 requires that "No person in the United States shall, on the ground of race, color, or national origin, be excluded from participating in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." While BDCP's funding assurances are far from clear, its funding plan in Chapter 8 of BDCP clearly indicates it anticipates obtaining at least some Federal financial assistance.

[287] 40 CFR Section 1508.8(b).

Figure 14



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- Executive Order 12898 states in pertinent part that "Each Federal agency shall conduct its programs, policies, and activities that substantially affect human health or the environment, in a manner that ensures that such programs, policies, and activities do not have the effect of excluding persons (including populations) from participation in, denying persons (including populations) the benefits of, or subjecting persons (including populations) to discrimination under, such programs, policies, and activities because of their race, color, or national origin."[288] This Executive Order further requires that each Federal agency may, whenever practicable and appropriate, translate crucial public documents, notices, and hearings relating to human health or the environment for limited English speaking populations. As

[288] Executive Order, 12898, published in *Federal Register* 59(32): February 16, 1994, section 2-2. Accessible online 13 May 2014 at http://www.archives.gov/federal-register/executive-orders/pdf/12898.pdf.

important, the Order also states that "Each Federal agency shall work to ensure that public documents, notices, and hearings relating to human health or the environment are concise, understandable, and readily accessible to the public."[289]

- There have been no notices of Bay Delta Conservation Plan community meetings or on the release of the project in any foreign language during 2014. (The official public review draft was released in December 2013.)

- An EWC request via email made through www.baydeltaconservationplan.com on April 8, 2014, to receive a copy of the Environmental Justice Community Survey Summary Report prepared by DWR and cited in the Draft EIR/EIS, Chapter 28, went unanswered until April 25, 2014. BDCP consultant's reply stated that the report "is available electronically at the DWR repository located at 3500 Industrial Blvd., Room 117, West Sacramento, CA 95961. The DWR document repository is open during regular business hours and closed on State and Federal holidays." Thus, even a request to receive a copy of the report, in a day and age when email and online file-sharing can provide nearly instantaneous transmittal of information, and is widely and often freely available, was met with an invitation to visit DWR's West Sacramento repository where an electronic version could be made available. Modern communication conveniences were apparently unavailable at the repository to fulfill this environmental justice related request until May 2nd.

- Hispanic and Asian community groups throughout the Delta region report no outreach to them concerning BDCP.

- Hispanic publications in San Joaquin County report that they received no media releases concerning community meetings on BDCP, on the release of BDCP-related documents, nor on how to participate in the comment period on BDCP documents.

- Regarding BDCP public community meetings held around the state: it appears there were no translators present, as BDCP claims. If they were, signage was not provided, nor was there indication that members of the public could ask for an interpreter at these meetings. This, combined with absence of BDCP-related media outreach to non-English language publications in the Delta region, means that as much as 40 percent of the Delta's population was precluded from participating in the comment period through May 30th, when the period was extended to July 29th.

With BDCP anticipating it would receive federal funds, the Applicants, despite being either agencies of the State of California or subdivisions of the State, must comply with Executive Order 12898. DWR has dragged its feet providing requested documents that relate to EJ issues during this comment period. Adding insult to the project's likely injuries to EJ communities, BDCP organizers made no effort that our member groups could find to reach out to EJ communities upon release of the December 2013 Plan and EIR/EIS documents in violation of standard environmental justice procedures during state and federal environmental review. This record represents a complete failure to fully inform the interested Delta region's public in violation of the spirit and letter of both the National Environmental Policy Act and the California Environmental Quality Act.

[289] *Ibid.*, Section 5-5(b) and (c).

C. The EIR/EIS is incomplete because the project description and description of alternatives fails to include analysis of the role and significance of the Implementing Agreement that is required for the incidental take permit application package by the fishery agencies.

The BDCP Implementing Agreement was released on May 30, 2014, very late in the overall BDCP public review process. This document represents the "current thinking" about that project from its proponents, according to BDCP officials. The Agreement is an essential part of implementing the governance of BDCP, which means that it must reach into every aspect of its 22 conservation measures and be accounted for in most if not all of the Draft EIR/EIS on BDCP. However, the current EIR/EIS does not "benefit" from the current thinking on BDCP, and the EWC's comments on the Draft IA will reflect the myriad ways the EIR/EIS fails to account for the role played in the BDCP framework by the Draft IA. Still unavailable to this public review process of the Bay Delta Conservation Plan are separate memoranda of understanding between the US Bureau of Reclamation and the California Department of Water Resources, which are intended to execute terms of Reclamation's extra-legal participation in and commitment to the policies and programs of the Bay Delta Conservation Plan, and the operational aspects of the Twin Tunnels project. ***Because these three agreements have not been reviewed or evaluated in the Draft EIR/EIS, the EIR/EIS should be revised to reflect their inclusion and recirculated as a draft document for further public comment.***

The Natural Community Conservation Planning Act requires each conservation plan to include an IA which contains, among other things, "provisions for establishing the long-term protection of any habitat," "provisions ensuring implementation of the monitoring program and adaptive management program," and "mechanisms to ensure adequate funding to carry out the conservation actions . . . ."[290]

For purposes of the BDCP, the IA commemorates commitments from each party under the BDCP specifying their contribution to the cost, construction, governance, and operation of the proposed project. The IA is an integral and indispensable necessity to the development and function of the BDCP. However, the BDCP Applicants who expect to benefit from the BDCP, have failed to establish each party's contribution to the cost, construction, and operation of the BDCP. Without the draft IA, it is not possible for the public to meaningfully review the draft BDCP and EIR/EIS. Accordingly, the absence of the draft IA has resulted in a violation of the National Environmental Policy Act (NEPA).[291] Our supplemental comments will examine this matter further.

Critical information is missing from the review process. For example, the BDCP proponents have been been internally admitting the obvious to the State, that "The cost of the BDCP is high, and there is significant concern that it will increase. Recent experience shows that the cost of large public works projects tends to increase during construction. The cost of the BDCP is so high there is no room for any increase in cost."[292] Another example is that the BDCP proponents seek a level of "water supply reliability of approximately 75% for both SWP and CVP water service contractors."[293]

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[290] Cal. Fish & G. Code § 2820(b).

[291] NEPA regulation 40 C.F.R. § 1502.25, Endangered Species Act (ESA) regulations 50 CFR § 17.22(b)(1)(i); § 222.307(b)(4), the California Environmental Quality Act (CEQA), and the Natural Communities Conservation Planning Act (NCCPA).

[292] Anonymous, "Critical Issues" memorandum, January 27, 2014, a one-page document obtained via a Freedom of Information Act request made to and released from the US Fish and Wildlife Service. Cited hereafter as "Critical Issues."

[293] "Critical Issues."

The water contractors also seek "Strong regulatory assurances [to] increase the willingness of local public agencies to fund the BDCP and construction of the new conveyance facilities [tunnels]."[294] Commitments like these would significantly worsen the already horrendous impacts on endangered fish species, the Sacramento River, and the San Francisco Bay-Delta resulting from operations of the massive Twin Tunnels. And they are not examined in the EIR/EIS.

It is also not possible for the public to meaningfully review the draft BDCP and EIR/EIS because of the failures, violating both the ESA and NEPA, of the federal agencies to have prepared the Biological Assessments and Biological Opinions required by the ESA relating the Bureau's Section 7 "participation" in BDCP.[295]

This absence of the critical information for public review and review by the decision-makers that would be found in the tardy Implementing Agreement, the missing MOUs between the Bureau and DWR, Biological Assessments, and Biological Opinions makes a mockery of the environmentally informed public and decision-maker review provisions and purposes of NEPA, CEQA, and the ESA. In addition, ***absence of this essential information unlawfully segments and postpones the review of those documents from the current review of the Draft BDCP Plan and Draft EIR/EIS.***

1. The late release of the Draft BDCP Implementing Agreement violates NEPA and its implementing regulations.

Under NEPA, each EIS must contain a discussion of the "environmental impacts of the proposed action . . . ." 42 U.S.C. § 4332(C)(i). An EIS "shall provide full and fair discussion of significant environmental impacts and shall inform decision-makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts . . . ." 40 C.F.R. § 1502.1.
The Draft BDCP Chapters 6, 7, and 8 frequently refer to the IA as a regulatory force of the BDCP operations, ensuring that the project will operate in accordance with law. Nowhere does the Draft BDCP or EIR/EIS list the terms or specific provisions that the IA will contain. Thus, the IA's terms and requirements are not integrated and analyzed in the EIR/EIS for the public or decision makers to review. Because the IA will directly relate to impacts and mitigation, it is a critically important component of the environmental review mandated by NEPA. Without the IA, it is impossible for the EIR/EIS to provide a "full and fair discussion" of the impacts and mitigation measures. Consequently, the EIR/EIS is incomplete and insufficient to provide meaningful public review of BDCP impacts and mitigation measures.

Under NEPA regulations, "To the fullest extent possible, agencies shall prepare draft environmental impact statements concurrently with and integrated with environmental impact analyses and related surveys and studies required by the . . . Endangered Species Act . . . ."[296] Thus, agencies must prepare environmental impact review documents concurrently.

Because the BDCP is expected to result in the take of endangered and threatened species, the parties must acquire an incidental take permit (ITP) before implementing the BDCP.[297] A party

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[294] "Critical Issues."

[295] These violations have been pointed out to you previously in comment letters by Friends of the River dated June 4, August 13, September 25, and November 18, 2013, their comment letters of January 14, and March 6, 2014, and at Friends of the River's meeting with federal agency representatives in Sacramento on November 7, 2013.

[296] 40 C.F.R. § 1502.25.

[297] 16 U.S.C. § 1539(a)(1).

applying for an ITP must submit a conservation plan that specifies, among other things, "what steps the applicant will take to *minimize and mitigate such impacts*, and the *funding that will be available to implement such steps* . . . ."[298] The Draft BDCP and EIR/EIS lack this information and suggest that it will appear in the IA.

Accordingly, the BDCP is incomplete without the IA because the BDCP does not specify any commitments the parties have made to fund and promote mitigation measures. As an impact analysis, the IA was required to have been prepared concurrently with the EIS. Nevertheless, the parties to the BDCP have failed to produce even a draft IA specifying their individual commitments to ensuring the integrity of the project. This has resulted in the staggered or piecemeal environmental review that NEPA Regulation 40 C.F.R. § 1502.25 prohibits.

2. The late release of the Draft BDCP Implementing Agreement violates ESA Regulations.

The BDCP is the heart of an application for an ITP. All applications for ITPs must include a "complete description of the activity sought to be authorized. . . ."[299] Further, all conservation plans must include "steps . . . that will be taken to monitor, minimize, and mitigate [the] impacts, and the funding available to implement such measures . . . ."[300] Before approving a conservation plan, the government must provide notice of the application and an opportunity for the public to review the application.[301]

The Draft BDCP fails to provide a complete description of the project because it does not specify the steps that will be taken to mitigate impacts and fund such mitigation. Instead, it insists that the IA will clarify details concerning mitigation measures and funding, which at present the IA does not. Consequently, the Draft BDCP and EIR/EIS lack critical information concerning how the conservation plan will address mitigation and funding requirements, rendering the review period inadequate under ESA Regulations.

3. The late release of the Draft BDCP Implementing Agreement violates CEQA.

Under CEQA, California agencies must make draft EIRs available for public review and comment.[302] An EIR "shall include a detailed statement setting forth . . . [a]ll significant effects on the environment of the proposed project" and "[m]itigation measures proposed to minimize significant effects of the environment . . . ."[303] Regulations define *project* to mean "the *whole of an action*, which has a potential for resulting in either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment . . . ."[304] Before approving a proposed project, the "lead agency shall determine whether a project may have a significant effect on the

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[298] 16 U.S.C. § 1539(a)(2)(A)(ii) (emphasis added).

[299] 50 C.F.R. § 17.22(b)(1)(i).

[300] 50 C.F.R. § 222.307(b)(5)(iii).

[301] 16 U.S.C. § 1539(c).

[302] 14 CCR § 15087.

[303] Cal. Pub. Res. Code § 21100(b).

[304] 14 CCR § 15378(a). Emphasis added.

environment based on *substantial evidence* in light of the whole record."[305] *Substantial evidence* does not include "speculation" or "unsubstantiated opinion"; on the contrary, *substantial evidence* includes "facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts."[306] Courts applying CEQA have held over and over that:

> An accurate, stable and finite project description is the sine qua non [absolutely indispensable requirement] of an informative and legally sufficient EIR. [Citation]. However, a curtailed, and enigmatic or unstable project description draws a red herring across the path of public input. [citation] Only through an accurate view of the project may the public and interested parties balance the proposed project's benefits against its environmental cost, consider appropriate mitigation measures, assess the advantages of terminating the proposal and properly weigh other alternatives.[307]

The IA is part of the project but was not even placed before the public for review until late during the Draft EIR/EIS public review period. Because the IA will contain critical project information that is not in the Draft EIR/EIS, the Draft EIR-EIS does not describe the *whole of the action*. Consequently, the EIR-EIS fails to provide an "accurate view of the project" and the public is prevented from understanding how the proposed project will operate. Further, this missing information demonstrates that the incomplete EIR/EIS fails to support its conclusions as to the impacts of the project. Whereas CEQA requires environmentally informed agency decisions, the absence of the IA prevents the agencies from forming decisions based on fully available information. Instead, the agencies rely on speculation as to what the terms of the IA might include.

4. The late release of the Draft BDCP Implementing Agreement violates NCCPA.

The NCCPA requires that any draft documents associated with an NCCP are made available for public review and comment.[308] As mentioned above, the NCCPA requires the NCCP to include an IA.[309] The Act further imposes a "requirement to make available in a *reasonable and timely manner* . . . planning documents associated with a natural community conservation plan that are subject to public review."[310]

Because the impact and mitigation analyses in the EIR/EIS must rely on the IA for full disclosure, the government agencies needed to make the draft IA available at the same time as the draft EIR/EIS in order to meet the *reasonable and timely manner* requirement. ***Releasing the draft IA months after the Draft EIR/EIS is neither reasonable nor timely because the government could have waited for completion of the draft IA before releasing the draft EIR/EIS.***

The government's plans to hold a 60-day public comment period for the draft IA after the Draft BDCP and Draft EIR/EIS comment period closes will not cure this defect in the overall review process. Staggering the release and comment periods for BDCP documents deprives the public of adequate review opportunities in two ways. First, once the government releases the Draft IA

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[305] Cal. Pub. Res. Code § 21082.2(a). Emphasis added.

[306] Cal. Pub. Res. Code § 21082.2(c).

[307] *San Joaquin Raptor Rescue Center v. County of Merced*, 149 Cal.App.4th 645, 672 (2007). Internal citations omitted.

[308] Cal. Fish & G. Code § 2815.

[309] Cal. Fish & G. Code § 2820(b).

[310] Cal. Fish & G. Code § 2815. Emphasis added.

containing specific details concerning BDCP operation, interested parties' understanding of the project will change. ***New information released in the IA can and is expected by BDCP officials to supersede comments received during the Draft BDCP and EIR/EIS comment period, undermining the integrity of the comment period. To ensure that interested parties have an adequate opportunity to review and comment on the project, all documents relating the BDCP need to be available for comment at the same time, and for the same length of time.***

Second, a 60-day comment period is drastically insufficient to provide interested parties enough time to review the IA and use the EIR/EIS to understand its effects on BDCP operations. Interested parties will need to both review the draft IA and determine how it alters 40,000+ pages of BDCP documents. Accomplishing this type of review in a mere 60 days is impossible. Limiting the draft IA comment period to 60 days will effectively ensure that interested parties are incapable of meaningfully reviewing the totality of the BDCP.

In order to provide meaningful public review, the BDCP federal and State agencies need to hold a new Draft BDCP comment period with *every* BDCP document—Implementing Agreement, Biological Assessments and Biological Opinions, the draft MOUs between DWR and the Bureau, and Draft BDCP Plan and Draft BDCP EIR/EIS-- available for public review and comment during the same time period. Additionally, the new comment period must remain open for at least four months. NEPA regulation 40 C.F.R. 1502.7 declares that the text of an EIS for "proposals of unusual scope or complexity shall normally be less than 300 pages." Here, there are already 40,214 pages of released documents which represent 20% more pages than the 32 volumes of the last printed edition of the Encyclopedia Britannica. The government's original four month comment period and subsequent two-month extension effectively conceded that extended public review periods are necessary for a project as massive as the BDCP.

Conclusion

The absence of the Draft IA during the Draft BDCP and Draft EIR/EIS comment period has violated NEPA, CEQA, ESA, and NCCPA. These violations have rendered the comment period inadequate to support meaningful public review and comments. In order to remedy these violations, the government must release the Draft IA and open a new, four-month Draft BDCP comment period with every BDCP document available for public review and comment. Beyond these violations of law, the government must open a new public comment period to restore any public confidence in the integrity of the BDCP. It is absurd to expect the public to trust the BDCP process without full disclosure of the project's impacts, costs, contractual relationships, and who will pay those costs.

5. Omission of needed biological assessments and biological opinions from the package of BDCP documents for public review violates NEPA.

As a result of discussion between representatives of EWC member group Friends of the River at a November 7, 2013 meeting with federal agency BDCP representatives, it was confirmed that the factual matters set forth in Friends of the River's September 25, 2013, comment letter are correct. ***First,*** it is correct that the Sacramento River Winter-Run Chinook Salmon is listed as an endangered species under the ESA. Likewise, it is correct that the Central Valley Spring-Run Chinook Salmon, Central Valley Steelhead, Southern Distinct Population Segment of North American Green Sturgeon, and Delta Smelt, are listed as threatened species under the ESA. ***Second***, it was confirmed that the reaches of the Sacramento River, sloughs, and the Delta that would lose significant quantities of freshwater and freshwater flows through operation of the proposed Twin Tunnels are designated critical habitats for each of these five listed endangered and threatened fish species. ***Third***, it was confirmed that no Biological Assessment has been prepared and issued by the federal Bureau of Reclamation with respect to the Twin Tunnels project. ***Fourth***, it was confirmed that no final or

even draft Biological Opinion has yet been prepared by NMFS or USFWS with respect to the impacts of the operation of the Twin Tunnels on the five listed fish species or their critical habitats.

NMFS reiterated its previous "Red Flag" comment in 2013 that the Twin Tunnels threaten the "potential extirpation of mainstem Sacramento River Populations of winter-run and spring-run Chinook salmon over the term of the permit. . . ."[311] In comments on the Administrative Drafts, the EPA explained that "many of these scenarios of the Preferred Alternative 'range' appear to decrease Delta outflow[312], despite the fact that several key scientific evaluations by federal and State agencies indicate that more outflow is necessary to protect aquatic resources and fish populations."[313]

Legal precedent underscores this need: "The goal of the ESA is not just to ensure survival but to ensure that the species recover to the point it can be delisted."[314] Pursuant to the commands of the ESA, each federal agency "shall . . . insure that any action authorized, funded, or carried out by such agency . . . is not likely to jeopardize the continued existence of any endangered or threatened species *or result in the destruction or adverse modification of [critical] habitat of such species*. . . ."[315]

And: "[T]he purpose of establishing 'critical habitat' is for the government to carve out territory that is not only necessary to the species' survival but also essential for the species' recovery."[316]

Also: "existing or potential conservation measures outside of the critical habitat cannot properly be a substitute for the maintenance of critical habitat that is required by Section 7 [of the ESA, 16 U.S.C § 1536]."[317]

The failure to prepare the ESA and National Environmental Policy Act (NEPA) required Biological Assessments and Opinions analyzing the threatened adverse modification of critical habitats renders the draft EIR/EIR essentially worthless as an environmental disclosure and informational document under NEPA. The draft EIR/EIS is also premature and unlawful under the ESA.

The ESA Regulations require that "Each Federal agency shall review its actions *at the earliest possible time* to determine whether any action may affect listed species or critical habitat. If such a determination is made, formal consultation is required. . . ."[318] The Biological Assessments and Biological Opinions are the written documents that federal agencies must prepare during the ESA consultation process. The NEPA Regulations require that "To the fullest extent possible, agencies shall prepare draft environmental impact statements concurrently with and integrated with

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[311] NMFS Progress Assessment and Remaining Issues Regarding the Administrative Draft BDCP Document, Section 1.17, 12, April 4, 2013.

[312] BDCP EIR/EIS, Chapter 5, *Water Supply*, p. 5-82.

[313] EPA Comments on Administrative Draft EIR/EIS, III Aquatic Species and Scientific Uncertainty, Federal agency Release, July 18, 2013.

[314] *Alaska v. Lubchenko,* 723 F.3d 1043, 1054 (9th Cir. 2013), citing *Gifford Pinchot Task Force v. U.S. Fish and Wildlife Service,* 378 F.3d 1059, 1070 (9th Cir. 2004).

[315] 16 U.S.C. § 1536(a)(2)(emphasis added).

[316] *Gifford Pinchot,* 378 F.3d 1059, 1070.

[317] *Gifford Pinchot,* 378 F.3d 1059, 1076.

[318] 50 C.F.R. § 402.14(a); and *Karuk Tribe of California v. U.S. Forest Service,* 681 F.3d 1006, 1020 (9th Cir. 2012) (en banc)(emphasis added), *cert. denied,* 133 S.Ct. 1579 (2013).

environmental impact analyses and related surveys and studies required by the. . . Endangered Species Act. . . ."[319] "ESA compliance is not optional," and "an agency may not take actions that will tip a species from a state of precarious survival into a state of likely extinction."[320]

The Biological Opinion is to determine "whether the action, taken together with cumulative effects, is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat."[321]

Consequently, against this threat of extinction, conducting the draft EIR/EIS public review and comment stage without Biological Opinions or even Biological Assessments and draft Biological Opinions, leaves the public in the dark and violates both the ESA and NEPA. Conducting the NEPA environmental draft process prior to and in a vacuum from the ESA consultation process violates the ESA command to carry out the ESA process "at the earliest possible time" and violates the NEPA command to conduct the NEPA and ESA processes "concurrently" and in an "integrated" manner.

The public and the decision-makers now have what they do not need: 40,000 pages of advocacy from the consultants including self-serving speculation that the adverse effects of reducing flows in the Sacramento River, sloughs, and Delta will be offset. ***The public and the decision-makers do not have what they do need and are entitled to by law***: the federal agency Biological Assessments and Biological Opinions required by the ESA and NEPA.

This draft EIR/EIS circulated prior to preparation and circulation of federal agency prepared Biological Assessments and Biological Opinions is "so inadequate as to preclude meaningful analysis,"[322] because the public and decision-makers do not have the basic federal agency analyses required by the ESA to determine whether DWR's preferred alternative—the Twin Tunnels—is even a lawful alternative, let alone an environmentally acceptable alternative.[323]

D. The EIR/EIS fails to properly explain and justify the underlying purpose and need for the Bay Delta Conservation Plan.

An Environmental Impact Statement must explain the "*underlying* purpose and need" to which the lead agency responds in proposing alternatives, including the proposed action.[324] It is important because it explains why the agency and the Applicants here undertake the proposed action and what they hope to achieve by doing it.

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[319] 40 C.F.R. § 1502.25(a).

[320] *National Wildlife Federation v. National Marine Fisheries Service,* 524 F.3d 917, 929-30 (9th Cir. 2008).

[321] 50 C.F.R § 402.14(g)(4).

[322] 40 C.F.R. § 1502.9(a).

[323] The Environmental Water Caucus further incorporates by reference letters of E. Robert Wright, Senior Counsel, Friends of the River, to Bay Delta Conservation Plan officials with the dates of November 18, 2013; August 13, 2013, and June 19, 2013. They are Attachments 3, 4, and 5 to these EWC Comments. These letters indicate low little substantive change in the quality of documents released by and about BDCP during 2013 occurred by the December 2013 release of the public review draft documents.

[324] 40 CFR 1502.13. Emphasis added.

Getting the purpose and need statement[325] right is crucial in and of itself. It also shapes the definition, screening and selection of alternatives. Review of a "reasonable range" of alternatives is vital under both CEQA and NEPA because meaningful comparisons between different courses of action that address the purpose and need statement are essential for good decision making.

The EIR/EIS states:

> One of the primary challenges facing California is how to comprehensively address the increasingly significant and escalating conflict between the ecological needs of a range of at-risk Delta species and natural communities that have been and continue to be adversely affected by a wide range of human activities, while providing for more reliable water supplies for people, communities, agriculture, and industry.[326]

BDCP EIR/EIS's purpose and need statement then moans and groans: Conflicts between species protection and Delta water exports have become more pronounced, says EIR/EIS Chapter 2. Recent outcomes of "continuing court decisions" over CVP/SWP operations criteria (apparently a reference to the string of decisions coming from the federal Eastern District Court in Fresno over the Delta smelt and salmonid biological opinions. Other factors affect the Delta—continuing land subsidence, "seismic risks and levee failures," and "sea level rise"exacerbate these conflicts, claim the Applicants, rendering conditions in the Delta "unsustainable." And so, "fundamental system change to the current system is necessary" to achieve the two co-equal goals of providing a more reliable water supply for California and protecting, restoring and enhancing the Delta ecosystem.

This bluster and hand-waving vents the Applicants' frustrations with recent court decisions, but does little to advance understanding of the project or justify BDCP's purpose and need. These decisions increased needed protections for endangered Delta smelt and salmonids, protections, actions that were not otherwise forthcoming from the State Water Resources Control Board (whose fiduciary responsibility it is to protect public trust resources in the state's water ways). These decisions ultimately aim to make the CVP and SWP operations better able to comply with the California Constitution's ban on wasteful and unreasonable uses and methods of diversion of water. The purpose and need statement resorts to unsubstantiated assertions about seismic risks to spread fear of earthquakes and of adaptation to sea level rise. It fails utterly to consider whether the legislatively-established co-equal goals can be achieved ***without*** resorting to further alterations of Delta hydrology and ecology. As noted in Section VI above, it provides no analysis of how and whether the Applicants have acted to reduce reliance on Delta imports.

The Purpose and Need statement incorrectly and inaccurately conflates the Applicants' desires for a more reliable water supply from the Delta with California's diverse water supply needs. The analysis of California's future water supply needs must rely on a more detailed and careful evaluation of supply, demand, cost of alternative water supplies, and price (i.e., water rates). Neither

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[325] "Purpose and need" and "purpose and need statement" are NEPA-related terms. The similar concept is the statement of project objectives referred to in CEQA. Our comments intend that the NEPA terms mean both "purpose and need" as well as project objective statements that are required in these environmental review documents.

[326] BDCP EIR/EIS, Chapter 2, *Project Objectives and Purpose and Need*, p. 2-1, lines 12-16. See also footnote 251 above.

Appendix 1C of the EIR/EIS, nor the EIR/EIS chapters, nor the Bay Delta Conservation Plan provide such an analysis.[327]

What is BDCP's underlying purpose? At this point in our comments, we have long since documented why BDCP will fail to "restore, enhance, and protect" the Delta ecosystem: salinity will increase, residence time of water will increase, modeling results for toxic contaminants in fish tissues like methylmercury and selenium increase, Delta outflows will decrease, the low salinity zone measured by X2 will migrate further east (after climate change effects are accounted for), rates of entrainment for Delta smelt in the north Delta are likely to increase, and at least four different races of salmonid smolts are expected to have decreased survival rates through the Delta over the course of North Delta diversion operations through 2060.

The statements of purpose and need and project objectives fail to explain *why* some kind of conveyance is needed, emotional bluster aside. Must *more reliable supplies* have to mean *more supplies?* Why is greater reliability of Delta supplies needed, and must they come from the Delta? Are there more supplies BDCP is not directly disclosing in its Plan and EIR/EIS? Reliable water supplies can have engineering, climatic, legal, technological, and economic (in terms of supply, demand and price) meanings. With so many ways to interpret the phrase "water supply reliability," BDCP's purpose and need statement obscures the underlying purpose and need for BDCP and the Twin Tunnels project.

BDCP fails to adequately inform lay readers and decision makers alike about what alternative approaches to water supply reliability may entail, whether some are more ecologically effective, more cost-effective, more technologically and climatically workable, or have more senior water rights to support more reliable water development.

The BDCP indicates in its economic analysis on one hand that the project would maintain and restore the ability of the state and federal water projects to divert and export similar levels of water over time. The No Action Alternative is expected to yield average Delta exports of about 4.4 million acre-feet annually, which is lower than current average Delta exports of the last 15 years of about 5.5 million acre-feet. BDCP EIR/EIS's nine alternatives would have annual Delta exports ranging between 3.1 to 5.5 million acre-feet on average.[328] Alternative 4's four operational scenarios would range from 4.4 to 5.4 million acre-feet.

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[327] *Ibid.*, Chapter 1, Appendix 1C, *Demand Management Measures.* This appendix concludes: "Demand for water continues to be much greater than available supplies if only because many groundwater basins south of the Delta are in overdraft. Aggressive implementation of [demand management measures] could contribute towards reducing this imbalance, but the reductions from even the most aggressive conservation programs will not be enough to eliminate the water supply deficit….[M]eeting the water supply and environmental objectives of the BDCP will require the implementation of a wide range of environmental and water management programs. Water conservation is a critical element in the portfolio programs, and the objectives of the BDCP will only be achieved through implementing a comprehensive water supply and environmental management, not solely through water conservation." The appendix fails to consider cost and price issues associated with water usage. And its characterization of the limitations of conservation is an argument employing a straw man: no one seriously believes that we can conserve our way out of the state's future water demand issues, just as no one seriously believes that we can build enough storage and conveyance to eliminate those same issues.

[328] *Ibid.*, *Executive Summary,* Table ES-11, p. ES-55.

Figure 14

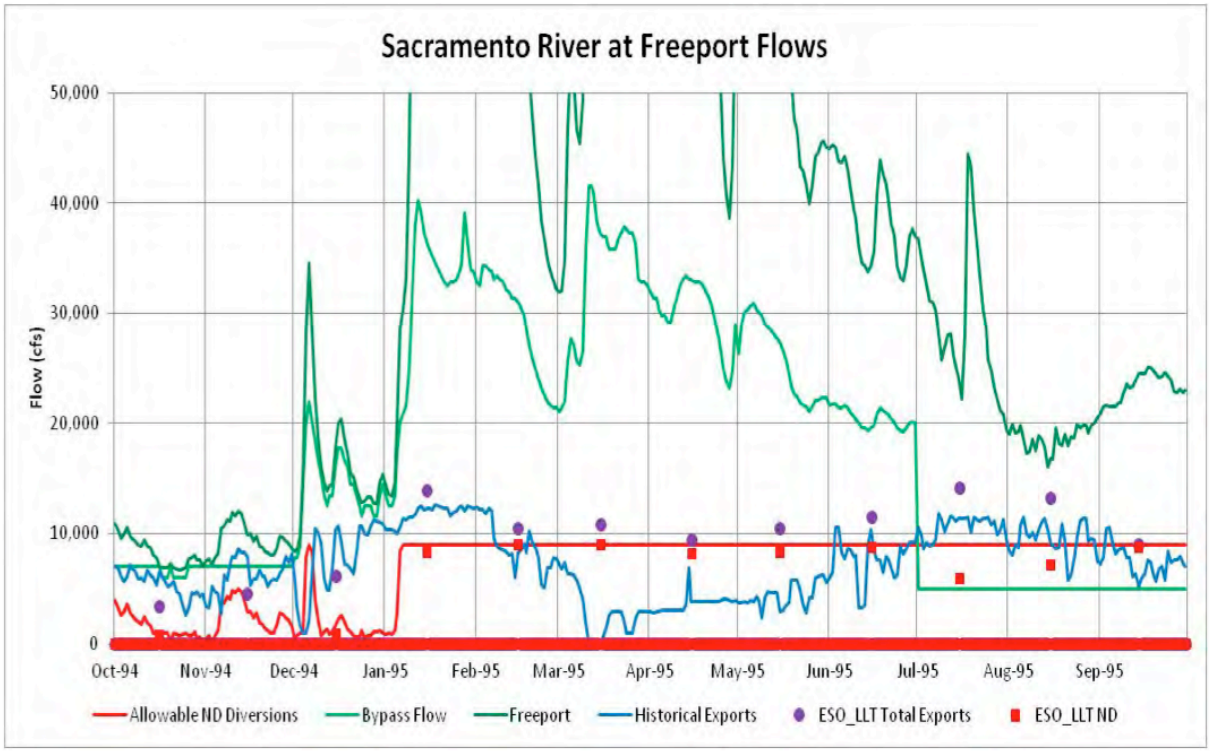


Figure C.A-58. Sacramento River at Freeport Daily Flow and Allowable BDCP North Delta Diversions for ESO (9,000 cfs capacity) with Bypass Flow Requirements in WY 1995

Figure 5.B.4-4 in Figure 1 of Section III showing average total BDCP exports by water year type, indicates that the Twin Tunnels' North Delta diversions will significantly increase total exports in wet and above normal years. In the Chapter 5, *Effects Analysis*, Appendix 5C, Attachment 5C.A, BDCP illustrates (Figure 14 above) how North Delta diversions could be routinely used to export *more* supplies during wet and above normal years than it now does. This appendix uses water year 1995 to describe how, had the North Delta Diversions been in operation that year with its attendant bypass and operational flow criteria, full capacity diversions of 9,000 cfs (red line at left) could occur from early January through September of that year, while without the tunnels, south Delta exports (blue line at left) were considerably less than that capacity from March through May.[329]

BDCP's purpose and need statement fails to clarify, disclose, and distinguish that one *underlying* purpose of BDCP's North Delta Diversions is to *retain* average exports over time compared with today while another purpose is to actually *increase* exports in wet and above normal years). We further examine this confusion in BDCP's purpose and need statement below.

BDCP also fails to disclose as an underlying purpose its intention to use the Twin Tunnels facility (the facilities identified in "Conservation Measure 1") to increase water market transfer activity whenever tunnels and pumping capacity permits. This will be especially operable, as appendices to

[329] BDCP, Appendix 5, Attachment 5C.A, *CALSIM and DSM2 Modeling Results for the Evaluated Starting Operations Scenarios*, Figure C.A-58, p. 5C.A-113.

Chapter 5 (EIR/EIS) acknowledge, when State Water Project allocations are 50 percent of Table A amounts or below, or CVP agricultural allocations are 40 percent or below, or when both projects' allocations are at or below these levels. Below these thresholds, according to BDCP, "supplemental demand" occurs among state and federal water contractors, indicating that a water transfer program for cross-Delta transfers will be inaugurated by the Bureau of Reclamation and the Department of Water Resources. We comment later about related omissions from the EIR/EIS's setting/affected environment and impact/effect analyses that follow from BDCP omitting this as a key purpose of the Twin Tunnels project and Conservation Measure 1. These omissions affect Chapters 5 (water supply) and 7 (groundwater) of the EIR/EIS chiefly.

Also, as we have pointed out above in our discussion of entrainment risk and fish screens related to the North Delta intakes, that the BDCP and its Twin Tunnels project fails to meet the stated purpose of "reducing the adverse effects on certain listed species due to diverting water." Placement of the North Delta intakes in the lower Sacramento River places a large amount of pumping and diversion capacity in the midst of both listed salmonids' migratory corridor and in close proximity to the Low Salinity Zone, which provides important habitat for listed pelagic species like Delta smelt and longfin smelt. None of these species fare better under BDCP, according to BDCP modeling results.

In our discussion of funding assurances, we also pointed out that the economic demand for Twin Tunnels water, which will be costly, may be much less than the Applicants anticipate. Their purpose and need statement have, in particular, failed completely to evaluate the need for the project by conducting a comprehensive economic analysis of future demand for Twin Tunnels water from both the municipal/industrial and agricultural water-user sectors. To the contrary, we have cited sources from among Metropolitan Water District of Southern California member agencies that indicate demand may not be nearly as strong as the Applicants hope.

Economist Jeffrey Michael of the University of the Pacific has also made a detailed critique of the BDCP economic analysis' treatment of demand for Twin Tunnels water. Dr. Michael found that BDCP employed outdated growth forecasts for southern California counties to overestimate water shortages that BDCP proposes to address.[330] Our review of the November 2013 documents find no changes to the BDCP purpose and need that would significantly change Dr. Michael's view.

E. The EIR/EIS fails to provide an adequate and reasonable range, descriptions, and justifications of alternatives.

Fundamental threshold violations of the National Environmental Policy Act (NEPA), California Environmental Quality Act (CEQA), and the Endangered Species Act (ESA) are being carried out right now by the Bay Delta Conservation Plan (BDCP) process. The lead federal and State agencies have failed to develop a range of reasonable alternatives to new upstream conveyance such as the massive Twin Tunnels. The Twin Tunnels would increase rather than decrease the capacity for exports from the San Francisco Bay-Delta by diverting enormous quantities of freshwater from the lower Sacramento River upstream from the Delta near Clarksburg.

1. The EIR/EIS fails to provide a reasonable range of alternatives.

Both CEQA and NEPA require that environmental review provide a reasonable range of alternatives in light of the purpose and need for the project. The BDCP EIR/EIS's screening process over several years eventually settled on nine alternatives besides the No Action Alternative. The Applicants also created eight separate operational scenarios, A through H, reflecting different operational modeling

[330] Jeffrey Michael, "New BDCP Economic Studies Use Outdated Growth Forecasts to Project an Artificial Water Shortage," *Valley Economy* (blog), June 4, 2013. Accessible online 11 April 2014 at http://valleyecon.blogspot.com/2013/06/new-bdcp-economic-studies-use-outdated.html.

assumptions for each of the nine alternatives. To complicate matters more, Alternative 4 (the NEPA-preferred alternative) has four distinct operational modeling scenarios H1 through H4. So, there are really 12 alternatives total, and 11 operational scenarios overall.

Of these alternatives, just one is for a "through-Delta" approach to conveyance. One relies on an operational scenario that attempts to meet a Delta inflow criterion of 55 percent of unimpaired flow, instead of the 75 percent of unimpaired flow Delta outflow criterion called for by the State Water Resources Control Board in its 2010 Delta flow criteria report.[331] Another alternative contains just one North Delta intake and one tunnel, but excises the other water program innovations called for in the original "Portfolio Alternative" concept which would take the difference in cost with Alternative 4 (the preferred alternative) and invest it in a comprehensive set of statewide water conservation, recycling, storm water capture, desalination, and other water supply investments that reduce reliance on the Delta for imported water.

A reasonable and feasible alternative that should have been considered is one that reduces reliance significantly on the Delta for imported supplies ***without relying on new conveyance schemes***. Alternative 8 (the dual conveyance design with Scenario F operational modeling criteria including 55 percent of unimpaired flow for Delta outflow) does not meet this criterion because it relies on investment in an expensive dual conveyance approach but its operational modeling scenario restricts Delta exports.

The EWC offered that its Reduced Exports Plan could serve as an alternative that did not rely on new conveyance. It would limit Delta exports to much the same level (about 3 million acre-feet on average annually) as that of Alternative 8 but would not include investment in a dual conveyance (Twin Tunnels) scheme. EWC staff transmitted the request for consideration twice to BDCP director Jerry Meral on December 17, 2012, and again on February 11, 2013.

Moreover, as we established in Sections III and VI of our comments, the Bay Delta Conservation Plan does not "improve the conveyance system" in the Delta. "Improvement" should improve not only water supply reliability but also protect, enhance, and restore Delta ecosystems as co-equal in legal status.

2. The EIR/EIS provides only "slight" differences in operational scenarios for the BDCP alternatives.

The BDCP EIR/EIS itself acknowledges that the differences among most of the alternatives are slight. The basis for the operational scenarios is the fact that the State Water Resources Control Board regulates existing Delta facilities of the CVP and SWP according to water quality and operational objectives. In addition, the US Fish and Wildlife Service and National Marine Fisheries Service issued biological opinions that require additional operational regulations on Delta facilities. BDCP's operational scenarios (as modifications to alternatives) would "require additions to, modification of, or elimination of some of the existing Delta operational rules." Changes in the operational rules may cause changes in Delta channel flows, outflows and exports, as well as to the fate of fish and ecosystems and other human and non-human beneficial users in the Delta. BDCP EIR/EIS's Executive Summary further states:

> Because each alternative has a *slightly different* set of applicable rules...and varying north Delta intake capacities, each BDCP alternative would have *slightly different* Delta operations in many months. Although the monthly Delta inflows, Delta channel flows, Delta outflow, and Delta exports may be *slightly different*

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for each BDCP alternative (as simulated using the CALSIM model), the basic changes in flow (patterns)...would likely cause differences in the aquatic habitat conditions for covered species…"[332]

And indeed, ***those differences are relatively slight when it comes to measures like Delta outflow.*** Table ES-11 shows that for Alternatives 1 through 9 (inclusive), Delta outflow would vary only within the range of a 7 percent decrease to a 9 percent increase. The highest outflow registers from Alternative 8, which applies a 55 percent of unimpaired flow criterion to achieve this modest 9 percent increase in Delta outflow, well below the 75 percent of unimpaired flow called for in the Delta Flow Criteria Report of 2010. No attempt is made in the Executive Summary to summarize what effect on fish these "slight" changes in Delta outflow would have.

While the percent increases for Delta exports that would result for each alternative are in the double digits, a more meaningful measure is the near zero-sum relationship that visible in a comparison of the magnitudes of Delta outflow and Delta export change. Table ES-11 also reveals that for most dual conveyance alternatives, the decrease in Delta outflow is nearly all accounted for by the increase in Delta exports, ***again with slight exceptions*** (Table 1).

Table 1

Alternative	Change in Delta Outflow (1,000s of Acre-feet)	Change in Delta Exports (1,000s of Acre-feet)
1	(1,081)	1,025
2	(647)	636
3	(985)	938
4-H3	(516)	505
4-H1	(982)	821
4-H2	(463)	269
4-H4	(123)	(27)
5	(347)	346
7	683	(682)
8	1,447	(1,329)

Source: BDCP, *Executive Summary,* Table ES-11, p. ES-55. Values in parentheses represent decreases in flow or exports.

We recognize that Alternative 9 would change existing Delta flow patterns dramatically. However, the EIR/EIS (understood as the totality of the BDCP conservation plan, appendices, etc.) does not study this alternative and its effects on fish nearly to the degree that the dual conveyance or isolated conveyance alternatives are studied. Even BDCP acknowledges, in summarizing Table ES-11 that

[332] BDCP, *Executive Summary*, p. ES-50, lines12-18. Emphasis added.

"Although there were some larger changes in monthly reservoir release flows or Delta outflows and exports, *these annual average values show that the BDCP alternatives would result in only moderate changes in Delta outflow or south Delta exports.*"[333]

In our view, BDCP Applicants have not complied with the CEQA and NEPA requirements to consider and evaluate a reasonable range of alternatives. BDCP has instead come up with a number of alternatives that for the most part accomplish their stated purpose and need through narrowly optimizing operational scenarios among a dozen largely similar designs off of three primary conveyance alignments (West Delta, tunnel, and isolated eastern Delta). ***They have accomplished a feat of engineering optimization, but failed to meet CEQA and NEPA requirements to select and analyze a reasonable range of alternatives.***

3. The EIR/EIS provides no substantive variation in either biological goals and objectives or conservation measures 2 through 22 as part of assembling reasonable alternatives to the proposed action alternative.

The lack of alternatives on the habitat restoration and other stressors side of the Bay Delta Conservation Plan is the same sort of CEQA and NEPA failure, if not even worse. The same twenty other conservation measures (numbers 2 through 21) are essentially retained throughout the consideration of BDCP alternatives. Table ES-8 in the Executive Summary of the EIR/EIS demonstrates that, like the BDCP operational scenarios, ***there are only slight differences between alternatives when it comes to the habitat restoration ("conservation") elements of BDCP.*** Variations in the extent of tidal habitat, seasonally inundated floodplain, and channel margin habitat affecting Alternatives 5 and 7 only are noted in this table. Alternative 9, the "through-Delta" alternative, would make no alteration in the alignment of water ways, so its conservation elements are uniformly "similar but expected different locations for restoration or enhancement actions could be chosen."[334]

The success of tidal wetland habitat restoration depends on the likelihood of tidal processes advecting food from shoreline locations out into open water to provide benefits to Delta smelt, and longfin smelt. As we showed in Section III above, BDCP's optimistic level of food export is not supported by most Delta estuarine ecologists. One important reason is the presence of the nonnative invasive overbite clam population, which filter feeds the open water column intensively every day and can strip it free of pelagic foodstuffs on which the smelts rely.

Given that BDCP fails utterly to protect, restore and enhance populations of listed species, nor can it be certain that its habitat restoration conceptual plans will work as intended, its approach to habitat conservation plan alternative elements is even narrower than the operational scenarios concocted for conveyance alignment alternatives that are only "slightly different" from each other.

In addition to this extremely narrow range of "conservation" elements in the alternatives, the "other stressors" conservation measures are similarly straitjacketed. These "conservation measures" address:

- Methylmercury management
- Nonnative submerged and floating aquatic vegetation in tidal habitat restoration
- Dissolved oxygen levels in the Stockton Deep Water Ship Channel
- Predator control on covered fish at hot spots

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[333] *Ibid.*, p. ES-54, lines 27-29. Emphasis added.

[334] *Ibid.*, Table ES-8, p. ES-37.

- Nonphysical fish barriers
- Reduction of "illegal harvest" of covered fish species
- Smelt hatchery
- Urban storm water pollution control
- Reduction of invasive species from recreational vessels
- Fish screen installation on non-project diversions

These are all apparently unchanged across the range of BDCP alternatives. A reasonable range of "other stressor" alternatives, given the scientific uncertainties identified earlier in these comments, would at least include provisions for using flow to manage the overbite clam (*Potamocorbula amurensis*) and manage selenium in the Plan Area and the Delta's Central Valley watershed (mainly the western San Joaquin Valley). This would entail developing a conservation measure containing different levels of flow variation aiming to consider which would reduce habitat suitability for the overbite claim while also creating hydrologic conditions in which selenium partitioning would be less likely to occur.

No range of such reasonable alternatives are developed, let alone considered, in the BDCP EIR/ EIS. This is deficiency is fatal to the adequacy of the EIR/EIS.

4. The EIR/EIS process failed to Develop any Alternatives Increasing Flows by Reducing Exports

Of the 15 "action alternatives" evaluated in the Draft EIR/EIS, all save one alternative, Alternative 9 —Through-Delta—would construct, and then operate for decades new upstream conveyance ranging from a diversion capacity of 3000 cubic feet per second (cfs) to 15,000 cfs.[335] Nine of the so-called "alternatives" have a North Delta diversion capacity of 15,000 cfs.[336] The Preferred Alternative 4 is claimed to have a capacity of 9000 cfs but as we have pointed out previously, that claim is false as the Twin Tunnels have the capacity of 15,000 cfs or greater and it would be relatively easy to add two new intakes down the road to use the full capacity of the Tunnels.[337]

The BDCP process also claims to have considered 11 "alternatives" as "take" alternatives pursuant to the ESA. (BDCP Plan, Chapter 9, Alternatives to Take, table 9-7, p. 9-20). Of the 11 "take alternatives" all save one, alternative F, Through Delta, would construct, and then operate for decades new upstream conveyance by way of Twin Tunnels similar to the descriptions of the "alternatives" contained in the Draft EIR/EIS. The Preferred Alternative 4 from the Draft EIR/EIS is referred to as the BDCP Proposed Action in Chapter 9 of the Plan.

To be clear, 14 of the so-called 15 "alternatives" in the Draft EIR/EIS and 10 of the so-called 11 "take alternatives" are not true alternatives at all. They are all peas out of the same pod that would create new upstream conveyance to divert enormous quantities of freshwater away from the lower Sacramento River, sloughs, and San Francisco Bay-Delta for export south. There is nothing new in this blinding of the BDCP process to development or at least consideration of a range of reasonable alternatives to construction and operation of new upstream conveyance. Three years ago the National Academy of Sciences declared in reviewing the then-current version of the draft BDCP that: "[c]hoosing the alternative project before evaluating alternative ways to reach a preferred outcome

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[335] Draft EIR/EIS, Executive Summary, Table ES-5, pp. ES 28-30.

[336] *Ibid.*

[337] Friends of the River (FOR) August 13, 2013 BDCP comment letter, Attachment 2 to FOR January 14, 2014 BDCP comment letter.

would be post hoc rationalization—in other words, putting the cart before the horse. Scientific reasons for not considering alternative actions are not presented in the plan."[338]

5. The EIR/EIS failed to consider alternatives developed for the BDCP lead agencies.

In addition to failing to develop a range of reasonable alternatives, the BDCP lead agencies have also failed to even consider reasonable alternatives handed to the State on a silver platter. Friends of the River is a California nonprofit public interest organization devoted to river protection, conservation and restoration. Friends of the River is also a member of the Environmental Water Caucus (EWC). The EWC is a coalition of over 30 nonprofit environmental and community organizations and California Indian Tribes. In our November 18, 2013 comment letter we urged those carrying out the BDCP to review the "Responsible Exports Plan" proposed by the EWC:

> [A]s an alternative to the preferred tunnel project. This Plan calls for reducing exports from the Delta, implementing stringent conservation measures but no new upstream conveyance. This Plan additionally prioritizes the need for a water availability analysis and protection of public trust resources rather than a mere continuation of the status quo that has led the Delta into these dire circumstances. Only that alternative is consistent with the EPA statements indicating that more outflow is needed to protect aquatic resources and fish populations. The EWC Responsible Exports Plan is feasible and accomplishes project objectives and therefore should be fully analyzed in a Draft EIS/EIR."[339]

We specifically pointed out that the plan was online.[340] The failure in the BDCP process to consider the Responsible Exports Plan alternative is inexplicable given that a similar, earlier version of the plan, EWC's "Reduced Exports Plan" of December 2012 was presented by Nick Di Croce, Co-Facilitator of the EWC to then-California Resources Agency Deputy Secretary Jerry Meral and other BDCP agency officers in December 2012 and presented to then-Deputy Secretary Meral again in person on February 20, 2013, in his office in the Resources Agency building. The Reduced Exports Plan had previously been presented in May of 2012 at the Federal/State/NGO meeting in San Francisco. As stated by Co-Facilitator Di Croce in his December 2012 message to Deputy Secretary Meral:

> Now that the project is nearing its EIR/EIS stage, we feel it is important to formally present it [Responsible Exports Plan] to you and request that you get it on the record as an alternative to be evaluated. We have done this with the Delta Stewardship Council and it is included as one of the Delta Plan alternatives being evaluated. As you know, CEQA and NEPA both require a full range of reasonable alternatives to be evaluated. And as far as we know, there are no alternatives being evaluated that do not include new conveyance, except for the No Action alternative; this is certainly not a No Action alternative.[341]

We attached (for BDCP.Comments@noaa.gov) and incorporated by this reference a copy of the 39-page "Responsible Exports Plan" of May 2013 (as well as a copy of the "Reduced Exports Plan" of December 2012) to this comment letter as setting forth a feasible alternative that must be considered in the BDCP process.

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[338] National Academy of Sciences, Report in Brief at p. 2, May 5, 2011.

[339] FOR November 18, 2013 comment letter at p. 3, Attachment 4 to FOR January 14, 2014 comment letter.

[340] *Ibid.*, p. 3, footnote 1. The EWC Responsible exports Plan was and still is online at http://www.ewccalifornia.org/reports/resonsibleexpltsplanmay2013.pdf.

[341] December 15, 2012 email from Di Croce to Meral.

Actions called for by the Responsible Exports Plan alternative include no development of new upstream conveyance; reducing exports to no more than 3,000,000 acre-feet in all years in keeping with State Water Resources Control Board (SWRCB) flow criteria; water efficiency and demand reduction programs including urban and agricultural water conservation, recycling, storm water recapture and reuse; reinforced levees above PL 84-99 standards; installation of improved fish screens at existing Delta pumps; elimination of irrigation water on drainage-impaired farmlands south of the Bay-Delta; return the Kern Water Bank to State control; restore Article 18 urban preference; restore the original intent of Article 21 surplus water in SWP contracts; conduct feasibility study for Tulare Basin water storage; provide fish passage above and below Central Valley rim dams for species of concern; and retain cold water for fish in reservoirs.

The Responsible Exports Plan alternative calls for a statewide benefit-cost analysis to determine economic desirability of any plan or alternative; water availability analysis to align water needs with availability; protecting the Delta ecosystem pursuant to public trust obligations; and meeting NCCP recovery standards for listed fish species. Other obvious alternatives would include actions ranging from meeting ESA recovery standards for listed fish species to halting the planting of almond orchards that cannot be fallowed in dry years on desert lands receiving export waters to consideration of the development of desalinated water supplies as is being done in the San Diego County Water Authority.[342]

Instead of enthusiastically embracing the duties mandated by our environmental laws to develop and consider a range of reasonable alternatives the BDCP proponents have concealed or misrepresented reasonable alternatives presented to them. The EWC Responsible Exports Plan has simply been concealed from the public and ignored. It is invisible in the alternatives chapters in the BDCP Plan and Draft EIR/EIS, nor is its consideration and rejection recorded in Appendix 3A of the EIR/EIS.

In addition to the EWC alternative, the Natural Resources Defense Council (NRDC) and several other environmental organizations and public agencies presented and requested consideration of the conceptual "Portfolio" alternative in December 2012. Like the EWC Plan, the Portfolio alternative emphasizes investment in such modern measures as

> local water supply tools including conservation, water recycling, and other approaches, [that] can provide reliable, sustainable and plentiful new sources of supply that will also be cost-effective over the long run. These sources can also be provided rapidly through additional investments. There is approximately as much new water available from these new water supply sources as is currently exported from the Delta." (Portfolio alternative).

Unlike the EWC Plan, the Portfolio alternative also proposes a new 3,000 cfs tunnel conveyance. The California Resources Agency began disparaging the Portfolio alternative almost immediately on its website. Then, after the release of the 40,000 pages of BDCP documents in December 2013, the government agencies running the BDCP website stopped posting any correspondence or comments from the public. The overt hostility of the State BDCP agencies to any evaluation and explanation of alternatives to the Twin Tunnels is revealed by the spectacle of the February 19, 2014 letter and its attachment from Resources Secretary John Laird to NRDC Litigation Director Kate Poole disparaging the Portfolio alternative. What is ludicrous about this is that the Resources Agency posted its anti-Portfolio advocacy on its website without also posting the Portfolio alternative itself that the Resources Agency complains about.

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[342] BDCP, Chapter 9, p. 9-43.

Like the EWC Responsible Exports Plan alternative, the Portfolio alternative is hidden from public view in the Draft BDCP Plan and Draft EIR/EIS. The logical conclusion is that the Twin Tunnels proponents are afraid of the appeal of the Responsible Exports Plan alternative and the Portfolio alternative if these alternatives are fairly and openly presented in the BDCP documents out for public review and comment.

6. Crashing Fish Populations Cry Out for Evaluation of Alternatives Increasing Flows

There should be a range of alternatives in the BDCP Draft EIR/EIS starting with the Responsible Exports Plan and related variants of that alternative. As pointed out in our previous comment letters several listed fish species are already in catastrophic decline in the subject area.[343] The reaches of the Sacramento River, sloughs, and the Delta that would lose significant quantities of freshwater and freshwater flows through operation of the proposed Twin Tunnels are designated critical habitats for listed endangered and threatened fish species including Winter-Run Chinook Salmon, Central Valley Spring-Run Chinook Salmon, Central Valley Steelhead, Southern Distinct Population Segment of North American Green Sturgeon, and Delta Smelt.

As explained last year by the U.S. Fish and Wildlife Service (USFWS) "There is clear evidence that most of the covered fish species have been trending downward."[344] The National Marine Fisheries Service (NMFS) has pointed out that the Twin Tunnels threaten the "potential extirpation of mainstem Sacramento River Populations of winter-run and spring-run Chinook salmon over the term of the permit. . ."[345] As explained by EPA in its 2013 letter to the SWRCB, "The State Board. . . has recognized that increasing freshwater flows is essential for protecting resident and migratory fish populations."[346] The EPA has also explained with respect to Administrative Drafts of the BDCP documents that "many of these scenarios of the Preferred Alternative 'range' appear to decrease Delta outflow (p. 5-52), despite the fact that several key scientific evaluations by federal and State agencies indicate that more outflow is necessary to protect aquatic resources and fish populations."[347]

The Delta Reform Act requires that:

> For the purpose of informing planning decisions for the Delta Plan and the Bay Delta Conservation Plan, the board [SWRCB] shall, pursuant to its public trust obligations, develop flow criteria for the Delta ecosystem necessary to protect public trust resources. In carrying out this section, the board shall review existing water quality objectives and use the best available scientific information. The flow criteria for the Delta ecosystem shall include the volume, quality, and timing of water necessary for the Delta ecosystem under different conditions.[348]

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[343] March 6, 2014 letter, January 14, 2014, letter and its four attachments.

[344] USFWS Staff BDCP Progress assessment, Section 1.2, p. 4, April 3, 2013.

[345] NMFS Progress Assessment, Section 1.17, 12, April 4, 2013.

[346] EPA letter to SWRCB re: EPA's comments on the Bay-Delta Water Quality Control Plan; Phase 1; SED, pp. 1-2, March 28, 2013.

[347] EPA Comments on Administrative Draft EIR/EIS, III Aquatic Species and Scientific Uncertainty, Federal Agency Release, July 18, 2013.

[348] California Water Code § 85086(c)(1).

The SWRCB did develop flow criteria, published online.[349] The criteria include:

75% of unimpaired Delta outflow from January through June;
75% of unimpaired Sacramento River inflow from November through June; and
60% of unimpaired San Joaquin River inflow from February through June.

These recommendations have not been the basis for the BDCP Twin Tunnels preferred project and would preclude development of the preferred alternative making that alternative infeasible pursuant to water quantity and quality considerations. In contrast, EWC's Responsible Exports Plan alternative reduces exports to increase flows and is designed to comply with SWRCB flow criteria. On the one hand, the BDCP Draft EIR/EIS used but rejected on spurious grounds the SWRCB flow criteria to evaluate alternatives. And on the other hand, the BDCP process does not await completion of pending SWRCB proceedings to update flow objectives.

The basic, flawed BDCP premise that taking water away from the fish and their habitats will be good for them is both nonsensical and contrary to science. As the EPA has noted, "[t]he benefits of increasing freshwater flows can be realized quickly and help struggling fish populations recover."[350] But in any event, it is necessary that the BDCP process develop and consider a range of reasonable alternatives that instead of decreasing Delta outflow, increase Delta outflow. Fair evaluation and consideration of a range of alternatives reducing exports would be a required first step in that process.

Alternatives reducing exports are consistent with the claimed project purpose of "Reducing the adverse effects on certain listed species due to diverting water."[351] Such alternatives are also consistent with findings that "the Delta is now widely perceived to be in crisis. There is an urgent need to improve the conditions for threatened and endangered fish species within the Delta."[352] On the other hand, the stated purpose to "restore and protect the ability of the SWP and CVP to deliver up to full contract amounts"[353] is contrary to the prevalence of "paper water" reflected by "information indicating that quantities totaling several times the average unimpaired flows in the Delta watershed could be available to water users based on the face value of water permits already issued."[354] Alternatives such as the Responsible Exports Plan alternative are 21st century alternatives focused on efficient, cost-effective measures to establish a more reliable water supply such as conservation and recycling as opposed to costly huge new delivery projects further depleting our rivers and the San Francisco Bay-Delta.

Alternative 9, through-Delta, is ***not*** the Responsible Exports Plan alternative. Alternative 9 comes from the BDCP Steering Committee back in 2010.[355] Without new upstream conveyance, Chapter 9 of the BDCP Plan discussing Alternatives to Take does concede that Take alternative F (similar to Draft EIR/EIS alternative 9) would result in less take over the decades of project operations than the BDCP Proposed Action—the Twin Tunnels—of Central Valley fall and late fall-run Chinook Salmon (p. 9-90); Central Valley Steelhead (p. 9-98); Sacramento Splittail (p. 9-104); White and

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[349] See footnote 59 above.

[350] EPA comments on the Bay-Delta Water Quality Control Plan; Phase 1; SED, March 28, 2013 at 1.

[351] BDCP Draft EIR/EIS, Executive Summary, p. ES-10

[352] *Ibid.*

[353] *Ibid.*

[354] *Ibid*., p. ES-11.

[355] BDCP Draft EIR/EIS Executive Summary, p. ES -30; Chapter 3, p. 3-6

Green Sturgeon (p. 9-112); and Pacific and River Lamprey (p. 9-121). But as we stated in Section III of our comments above, these are relative take assessments, not absolute take amounts. The appendix to Chapter 9 also concedes that the through-Delta alternative would result in greater net economic benefits to the water exporters than would result from development of the Twin Tunnels. (Chapter 9, appendix A, Table 9.A-2 at p. 9.A-4). The BDCP proponents, however, load up their so-called through-Delta alternative with construction features not included in the Responsible Exports Plan and then label the through-Delta alternative as resulting in greater take than the BDCP Proposed Action during construction.

Likewise, Draft EIR/EIS alternative 5 which includes a 3000 cfs Tunnel is not the Portfolio alternative. Alternative 5 (Take alternative D) comes from the BDCP Steering Committee back in 2010.[356]

None of the useful and implementable water supply availability action measures in the Responsible Exports Plan alternative or the Portfolio alternative have been included as alternatives or portions of alternatives in the BDCP Draft EIR/EIS currently out for public review and comment. The BDCP Applicants have "tunnel vision" confined to the sole alternative of developing new upstream conveyance. Moreover, there is no consideration of the opportunity cost that would result from construction and operation of the Twin Tunnels costing many billions of dollars. Those billions of dollars would be lost to developing such modern water supply measures as conservation and recycling.

7. The Absence of a Range of Reasonable Alternatives Violates CEQA, NEPA and the ESA

The failure to include a range of reasonable alternatives violates CEQA. An EIR must " describe a range of reasonable alternatives to the project. . . which would feasibly attain most of the basic objectives of the project but would avoid or substantially lessen any of the significant effects of the project, and evaluate the comparative merits of the alternatives."[357] "[T]he discussion of alternatives shall focus on alternatives to the project or its location which are capable of avoiding or substantially lessening any significant effects of the project, even if these alternatives would impede to some degree the attainment of the project objectives, or would be more costly."[358] Recirculation of a new Draft EIR/EIS will be required by CEQA Guidelines section 15088.5(a)(3) because the Responsible Exports Plan alternative and other alternatives that would reduce rather than increase exports have not been previously analyzed but must be analyzed as part of a range of reasonable alternatives.

In addition, EIR conclusions must be supported by substantial evidence. "Argument, speculation, unsubstantiated opinion or narrative" "does not constitute substantial evidence."[359] All that the BDCP Draft EIR/EIS contains to support the Preferred Project alternative is argument, speculation, unsubstantiated opinion, narrative and saying "we don't know." For example, the Draft EIR/EIS made "no determination (ND)" findings under NEPA as to whether the Twin Tunnels, even after "mitigation," would have adverse impacts on spawning, incubation habitat, and migration

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[356] BDCP Draft EIR/EIS Executive Summary, p. ES-29.

[357] 14 Code Cal. Regs (CEQA Guidelines) § 15126.6(a).

[358] CEQA Guidelines, § 15126.6(b).

[359] CEQA Guidelines, § 15384.

conditions for winter-run Chinook salmon[360] and spring-run Chinook salmon[361]; and migration conditions for fall-run Chinook salmon[362], steelhead[363], green sturgeon[364], and white sturgeon.[365] A new Draft EIR/EIS must be prepared and recirculated because "the draft EIR[/EIS] was so fundamentally and basically inadequate and conclusory in nature that meaningful public review and comment were precluded."[366]

The rules under NEPA are similar. Under the NEPA Regulations, "This [alternatives] section is the heart of the environmental impact statement. The alternatives section should "sharply" define the issues and provide a clear basis for choice among options by the decision-maker and the public.[367] The EIS alternatives section is to "Rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated."[368] Moreover, if "a draft statement is so inadequate as to preclude meaningful analysis, the agency shall prepare and circulate a revised draft of the appropriate portion. The agency shall make every effort to disclose and discuss at appropriate points in the draft statement all major points of view on the environmental impacts of the alternatives including the proposed action."[369]

Instead of discussing all major points of view, lost in the 40,000 pages of BDCP Plan and Draft EIR/EIS advocacy and speculation by the consultants who prepared the documents are any alternatives reducing exports and increasing flows instead of constructing and operating expensive new upstream diversions with the capacity to increase exports and reduce flows. Under NEPA as well as CEQA, recirculation of a new Draft EIR/EIS will be required because of the extreme deficiencies in the Draft EIR/EIS out for public review at this time. The deficiencies in the Draft EIR/EIS cannot and will not be evaded by responses to comments in a Final EIR/EIS.

With respect to the ESA, we have repeated several times over the past year that the failure of the federal agencies to have prepared the ESA required Biological Assessments and Opinions violates both the ESA Regulations[370] "at the earliest possible time" requirement and the NEPA Regulations[371] "concurrently with and integrated with" requirement.[372] The missing Biological Assessments and

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[360] Draft EIR/EIS, Executive Summary p. ES-73.

[361] *Ibid.*, p. ES-75.

[362] *Ibid.*, p. ES-77.

[363] *Ibid.*, p. ES-79.

[364] *Ibid.*, p. ES-81.

[365] *Ibid.*, p. ES-83.

[366] CEQA Guidelines § 15088.5(a)(4).

[367] 40 C.F.R. § 1502.14.

[368] § 1502.14(a).

[369] § 1502.9(a).

[370] 50 C.F.R. § 402.14(a).

[371] 40 C.F.R. § 1502.25(a).

[372] FOR January 14, 2014 comment letter and its four attachments.

Biological Opinions would be essential to any meaningful public review and comment on a project claimed to be responsive to crashing fish populations.

As conceded by BDCP Chapter 9, Alternatives to Take, the analysis of take alternatives must explain "why the take alternatives [that would cause no incidental take or result in take levels below those anticipated for the proposed actions] were not adopted."[373] Here, the lead agencies failed to even develop let alone adopt alternatives reducing exports and increasing flows to eliminate or reduce take. The agencies ignored the Responsible Exports Plan (Reduced Exports Plan version) alternative and the Portfolio alternative that were handed to them on a silver platter a full year ***before*** they issued the Draft Plan and Draft EIR/EIS for public review and comment.

In short, the fundamental flaws in the alternatives sections in the BDCP Draft EIR/EIS and Chapter 9 of the BDCP plan have led to a Draft EIR/EIS and Alternatives to Take analysis so fundamentally and basically inadequate and conclusory in nature that meaningful public review and comment is precluded."

The most important and fundamental planning decision in the history of the Delta will be whether or not to on the one hand finally begin to reduce Delta export reliance on the Delta so its ecosystems and listed fish species may recover, or on the other hand to develop massive, new Twin Tunnels conveyance. An epic choice will be made between those two basic options. The BDCP Plan and Draft EIR/EIS are at this time fatally deficient for informing this epic choice. At stake is whether five or more endangered and threatened species of fish go extinct just to increase Delta exports. Delta exports may come and go, but extinction is forever.[374]

8. The EIR/EIS fails to provide alternative descriptions at an equal level of detail.

The Bay Delta Conservation Plan *is* the proposed action description for the EIR/EIS. It contains about 9,000 pages, including appendices and attachments. Chapter 8 discusses alternatives to take, but these alternatives to take differ from the alternatives to the EIR/EIS. These differences are briefly described and summarized. But the bulk of the 9,000 pages is spent describing and analyzing the proposed action alternative, which is the Bay Delta Conservation Plan with its Twin Tunnels project as "Conservation Measure 1." By contrast, the entirety of EIR/EIS Chapter 3, Description of Alternatives is 212 pages. While Alternative 4 (the proposed, preferred action) is provided with a "project-level" analysis that amounts to nearly 9000 pages, the other alternatives are provided only with what is contained in Chapter 3 and a sequence of Map Books for each alternative's alignment. There is no effects analysis or similar list of covered actions. This violates NEPA's requirement that alternatives be considered at an equal level of detail.

9. The EIR/EIS fails in its "project-level" analysis of Conservation Measure 1 (the Twin Tunnels project) because it omits important details.

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[373] BDCP Plan, Chapter 9, pp. 9-1, 9-2.

[374] Comments to this point on the inadequacy of BDCP alternatives being inadequate are also reported in the letter from E. Robert Wright, Senior Counsel, Friends of the River to BDCP officials, "Comment Letter re Failure of BDCP Draft Plan and Draft EIR/EIS to Include a Range of Reasonable Alternatives Including the Responsible Exports Plan Submitted by the Environmental Water Caucus," May 21, 2014. Accessible online at http://www.friendsoftheriver.org/site/DocServer/Cmt_814.pdf?docID=8701.

Despite being listed in specifications in Chapter 4 of the BDCP, fish screens are not shown on either schematic site plans or conceptual renderings of North Delta intake structures[375], though general specifications are described in the project description (that is, Chapter 4 of the BDCP) and the fish screens are claimed by BDCP to be important mitigations of the Intakes' potential effects on covered species.[376]

Moreover, the "project-level" designs that are provided are typically "schematic" or "conceptual" and do not represent near-construction phase treatments of the Twin Tunnels project in "Conservation Measure 1." Public statements by BDCP and DWR officials regularly still indicate that even after eight years in the planning stages, the Twin Tunnels project portion of BDCP is only 5 to 10 percent designed at this point. The map books showing alignment for each action alternative fails to provide sufficient detail for use of the BDCP EIR/EIS in obtaining various other permits besides incidental take permits, such as streambed alteration permits from the California Department of Fish and Wildlife, or the wetlands alteration permits that would be needed from the US Army Corps of Engineers.

The EIR/EIS also fails to provide adequate project-level detail about neighboring water right holders in the immediate vicinity of the North Delta Intakes and at various points along the alignment. The State Water Board will require information like this in order to make findings as to whether other water right holders in the Delta may be injured or not by construction and operation of the Twin Tunnels project of "Conservation Measure 1." This is needed to show that the project complies with the "no injury rule" of California water rights law. BDCP must comply with all applicable laws, as required in the Implementing Agreement.

10. The EIR/EIS lacks information sufficient to satisfy statutory findings needed to issue incidental take permits for any of the alternatives.

Despite its 9,000 page proposed action description and a 30,000 page EIR/EIS, the EIR/EIS lacks information that demonstrates it can make statutory findings under the ESA and Natural Communities Conservation Planning Act required of the fishery agencies that the Bay Delta Conservation Plan can meet its ecological and funding assurances over the 50-year term of the plan. See our comments in Sections III, IV, and VI above**.** It fails to provide incidental take thresholds for covered and listed fish species, essential information for fishery agencies relying on these documents to issue incidental take permits. It lacks an evaluation of whether adequate ecological and funding assurances are provided in BDCP to satisfy statutory finding requirements under the state and federal endangered species acts.

11. The EIR/EIS fails to provide an adequate project description under CEQA and violates the equal level of detail analysis required under NEPA.

What constitutes the project description for the BDCP and its EIR/EIS? We are confused. Chapter 1 of the BDCP EIR/EIS contains footnote 3 which states:

> The full Draft EIR/EIS should be understood to include not only the EIR/EIS itself and its appendices but also the proposed BDCP documentation including all appendices. For example, the Chapter 5, *Effects Analysis*, and its associated appendices are repeatedly referred to herein and include much of the

[375] BDCP Chapter 4, *Covered Activities and Associated Federal Actions*, Figure 4-6.

[376] *Ibid.,* Table 4-2, p. 4-9.

> substantial evidence supporting the environmental analysis and conclusions herein, and Chapter 3, *Conservation Strategy,* more fully describes the proposed project.

However, footnote 3 in Chapter 3, *Description of Alternatives*, of the EIR/EIS states:

> As described in Chapter 1...the full Draft EIR/EIS should be understood to include not only the EIR/EIS itself and its appendices but also the proposed BDCP documentation including all appendices.

This footnote is appended to a textual statement that Alternative 4 is the CEQA preferred alternative and is consistent with the proposed BDCP published concurrently with the EIR/EIS. The footnote in Chapter 3 thus strongly implies that Chapter 5, Effects Analysis, and its associated appendices are part of the project description of the EIR/EIS.

This contrasts with footnote 3 of Chapter 1 of the EIR/EIS which indicates that Chapter 5, *Effects Analysis* supports much of the substantial evidence supporting the EIR/EIS's environmental analysis and conclusions. It also singles out Chapter 3 as really representing the proposed project description, since it contains the Conservation Strategy in its entirety. Attentive readers may be left confused whether the entire BDCP is also part of the EIR/EIS or whether certain portions serve the EIR/EIS in parallel, while other sections, such as the governance, implementation, alternatives to take, benefit cost analysis, and existing conditions are not given direct relevance in the EIR/EIS proper. It is possible that one must think of the EIR/EIS's project description as containing the effects analysis, which blurs the categories of analytic legal requirements under both CEQA and NEPA.

Is one of these footnotes more correct than the other? How should readers understand the BDCP as the project description that also contains an effects analysis? If as the preferred alternative, it contains an effects analysis, then the NEPA alternatives analysis of this EIR/EIS fails to incorporate the same level of detail for each alternative, particularly when it comes to having robust effects analyses of alternatives like Alternative 5 (the single intake, 3000 cfs alternative), Alternatives 8 (with its 55 percent of unimpaired flow operational modeling scenario) and 9 (the through-Delta alternative providing a fish-freeway along Old River for salmonid migration). None of these three alternatives can be construed as having received the same level of analysis and scrutiny for NEPA purposes as the other six (or nine, depending on how one counts) alternatives.

12. The project description fails as a habitat conservation plan under Section 10 of the federal Endangered Species Act and Section 2820 of the state Natural Communities Conservation Planning Act.

Refer to comments above on the Bay Delta Conservation Plan about how BDCP fails to contribute to the survival and recovery of listed species, in Section III above.

We also incorporate by reference the Delta Science Program Independent Review Panel's Phase 3 review of of the BDCP Effects Analysis. This review finds in pertinent parts that:

- The Effects Analysis was difficult to review and comprehend because its presentation is "fragmented" and its main conclusions are "sometimes inconsistent with the technical appendices." The EWC has pointed out this problem occurs in several key areas of the BDCP.

- There is an "apparent disconnect between the assessments of the levels of scientific uncertainty presented in Chapter 5 [the Effects Analysis, which is part of the proposed action description] versus what is characterized in the technical appendices."

- There is a "lack of an integrated or quantitative assessment of net effects…" which results in BDCP conclusions in Chapter 5 resembling sales pitches about "potential effects" or "intended effects" stemming from someone's professional judgment or preference rather than projected or forecasted effects derived from a reproducible methodology.[377]

13. The project description relies improperly on adaptive management to paper over gaps in how the BDCP would be implemented, thereby improperly defeating the requirement of providing in the EIR/EIS a stable project description and alternatives analysis.

Refer to comments above on the Bay Delta Conservation Plan and how it employs adaptive management to excess, in Section III above.

The Delta Science Program Independent Review Panel states that while adaptive management is identified as a needed component of BDCP, "it remains characterized as a silver bullet but without clear articulation about how key assumptions will be vetted or uncertainties resolved to the point that the BDCP goals and objectives are more assured."[378]

F. The EIR/EIS fails to provide adequate disclosure of the Setting and Affected Environment of the Bay Delta Conservation Plan and its Twin Tunnels Project.

The EIR/EIS fails to provide adequate setting and affected environment disclosure in several key areas:

- ***Environmental Justice:*** Failure to identify the human right to water, the Delta common pool resource and the state constitutional protection of fishing rights for all Californians in the state's public water ways.

- ***Water Supply:*** Over-appropriation of water rights claims in the Central Valley watershed of the Delta.

- ***Water Quality Regulatory Regime Change and Violation Priors:*** BDCP operational modeling criteria will require new water quality objectives in the Delta. The California Department of Water Resources and the US Bureau of Reclamation have chronically violated South Delta salinity objectives since 2006, when a cease and desist order was first issued by the State Water Resources Control Board.

- ***Land Use and the Delta as Place.***

- ***Cultural Resources.***

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[377] Independent Review Panel, *op. cit.*, footnote 41, pp. 5-6.

[191] *Ibid.*, p. 9.

1. The EIR/EIS fails to disclose the full environmental justice setting, including California's human right to water, the Delta common pool resource recognized in area of origins water rights law, and the state constitutional right to fish in state water ways in the setting/affected environment of Chapter 28, or any other chapter.

Chapter 28, Environmental Justice is over 100 pages long, and is mired in the complexity of the nine/twelve BDCP alternatives without any kind of summary of impacts.

The maps in Chapter 28 identify census blocks, block groups or tracts as raster data but fail to show the location and place names of specific communities where environmental justice communities are concentrated. This obscures where these communities are arrayed spatially, despite many of them being mentioned in the setting/affected environment description. It is like a data dump lacking any interpretive framework.

Moreover, Chapter 28 fails to identify the Delta common pool resource and the beneficial uses it supports as evidence of environmental justice-related area of origin water rights. They are an integral part of the demand for water as instream flows needed to sustain the fisheries on which subsistence fishers rely. See our discussion above in Section VI.

The EIR/EIS also fails to incorporate into Chapter 28 any reference in the regulatory setting to Assembly Bill 685, the "Human Right to Water" law in California.[379] This law established, first, that "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes." It then requires that all relevant state agencies shall consider this state policy when "revising, adopting, or establishing policies, regulations and grant criteria when those policies, regulations, and criteria are pertinent to the uses of water described in this section.

Environmental justice communities are present throughout the Delta. Their members fish, swim, work and live in and near Delta waters. Delta waters are useful and beneficial to them for naturally propagating and enhancing fish and other species which they cook for human consumption, despite their often low-income or impoverished social and economic status. Among the BDCP Applicants is the California Department of Water Resources. AB 685 requires DWR as a state agency to incorporate low-income and disadvantaged communities in the Plan Area into its Bay Delta Conservation Plan. It does not.

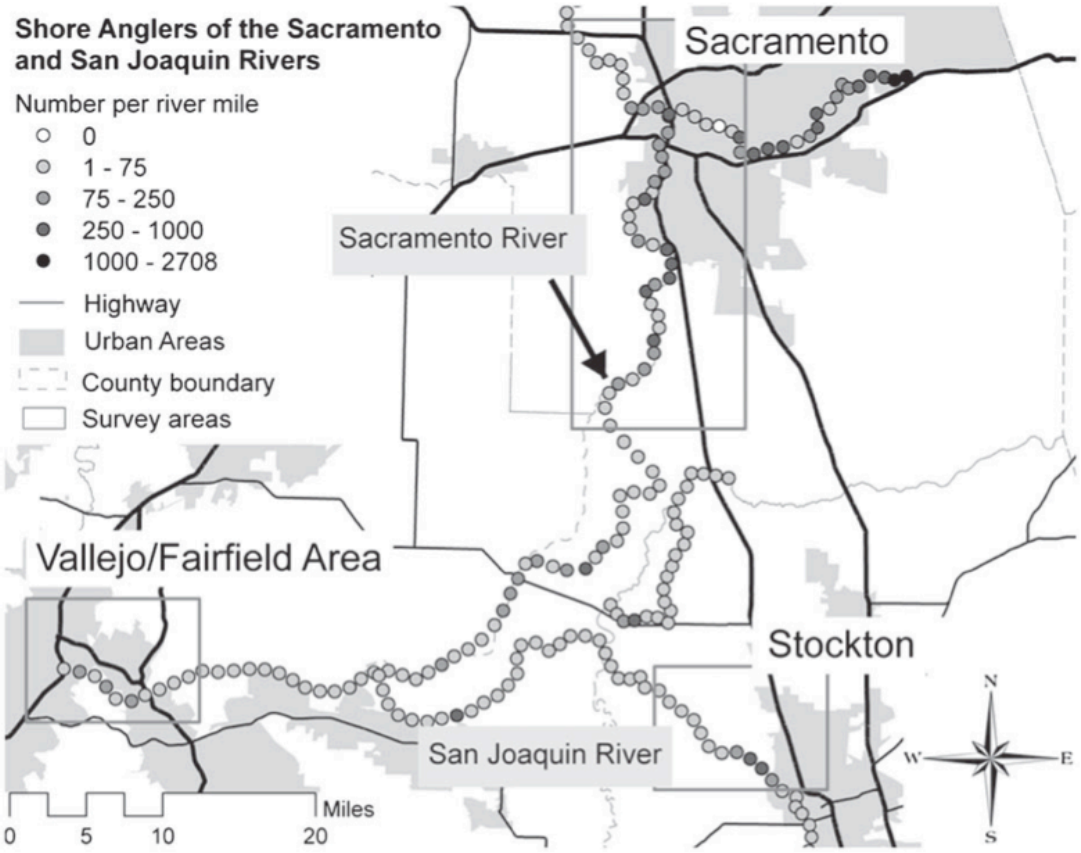
Chapter 28 of the BDCP EIR/EIS contains no description of AB 685 and fails to incorporate into the scope of the EIR/EIS a description of whether there are any environmental justice communities in the Plan Area which have inadequate water supplies or are otherwise reliant on the waters of the Delta for human consumption, cooking, and sanitary purposes. This omission renders the EIR/EIS inadequate to meet NEPA and CEQA requirements for full disclosure in order to fully inform decision makers and the public.

Chapter 28 of the EIR/EIS fails to correlate environmental justice communities' locations with environmental inequality burdens of hazards in the Delta. The maps in Chapter 28 show only the relation of environmental justice communities to the grouped alignments of the BDCP alternatives. This fails to disclose existing and potential vulnerabilities and inequalities of these communities in the Delta in relation to the Bay Delta Conservation Plan alternatives. See Attachment 1 to these comments for a more in-depth analysis of the ***social vulnerabilities and the environmental***

[379] California Water Code Section 106.3. Signed into law by Governor Jerry Brown, September 25, 2012.

inequalities in the Delta Region (i.e., the Plan Area). Some of these hazards include mercury contamination of fish and levee vulnerability to flood hazards.

Figure 15



Chapter 28 of the EIR/EIS also fails to adequately characterize the geographic and social extent of subsistence fishing activity available from recent academic environmental justice literature (Figure 15). Shilling and others have recently addressed the lack of data correlating fish consumption, subsistence fishing, and public health consequences of mercury contamination and other toxins.[380]

Shilling, et al (2010) found that subsistence fishers commonly caught and consumed Chinook salmon, Sacramento splittail, steelhead, and sturgeon (among the listed and covered species of the Bay Delta Conservation Plan). They also consumed a wide variety of introduced nonnative fish common in the Delta, several of which are not addressed by BDCP, including shad, bluegill, carp, catfish, crappie, largemouth bass, striped bass, pike minnow, Sacramento sucker, and sunfish. In a recent survey, these commonly eaten fish contained measurable concentrations of mercury in their tissues.[381] Hmong, Vietnamese, and Lao community members were found by Shilling, et al, among

[380] Fraser Shilling, Aubrey White, Lucas Lippert, and Mark Lubell, "Contaminated fish consumption in California's Central Valley Delta," *Environmental Research* (2010), doi:10.1016/j.envres.2010.02.002.

[381] *Ibid.*, Table 1.

the most active subsistence fishers among environmental justice communities, but also include African-Americans, Latinos, and people of Russian descent. Few were aware of health advisories issued by state agencies warning that people should limit their consumption of fish caught in the Delta due to mercury contamination.[382]

In addition to mercury contamination concerns, sturgeon and catfish are among the benthic fish predators in the Delta. Sturgeon are well-known to feed on *Potamocorbula amurensis*, the invasive nonnative clam that bioaccumulates selenium intensively, in addition to concerns about mercury consumption. Are there studies showing whether catfish consume the nonnative invasive overbite clam, *Potamocorbula*? ***BDCP should research this question and report back on this subject in the recirculated Draft EIR/EIS. This will be needed because of other serious omissions and deficiencies of the BDCP documents. The hydrodynamic conditions and the uncertainties involved with future selenium loading to the Delta, could lead to greater selenium contamination through benthic food web pathways to bioaccumulation.*** See our comments about selenium and methylmercury, in Sections II and III. This increased contamination, regardless of water year type, could have significant public health consequences for environmental justice communities in the Plan Area, of which the EIR/EIS fails to take account, including in Chapter 25, Public Health.

2. The EIR/EIS fails to acknowledge the over-appropriation of water rights in the Setting and Affected Environment.

Please refer to our comments above, Section II. The absence of the over-appropriation of water from the Setting/Affected Environment of Chapters 5, 6, and 7 means that members of the public cannot form a clear picture of current affairs with water rights in the Central Valley watershed of the Delta. The Setting/Affected Environment section of Chapter 5 fails to disclose that the North Delta intakes would be new points of diversion requiring review and approval of new water rights permits by the State Water Resources Control Board. Without this context, the EIR/EIS improperly defeats its own purpose under NEPA and CEQA to disclose fully the setting as a baseline for evaluating water rights and water supply impacts of alternatives and recommending mitigation measures.

3. The EIR/EIS fails to disclose as a point of controversy DWR and the Bureau's continuing failure to conduct program-level environmental review of cross-Delta water transfers, preferring instead to conduct project-level review under alleged "emergency" conditions on a year-by-year basis.

The California Department of Water Resources conducted a program EIR on its cross-Delta water transfer program in 1993, but apparently never certified it. In 2000, DWR issued a Drought Contingency Plan in which it promised to prepare a program EIR for a long-term approach to water transfers that went from the Sacramento Valley to the San Joaquin Valley, across the Delta. That EIR was never prepared. The DWR and the Bureau of Reclamation have since 2008 prepared annual environmental documents that address "emergency" water supply situations that they have failed to plan adequately for despite the fact that the state and federal governments have known since the 1930s that California's climate delivers three to six year droughts with some regularity.

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[382] *Ibid.*, Table 3. See also J.A. Davis, B.K. Greenfield, G. Ichikawa, and M. Stephenson, "Mercury in sport fish from the Sacramento-San Joaquin Delta region," California, USA," *Science for the Total Environment* 391 (2008): 66-75. Accessible online 14 April 2014 at http://www.researchgate.net/publication/223890520_Mercury_in_sport_fish_from_the_SacramentoSan_Joaquin_Delta_region_California_USA/file/79e4150b531bc58db0.pdf.

Paleoclimatologists have assembled evidence, cited earlier in this comment letter, that indicate that dry periods can last on the scale of centuries in California's recent geologic history. DWR and the Bureau have promised orally since 2009 to prepare a program-level environmental document for cross-Delta water transfers, but have deferred completing it for at least another year this year. None of this history is recounted in the Setting/Affected Environmental section of Chapter 5 even though it is vital to understanding the project's purpose and need and water supply impacts.

EWC members groups have actively commented on and successfully challenged "emergency" bases for these transfers and won in recent years.[383] DWR and the Bureau acknowledge their intention to continue arranging cross-Delta water transfers using Delta export facilities as best they can, but continue to shirk their responsibility to refrain from serial projects under NEPA and CEQA when it is clear they operate as long-term, recurring water transfer programs. BDCP would continue this chronic misbehavior, however. The EIR/EIS states:

> This EIR/EIS provides project-level CEQA/NEPA coverage for the flow of water in-Delta and south-of-Delta associated with all project and non-project water transactions. There is no maximum on the amount of water that can be conveyed through or delivered from the Delta as long as it is consistent with the operational criteria described in [Conservation Measure 1 of BDCP and the Chapter 5 Effects Analysis], and it is not limited by other factors including hydrological, regulatory and contacts [*sic*] conditions. *Because specific agreements have not been identified for water transfers and other non-project voluntary water market transactions, project-level analysis of impacts upstream of the Delta is highly speculative and this EIR/EIS does not constitute the CEQA/NEPA coverage required for any specific transaction. Rather, it provides an analysis of how transfers relate to the BDCP facilities.* Any future water transfers will require separate approvals as outlined below. *The analysis of any potential upstream impacts is not a part of this EIR/EIS and must be covered pursuant to separate laws and regulations once the specific transfer has been proposed.*[384]
>
> Any transfers conveyed through BDCP facilities will need to satisfy all of the applicable requirements in force at the time of the transfer's approval. This EIR/EIS does not comprise the CEQA/NEPA coverage required for any specific transfer approval. Rather, it provides an analysis of how transfers relate to the operation of BDCP facilities and covers the movement of water once it has been brought to the Delta through transfers and other types of transactions. *Any future water transfers will require separate approvals, including separate coverage of any upstream source area impacts.*[385]

This is faulty reasoning under NEPA and CEQA. It constitutes piece-mealing of BDCP with respect to its water transfer role and the recurring annual character of DWR's and the Bureau's water transfer programs. Piece-mealing is illegal under CEQA and NEPA.

The California Environmental Quality Act defines a "project" to mean "an activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment, and which is" undertaken by any public agency, supported through monetary or contractual arrangements from one or more public agencies, or involves issuance to a person of a lease, permit, license, certificate or other such entitlement by one or more public

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[383] *Butte Environmental Council, California Sportfishing Protection Alliance, and California Water Impact Network v. California Department of Water Resources, et al*, Superior Court of State of California, Alameda County, RG09446708, filed March 15, 2010. Accessible online 12 May 2014 at http://www.c-win.org/sites/default/files/OR010%20Order%20and%20Decision%20on%20Petition%20for%20Writ.pdf.

[384] BDCP EIR/EIS, Chapter 5, *Water Supply*, p. 5-28, lines 30-42. Emphasis added.

[385] *Ibid.*, p. 5-41, lines 27-33.

agencies.[386] The CEQA Guidelines further define a "project" to mean the "whole of an action" that would cause direct or reasonably foreseeable indirect physical environmental changes.[387]

CEQA case law has resulted in the definition of "project" receiving a broad interpretation in order to maximize environmental protection. Plans or programs are typically schemes in which multiple actions are coordinated or facilitated within a framework of policies that govern the sequence or series of those actions. In performing CEQA analysis of a plan or program, then, agencies should not "piecemeal" or "segment" a project by splitting it into two or more segments.[388] CEQA prohibits piece-mealing because to segment a project can submerge the cumulative impact of individual environmental impacts. In *Laurel Heights Improvement Association v. Regents of the University of California* (1988) 47 Cal. 3d 376, 396 [253 Cal. Rptr. 426] the court declared that environmental reviews must "include an analysis of the environmental effects of future expansion or other action if: (1) it is a reasonably foreseeable consequence of the initial project; and (2) future expansion or action will be significant in that it will likely change the scope or nature of the initial project or its environmental effects."

Under NEPA, federal agencies may not chop or segment a proposed action into small pieces to avoid the application of NEPA or to avoid a more detailed assessment of environmental effects of an overall action.[389] In this instance, it is clear from our analysis (see below) on water supply impacts of the proposed Twin Tunnels project that ***expanding water transfers is an important unrevealed yet underlying purpose and need for the proposed Bay Delta Conservation Plan***. Enlarging the conveyance capacity of the Delta facilities through construction and operation of the North Delta Intakes and Twin Tunnels project is part and parcel of expanding the ability of DWR and the Bureau to arrange and carry out more cross-Delta water transfers in the future. This purpose is not revealed in BDCP's purpose and need statement.

> The Delta pumps are currently unlikely to have available capacity for transfers at the start of the irrigation season under conditions imposed by the Biological Opinions. *This constraint may be removed, however, if the transfer water is moved in BDCP facilities.*[390]
>
> Under the BDCP alternatives, if export conveyance capacity were available constantly throughout the period of April through October, then the reservoir elevations would remain at their without-Transfer levels.

This second statement in particular signals that the North Delta Intakes and Twin Tunnels project would increase capacity to deliver water (see Figure 14 above), and the EIR/EIS asserts that groundwater substitutions for foregone surface water from senior water rights holders in the Sacramento Valley would reduce or remove the need to release precious surface water from CVP and SWP upstream reservoirs. Groundwater substitution transfers have been the preferred type of transfers in recent California water market transfers experience. The primary source of

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[386] California Environmental Quality Act, §21065.

[387] CEQA Guidelines, §15378.

[388] "This approach ensures 'that environmental considerations not become submerged by chopping a large project into many little ones, each with a potential impact on the environment, which cumulatively may have disastrous consequences." *Burbank-Glendale-Pasadena Airport Authority v. Hensler* (2d Dist. 1991) 233 Cal. App. 3d 577, 592 [284 Cal Rptr. 498], cited in Michael Remy, Tina A. Thomas, James G. Moore, and Whitman F. Manley, *Guide To CEQA*, 11th ed., Point Arena, CA: Solano Press Books, 2007, p. 89.

[389] 40 CFR 1508.25(a)(1).

[390] BDCP EIR/EIS, Chapter 5, *Water Supply,* Appendix 5C, p. 5C-17, lines 34-36.

groundwater available to substitute for foregone surface water supplies from "willing sellers" is the Sacramento Valley's aquifers.

Indeed, Appendix 5C reads quite a lot like a marketing brochure for DWR's and the Bureau's expanding water transfer market:

> Agencies could engage in groundwater substitution transfers with Anderson Cottonwood Irrigation District, Glenn-Colusa Irrigation District, Maxwell Irrigation District, Natomas Central Mutual Water Company, River Garden Farms, Reclamation District 108, other Sacramento River Settlement Contractors, Butte Water District, Garden Highway Water District , Sutter Extension Water District, Western Canal Water District, Yuba County [Water Agency], and Merced [Irrigation District].[391]

> As noted elsewhere, the availability of cross-Delta transfer capacity is frequently an issue under existing conditions. The potential cross-Delta transfer volume may be limited by the capacity of the export facilities, by regulatory constraints, and by the availability of water for transfer from willing sellers upstream of the Delta. *The provision of added capacity to the export pumps through BDCP facilities [i.e., the North Delta Intakes and Twin Tunnels project] would ease the through-Delta and timing constraints of moving the transfer water.* There would still need to be remaining capacity in the export pumps beyond that required for project water to move the transfer water south from that point, capacity that would generally be available in the dry year types but problematic in other year types.[392]

All of these potential "willing sellers" are located in the Sacramento Valley, except for Merced Irrigation District.

Failure to disclose this controversy over program-level environmental review bears on the piece-mealing issue. Every year since 2008, DWR and the Bureau have proposed and prepared to implement cross-Delta water transfers and now BDCP proposes to increase cross-Delta water transfer activity. Regardless of whether "project-level" individual transfer agreements occur, the EIR/EIS is deficient for failing to disclose the environmental review controversy involved in cross-Delta water transfers, and consequently failing to include DWR and USBR water transfer program review at the program level of specificity. BDCP should review the likely effects of cross-Delta water transfers on the Plan Area and the study area of the Sacramento Valley watershed from which most transfers originate based on how BDCP would facilitate such increased activity.

This is a serious deficiency of the EIR/EIS and requires revision of the document and eventual recirculation to the public. It compromises full disclosure of purpose and need, setting/affected environment, and impacts of the proposed action.

4. The EIR/EIS fails to disclose present and recent past groundwater conditions in the Sacramento Valley and in the Delta.

The setting section of Chapter 7, *Groundwater*, fails to include a map of recent groundwater elevations throughout the Central Valley watershed of and in the Delta. This would be the *existing condition* of groundwater and it goes undisclosed. Maps of DWR-defined sub-basins, while descriptive of what DWR thinks are significant groundwater regions, do not provide this information. Maps of such sub-basins are insufficient for lay readers and decision-makers to learn of the existing groundwater elevations so they may evaluate the true significance of the groundwater elevation impact maps that come later in the EIR/EIS. Even Figure 7-6 is insufficient. It records the "forecasted peak groundwater level *changes* in the San Joaquin and Tulare Export

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[391] *Ibid.*, p. 5C-18, lines 9-15.

[392] *Ibid.*, p. 5C-23, lines 22-29.

Service Areas" for the No Action Alternative "as compared to existing conditions," but this too is not the same as simply mapping existing groundwater elevations throughout the Central Valley (including the Sacramento Valley and Delta as well). This map portrays the *difference* between existing conditions and no action by 2060. Thus, no CEQA-mandated baseline information on groundwater elevations is provided in Chapter 7. This impairs understanding of current groundwater conditions by the public and decision-makers, and violates CEQA and NEPA

Similarly, the No Action Alternative groundwater elevation condition (projected to 2060 without BDCP) is not provided. Chapter 7 thus fails to give readers and decision makers a clear sense of what could be expected as to where Central Valley and Delta groundwater elevations would be found in 2060 if no action was taken.

None of the maps in Chapter 7 include the Sacramento Valley. The chapter claims this Valley's aquifers are "full." but this does not show us the geographical extent of the Sacramento Valley groundwater basin and its relationship to the Delta and San Joaquin Valley.

The word "overdraft" is not employed in the setting description of groundwater production and use in the descriptions of the San Joaquin River Basin. This is so despite the fact that the San Joaquin River Basin setting discussion does discuss "land subsidence," which is an effect of overdraft. It obscures the reality of overdraft there:

> The majority of land subsidence in the southern portion of the San Joaquin Valley [which is the Tulare Lake Basin] groundwater basin is considered to have been caused by groundwater pumping where the Corcoran Clay is present. *Groundwater withdrawal has lowered groundwater levels*, which allows the compression of the Corcoran Clay and other fine-grained units where groundwater supports the aquifer framework, resulting in inelastic subsidence and causing the overlying ground to lower. Once the inelastic compression occurs, it cannot be restored.[393]

As we understand groundwater withdrawals, if they lower groundwater levels or elevations, that means they exceed the *safe yield* of the groundwater basin. This is the definition of when a basin is considered overdrafted. This definition appears to be applied to the Tulare Lake Basin, however:

> Most groundwater subbasins in the Tulare Lake watershed are in a state of overdraft as a consequence of groundwater pumping that exceeds the basin's safe yield [citation]. As a result the aquifers in these groundwater basins contain a significant amount of potential storage space that can be filled with additional recharged water. Groundwater banking is the storage of excess water supplies into aquifers during wet periods for later withdrawal and use during dry periods [citation]. The stored water is used through conjunctive use programs by users directly overlying the basin, or it is conveyed to users in regions outside of the groundwater basin. Water for storage may be imported from other regions or agencies for temporary or long-term storage and subsequent export from the basin.[394]

This disclosure about conjunctive use and storing water underground is relevant to the water transfer market to which we allude earlier. This information is important to the setting but has no context associated with the underlying purpose and use of water supplies to be delivered by BDCP. In fact, this empty storage space is generated by overdraft of naturally occurring groundwater supplies, which were once abundant in the San Joaquin Valley and Tulare Lake Basin regions.

Chapter 7 of the EIR/EIS provides a brief descriptive overview of groundwater resources and conditions in the Sacramento Valley. It fails to mention that in recent years when the Bureau of

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[393] *Ibid.*, Chapter 7, *Groundwater,* p. 7-18, lines 15-20. Emphasis added.

[394] *Ibid.*, p. 7-20, lines 38-44, and p. 7-21, lines 1-2.

Reclamation and the California Department of Water Resources operated water transfer programs (e.g., in 2009, 2010, and 2013) groundwater substitution transfers were employed to a large degree to replace surface water supplies sold by senior water right holders in the Sacramento Valley.

It also fails to disclose that the Sacramento Valley is the focus of considerable planning, engineering, and hydrogeological research into the Valley's potential for use as the state's largest reservoir for conjunctive use water management. In recent years, the Glenn Colusa Irrigation District and the Natural Heritage Institute are studying this potential in hopes of positioning Glenn Colusa Irrigation District as a major broker of water transfers and groundwater substitution sources for "willing sellers" of water from the Sacramento Valley.

In its history of cross-Delta water transfers, BDCP also fails to identify just how many, or what percentage (by number and by transferred volume) of water transfers involved groundwater substitutions. Such information is important for gaining insight into potential future cross-Delta water transfer activity by transfer type (i.e., groundwater substitution).

The setting/affected environment portion of Chapter 7 also fails to acknowledge the Delta-wide practice of "sub-irrigation." It is a conscious Delta farming practice that manages salt and sustains their lands fertility. It is practiced from the lower lands of the southern Delta to the south banks of the Sacramento River,

The extent reaches from the lower lands of the southern Delta to the south banks of the Sacramento River (as shown in the 1991 map below). The Department of Water Resources studied application of irrigation water and associated drainage in the Delta in 1954 and 1955 prior to the State Water Project. It found that salt in Delta lowlands (a substantial portion of which occur in the South Delta) varied widely by month, with most of it accruing in Delta island soils during the irrigation season. By applying water to Delta island fields during winter months, however, farmers leached salts out of Delta soils. Department of Water Resources engineers concluded at the time that:

> The Delta Lowlands act as a salt reservoir, storing salts obtained largely from the channels during the summer, when water quality in such channels is most critical and returning such accumulated salts to the channels during the winter when water quality there is least important. Therefore agricultural practices in that area enhanced rather than degraded the good quality Sacramento River water en route [*sic*]to the [Central Valley Project's] Tracy Pumping Plant.[395]

The Board's own 1978 Water Quality Control Plan comments on this irrigation practice. High groundwater table conditions in Delta lowlands coupled with the erodible and settling organic soils there

> Make subirrigation a desirable method of water application for crop production. Subirrigation is the delivery of water to plant roots by capillary action from the underlying saturated soil strata, and is the primary method of irrigation in the Delta organic soils. (RT Vol. XX, pp. 112-115) *As practiced in the Delta, subirrigation may be the most efficient irrigation process in California from the standpoint of net water consumption.* (RT Vol. XIII, pp. 107-108). *However, because of soil and crop management constraints, this form of irrigation must be tied to a winter leaching program to remove salts accumulated in the root zone.* (RT Vol. XII, p. 47).

The Board's 1991 Water Quality Control Plan for the Bay-Delta Estuary also mentions Delta organic soils and the practice of subirrigation to maintain them, stating that "subirrigation is an irrigation

[395] California Department of Water Resources, *Investigation of the Sacramento-San Joaquin Delta. Report No. 4, Quantity and Quality of Waters Applied to and Drained from the Delta Lowlands*, July 1956, p. 30.

technique by which water is delivered to the crop root zone by horizontal flow through the soil from the spud ditches."[396] The Board adds in a footnote about winter ponding that:

> Winter ponding, currently in use in the Delta, is the practice of flooding large agricultural field areas for the purpose of controlling weeds, and reducing salt in the upper region of the soil profile. Other benefits are recreation, and possibly salt leaching.[397]

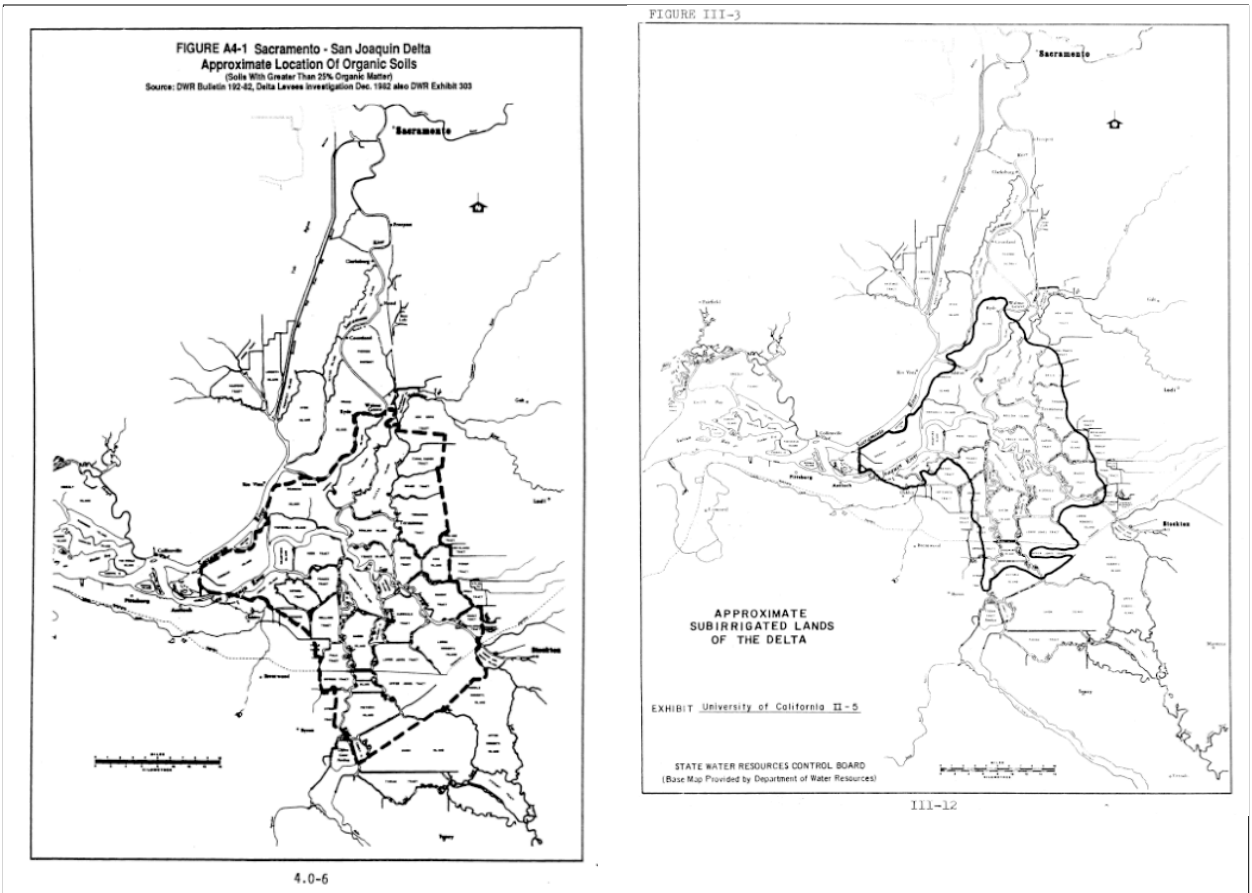


Figure 5: Maps of Delta areas employing subirrigation techniques. Map from 1991 Bay-Delta Plan at left; map from 1978 Bay-Delta Water Quality Control Plan at right.

Both the 1978 and 1991 Water Quality Control Plans present maps showing where subirrigation practice were applied. Dante Nomellini of Central Delta Water Agency confirmed to Tim Stroshane, consultant to the California Water Impact Network, that subirrigation practices continue in the water agency's service area today.[398]

The BDCP EIR/EIS fails to include a description of this irrigation practice involving subsurface flow of water in the Delta and where it occurs. Indeed it is the subirrigation and winter leaching

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[396] State Water Resources Control Board, *Water Quality Control Plan for San Francisco Bay/Sacramento-San Joaquin Delta Estuary Technical Appendix*, 91-16WR, May 1991, p. 4.0-5.

[397] *Ibid*.

[398] Nomellini to Stroshane, personal communication to Tim Stroshane, February 15, 2013.

practices that sustain irrigated cultivation there. BDCP must analyze the occurrence and locations at a project level with respect to construction and operational activities of its Conservation 1 and Twin Tunnel Delta facilities. Without such detailed treatment, BDCP fails to account for the full nature of the agricultural beneficial use and irrigation practice.

5. The EIR/EIS fails to disclose that operational modeling criteria scenarios used for alternatives analysis and evaluation would have to be adopted as new water quality objectives for the Bay-Delta Estuary by the State Water Resources Control Board, and further fails to disclose comparison of what objectives exist now in the Delta with each of the eight operational scenarios.

As we noted above, there are eight/eleven operational modeling scenarios applied to the nine/twelve design alternatives in the EIR/EIS analysis. A large but wholly implicit assumption through the BDCP and its EIR/EIS is that any one of these alternatives would require wholesale revision to the water quality control objectives of the Bay Delta estuary, now the responsibility of the State Water Resources Control Board. The setting sections of Chapter 5, 6, 7, and 8 (comprising water supply, surface water, groundwater, and water quality) contain no descriptions of the existing water quality objectives as they apply to flow and operational actions by the state and federal water facilities in the Delta. The Executive Summary only hints at this matter, titling one section "New Rules for North Delta Diversions." However, this section also makes no mention of the regulatory regime change that would apparently be required of the State Water Board.[399]

This is necessary for the public and decision makers to understand because addition of North Delta intake diversions will change hydrodynamics and water quality throughout the Delta. ***The Delta's hydrologic regime will change fundamentally, as we noted above in Section III.*** The State Water Board will be forced to take up not only whether and how to approve any change in the point of diversion (i.e., BDCP's water rights), but how and whether to utilize any or all of the operational modeling criteria used to structure and describe the impacts of the North Delta diversions on the entire Delta and beyond (i.e., its water quality objectives). ***As a result, the Delta's water quality regulation regime will be forced to change fundamentally.*** This obvious and logical result is entirely ignored by the EIR/EIS. As currently described, there is no legal reason why the North Delta diversions will be operated in the manner described in these documents ***except that the operational modeling criteria that the Applicants apply to its analysis and description become the water quality objectives of the BDCP-dominated regulatory regime.*** This appears to be BDCP's arrogant assumption about what happens to Delta water quality regulation. But it is nonetheless just an assumption, and to comply with NEPA and CEQA full-disclosure requirements, the required action for "regime change" by the State Water Board must be acknowledged and analyzed.

Further complicating this picture is the role and regulation by SWRCB of "Real-Time Operations [RTOs]." The quality of real-time operations forces, we believe, a fundamental issue: are society's actions managing Delta listed fish species to remain under the rule of law, or will they become ruled by carefully selected individuals?

Yet these operating criteria, when applied in BDCP's massive modeling effort, demonstrably fail to meet basic assurances for the federal and state habitat conservation planning and incidental take permit requirements, as we have shown earlier in these comments. RTOs, BDCP Applicants

[399] *Ibid.*, *Executive Summary*, Section ES.9.1.4, "New Rules for North Delta Diversions," pp. ES-52 to ES-53.

acknowledge, cannot be modeled.[400] The EIR/EIS fails to disclose the existing regulatory setting, the likelihood that dramatic change in the water quality/flow/rights regulatory framework will be necessary to accommodate BDCP, and consequently defeats NEPA and CEQA requirements to fully inform the public and decision-makers on such crucial issues.

6. The EIR/EIS fails to disclose in the regulatory setting of Chapter 8, *Water Quality*, that interior Delta salinity objectives are chronically violated by the Bureau of Reclamation and the Department of Water Resources. These objectives are routinely waived by the State Water Resources Control Board in drought years.

The regulatory baseline of water quality control of DWR and Bureau past practice with Delta salinity regulation is ignored in the regulatory setting of Chapter 8, *Water Quality*, in the Draft EIR/EIS. The Bureau of Reclamation and the Department of Water Resources are responsible under D-1641 for achieving Delta water quality objectives (for both flow and salinity). The Board does not review available data to determine whether the Bureau and the Department meet water quality objectives. The State Water Board has never evaluated its water quality control plans or its water right decisions in the Delta, although the Legislature compelled the Department to do so in 2006 before its responsibility kicked in under D-1641.[401] The Bay Delta Conservation Plan and its EIR/EIS Chapter 8 fails to describe how the Plan and the Twin Tunnels project would affect the Bureau and DWR's ability to meet ongoing Delta salinity and flow objectives.

Table 2 is based on salinity data from Old River near Tracy Boulevard. It reveals a consistent pattern of the Bureau and DWR violating the salinity standard at station P-12: Since August 2006, ***the Bureau and DWR have violated the salinity standard at this station for nearly 2.8 years out of the last 8, about one-third of the time.*** And it does not matter whether the objective in force is during the irrigation season (April 1 to August 31) or during the winter season (September 1

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[400] This is most explicitly noted in BDCP Appendix 5.C, Attachment 5C.A, *CALSIM II and DSM2 Modeling Results for the Evaluated Starting Operations Scenarios*, pp. 5C.A-157 to 162. Old and Middle River flow real-time operations are an example, p. 5C.A-157, lines 31-44. "The magnitude of the export restrictions [relating to Old and Middle River flows] cannot be simulated accurately with CALSIM because the limits will be adaptively specified by the USFWS smelt working group, based on real-time monitoring of fish and turbidity and temperature conditions. The assumed restrictions provide a representative simulation compared to D-1641 conditions without any OMR restrictions." Moreover, real-time operations pose dramatic uncertainties for South Delta export operations with real-time adaptive operations in place. "If the least restrictive OMR flow of -5,000 cfs were allowed for 6 months (January-June), a maximum of 1,800 taf per year could be pumped (assuming the San Joaquin River diversion to Old River satisfied the 35% of the net Delta depletion that is south of the OMR flow stations. But because of the 1,500 cfs limit on exports in April and May (2009 NMFS BiOp), the maximum exports would be 1,400 taf per year. If the OMR restriction was reduced to -2,500 cfs for the 6 months (with 1,500 cfs in April and May), a total of 780 taf could be pumped from the South Delta. This is a very dramatic reduction for the CVP and SWP exports which historically have exported about half (45%) of the total exports during these months. This uncertainty in the potential south Delta exports is a consequence of the adaptive management framework for the 2008 USFWS BiOp and 2009 NMFS BiOp actions regarding OMR flow." Since BDCP contemplates real-time operations in several other Delta and Yolo Bypass locations, uncertainties will compound for planning operations, exports, and outflows.

[401] California Department of Water Resources, *Description of Department of Water Resources Compliance with State Water Resources Control Board Water Right Decision 1641*, Response to Senate Bill 1155 Enacting California Water Code Section 138.10, January 2006, 67 pages. Accessible online 8 May 2014 at http://baydeltaoffice.water.ca.gov/announcement/D1641_final.pdf.

through March 31). The irrigation season objective of 700 mS/cm EC[402] (on a 30-day running average) has been violated about 1⅓ years (501 days) since 2006. The winter season objective of 1000 mS/cm EC (also on a 30-day running average) has been violated almost exactly for a year's worth of days.

Table 2

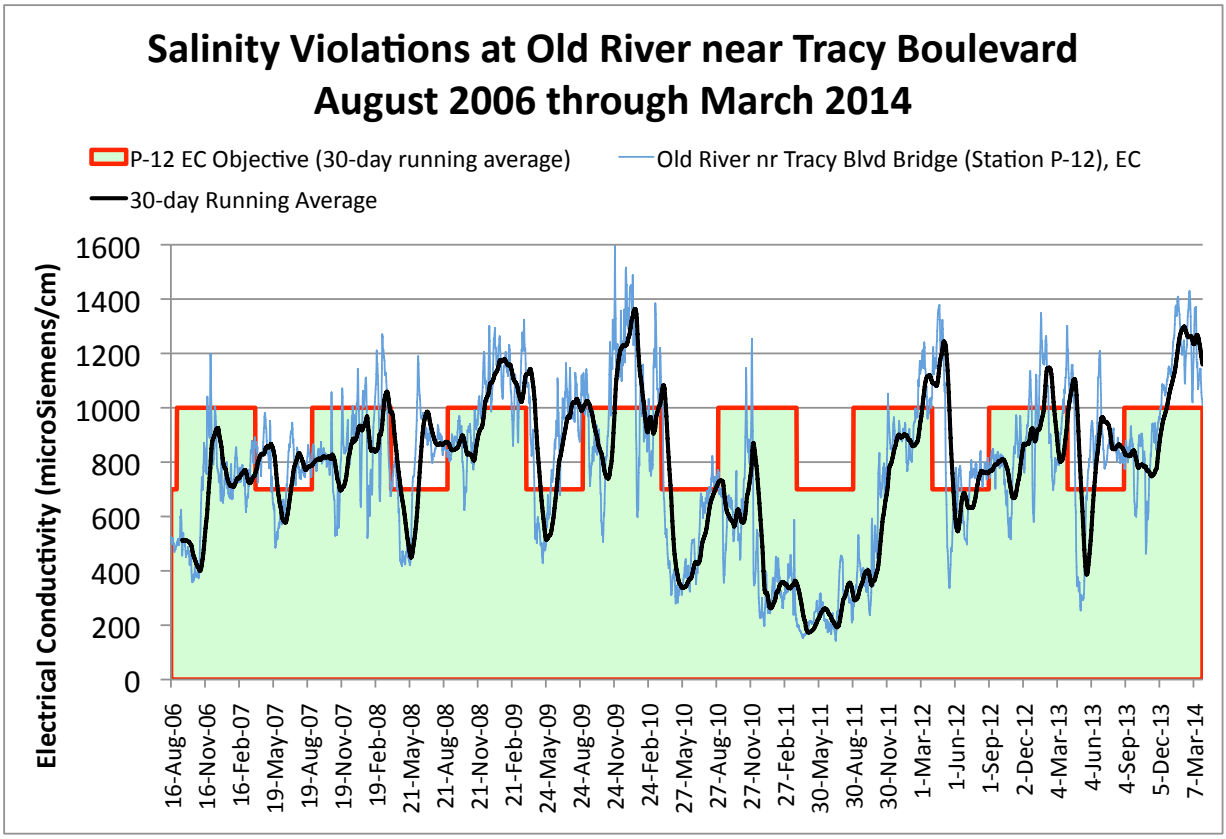
Interior South Delta Salinity Violations - Old River near Tracy Boulevard Bridge			
From	To	Number of Days (inclusive of dates)	Salinity Standard Violated (EC = microSiemens/cm)
April 1, 2007	May 30, 2007	60	700 EC
July 6, 2007	**August 31, 2007**	57	700 EC
March 8, 2008	March 28, 2008	21	1000 EC
April 1, 2008	April 26, 2008	26	700 EC
June 15, 2008	**August 31, 2008**	47	700 EC
December 10, 2008	May 9, 2009	151	1000 EC
June 22, 2009	**August 31, 2009**	72	700 EC
September 2, 2009	September 20, 2009	19	1000 EC
November 26, 2009	February 12, 2010	79	1000 EC
March 24, 2010	April 25, 2010	32	1000 EC/700 EC as of April 1
August 25, 2010	**August 31, 2010**	6	700 EC
March 5, 2012	May 27, 2012	23	1000 EC/700 EC as of April 1
July 30, 2012	**August 31, 2012**	33	700 EC
January 27, 2013	February 23, 2013	28	1000 EC
April 1, 2013	May 7, 2013	37	700 EC
June 12, 2013	**August 31, 2013**	81	700 EC
December 25, 2013	March 31, 2013	96	1000 EC
Total Violation Days Since 2007 by Bureau of Reclamation and the Department of Water Resources		868	501 days 700 EC standard violated; 367 days 1000 EC standard violated.
Source: California Data Exchange Center, Station = OLD; AquAlliance.			

[402] "mS/cm" means "micro-Siemens per centimeter," a measure of electrical conductivity.

In addition, this table indicates that the irrigation season violations routinely occur during dry years (2007 through 2009) often beginning June to early July and lasting all the way to August 31, when the salinity objective at this station rises from 700 EC to 1000 EC. This pattern recurred in July 2012 and again in 2013.

Violations also occur at the transition from the winter season objective to the spring objective. Although dry years are when the bulk of their salinity violations occur, there were two winter-period violations totaling 111 days (nearly four months) in the fall and winter of Water Year 2010, a comparatively normal year.

Figure 16



Source: California Data Exchange Center, Station: OLD; Environmental Water Caucus.

Figure 16 indicates the frequent pattern of salinity violations at this station by the Bureau and DWR since August 2006. The EIR/EIS omits from disclosure the fact that the State Water Resources Control Board issued a Cease and Desist Order (CDO) in 2006 when DWR and the Bureau informed the Board that they anticipated violating salinity objectives in the Delta. In that CDO, the Board gave the Bureau and DWR three years, until June 30, 2009, to come into compliance by choosing from a menu of options that would help them meet the salinity objectives. Instead, the state and federal water agencies delayed action, preferring instead to continue violating the objectives as they attempted to design and construct operable agricultural and fish gate systems (originally proposed in the South Delta Improvements Program) in the interior Delta to facilitate water flows from the

central Delta to the area of the South Delta pumps.[403] In June 2009, DWR and the Bureau petitioned the Board to modify the CDO, and the Board agreed to do so, extending the compliance date to 2016.

The EIR/EIS fails to describe the setting of chronic salinity violations, and fails to analyze how the Bay Delta Conservation Plan would affect enforcement of the modified Cease and Desist Order. Without this information, decision makers and the public are unable to form an informed viewpoint on the water quality effects of the Twin Tunnels project and the Bay Delta Conservation Plan, and DWR's and the Bureau's responsibility for them especially during dry and drought years. Therefore the BDCP EIR/EIS is legally inadequate. It should be revised and recirculated as a Draft EIR/EIS because of having to add new information.

However, the EIR/EIS does provide modeling results that help us visualize the Delta's saline future. BDCP's EIR/EIS provides ample modeling results to indicate that this pattern of sustained, wanton, and profligate Delta salinity violations will continue under BDCP construction and operation. These results are summarized in Figure 17 below. The EIR/EIS employs a 16-year time series (1975-1991) to model electrical conductivity in the Delta under Twin Tunnels (Alternative 4) operations. The modeling method focuses on the number of days salinity objectives are exceeded. Salinity objectives are based on 30-day running average values at each monitoring station. The modeling effort determines the number of individual days that flows in the Delta exceed the nominal salinity objectives at these stations. It also estimates the number of days during which Delta flows are out of compliance with the 30-day running average value salinity objective. The effort presented results averaged over all 16 years and for drought years (of which there were six in the period studied).

Implementation of the BDCP will require CWA Section 401 Certification. BDCP must be accountable to the Clean Water Act. The BDCP EIR/EIS fails to provide an analysis of what requirements exist under Clean Water Act Section 401. BDCP's Delta facilities (i.e., the North Delta Intakes and Twin Tunnels, which will be owned by DWR) must demonstrate they comply with water quality objectives and criteria authorized under the Clean Water Act. Therefore, sound planning dictates that consideration of the CWA's requirements must be made ***now***, to prevent violations arising from the implementation phase of the BDCP.

One CWA requirement that will arise during BDCP implementation is CWA Section 401 certification, which is necessary for any "[f]ederal license or permit to conduct any activity … [that] may result in any discharge into navigable waters."[404] A key federal license or permit that will trigger the 401 certification process is a CWA Section 404 permit. This will be needed from the Army Corps of Engineers because implementation of the BDCP will result in discharges of dredged or fill material into waters of the United States.[405] Section 401 requires that the California SWRCB certify that the

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[403] Meanwhile, the National Marine Fisheries Service refused to approve interior agricultural operable gates of the South Delta Improvement Program because they would increase predation opportunities against listed fish species.

[404] 33 U.S.C. § 1341(a)(1).

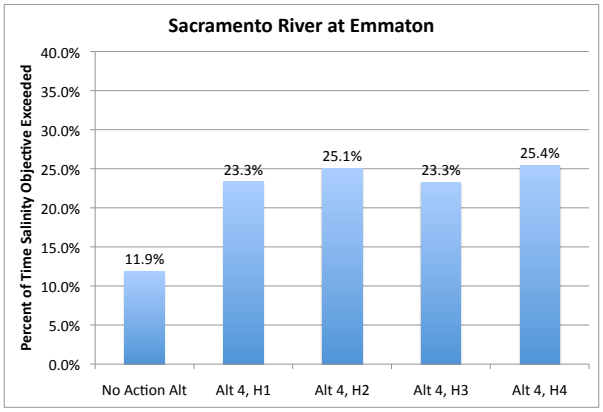
[405] "Many of the actions that will be implemented under the BDCP will result in the discharge of dredged or fill materials into waters of the United States and will need to be authorized by USACE." Public Draft Plan § 1.3.7.1 (Nov. 2013), available at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Public_Draft_BDCP_Chapter_1_-_Introduction.sflb.ashx.

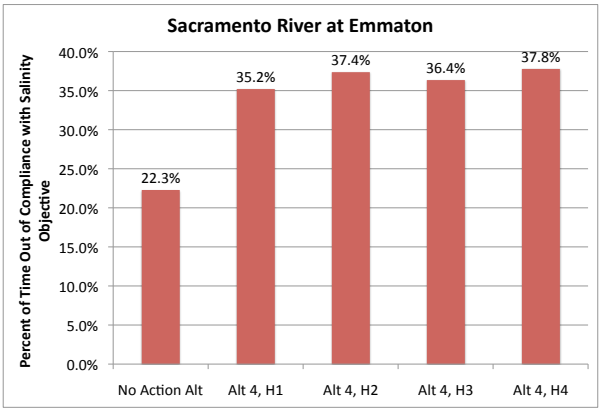
Corps' Section 404 permit meets CWA requirements before the necessary Section 404 permit may be legally issued.[406]

Figure 17
Projected Salinity Effects by 2060
of the Twin Tunnels Project/Bay Delta Conservation Plan
Percentage of Time Salinity Exceedances and Violations Would Occur

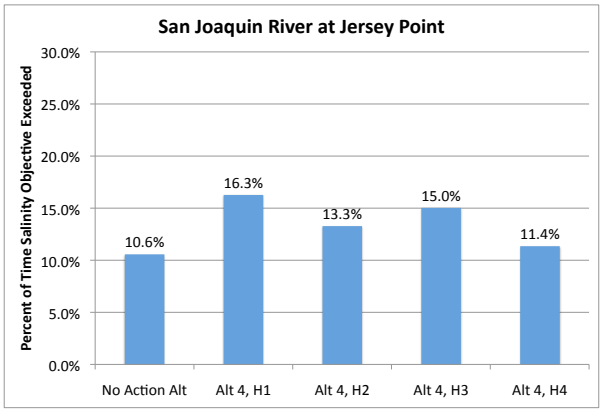
Exceeding Water Quality Objectives **Out of Compliance with Water Quality Objectives**

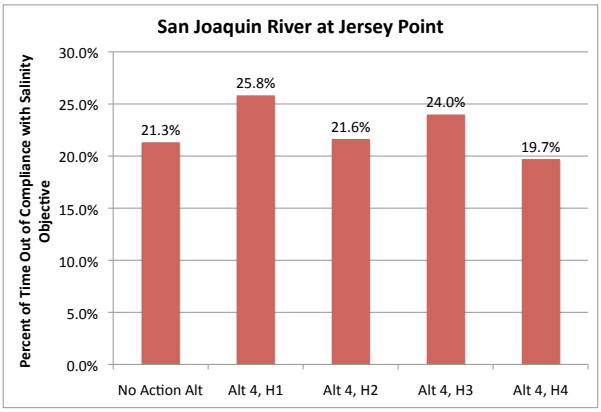
Delta Agricultural Beneficial Use Water Quality Objectives





- **Sacramento River at Emmaton:** Exceedances increase over the No Action Alternative by nearly to over 100 percent of the time in the Alt 4 scenarios, while noncompliance with the objective increases by over 50 percent of the time over the No Action Alternative.



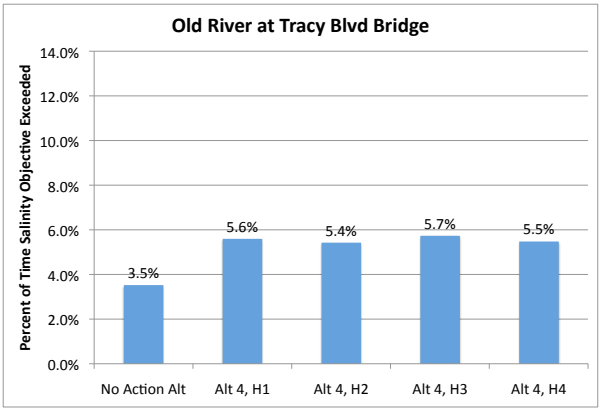


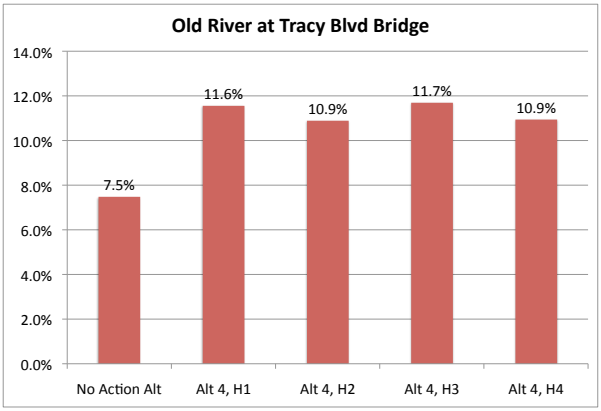
- **San Joaquin River at Jersey Point:** exceedances increase over the No Action Alt by nearly 15 to 80 percent, while non compliance with the objective increases similarly, and decreases slightly in the High Outflow Scenario (where both Spring and Fall X2 apply).

[406] "No license or permit shall be granted until the certification required by this section has been obtained or has been waived as provided in the preceding sentence. No license or permit shall be granted if certification has been denied by the State, interstate agency, or the Administrator, as the case may be." 33 U.S.C. § 1341(a)(1).

Figure 17
Projected Salinity Effects by 2060
of the Twin Tunnels Project/Bay Delta Conservation Plan
Percentage of Time Salinity Exceedances and Violations Would Occur

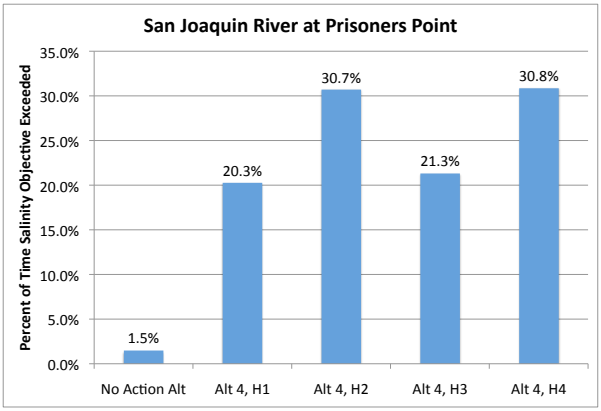
Exceeding Water Quality Objectives **Out of Compliance with Water Quality Objectives**

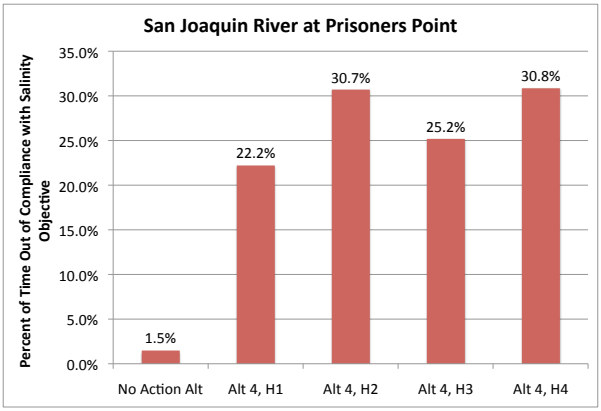




- **Old River at Tracy Blvd Bridge:** Exceedances increase by about two-thirds typically over the No Action Alternative. Noncompliance with the objective would increase by one-third to 40 percent. These percents are lower because as shown above (Table 2) the existing rate of violations is already high.

Delta Fish and Wildlife Water Quality Objective





- **San Joaquin River at Prisoners Point:** The percent of time exceedances would occur increases sharply—1200 to 1900 percent increase in exceedances and a similar similar range for noncompliance. This is a fish and wildlife-related salinity objective, while the other three are agricultural beneficial use salinity objectives.

Source: Bay Delta Conservation Plan EIR/EIS, Appendix 8H, *Electrical Conductivity,* Table EC-4, p. 8H-5.

Note: Percentage of time is based on a 16-year hydrology modeled using DSM2 in Appendix 8H. Being "out of compliance" is the number of days that the 30-day running average at the monitoring site registers violations of the salinity objective. "Exceeding Water Quality Objective" refers to the number of days that the monitoring equipment actually registers salinity exceeding the threshold level the objective.[224]

State and federal agencies have already recognized the importance of this requirement, meeting several times to discuss it in the context of the preparation of the EIR/EIS.[407] As reflected by U.S. EPA in its comments on these discussions:

> [a]lthough there is no statutory requirement that the NEPA document prepared for an HCP under the Endangered Species Act be used as the basis for permits and certifications required under CWA §404 to authorize and implement the project, EPA recognizes the importance of coordination in federal review. Toward this end, EPA and the Corps have met with the project proponent on numerous occasions over the past several years in the interest of using the BDCP EIS/EIR to inform the Corps' 404 regulatory decisions. Despite these efforts, significant unresolved issues remain about the scope of analysis for the proposed project, the level of detail required to trigger the consultation process and federal permitting, and the structure of a comprehensive permitting framework for the proposed project.[408]

Among other concerns that have arisen during this consultation process, EWC contends that the inadequate flow proposals contained in the EIR/EIS alternatives will ensure that implementation of the BDCP violates mandatory compliance with the Clean Water Act. Inclusion and evaluation of flow regimes that fully protect Delta ecosystems and species are necessary to avoid this result.

To obtain 401 certification, the project at issue must meet several CWA requirements,[409] including the requirement to meet water quality standards under CWA Section 303.[410] If these requirements are met, then either the Regional Water Quality Control Boards (RWQCB) or the SWRCB[411] may grant Section 401 certification.

As implementing U.S. EPA regulations assert,[412] Section 401 certification "shall" include "a statement that there is a reasonable assurance that the activity will be conducted in a manner which will not violate applicable water quality standards."[413] In other words, the state *cannot* grant Section 401 certification to a project if there is no reasonable assurance that it will meet water quality standards. The examination of whether a project violates water quality standards does not include "balancing" factors such as economic considerations—a project either meets water quality

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[407] U .S. EPA, "EPA's Comments on BDCP ADEIS," p. 6 (July 03, 2013), available at: www2.epa.gov/sites/production/files/documents/july3-2013-epa-comments-bdcp-adeis.pdf.

[408] *Ibid.*

[409] 33 U.S.C. § 1341(a)(1), (d). A state agency may also condition, deny or waive certification under certain circumstances. 33 U.S.C. § 1341(a)(1)-(2).

[410] 33 U.S.C. § 1341(d). According to § 401(d), certification "*shall* set forth any effluent limitations and other limitations … necessary to assure that any applicant" complies with certain provisions of the CWA. The Supreme Court in *PUD No.1* held that this includes CWA § 303, since § 301 incorporates it by reference. *PUD No. 1* at 713-715.

[411] In California, the Regional Water Quality Control Boards are responsible for granting water quality certification, unless the project occurs in two or more regions, in which case the SWRCB is responsible. *See* SWRCB, "Instructions for Completing the Clean Water Act Section 401 Water Quality Certification Application" (Jan. 2005), available at: www.swrcb.ca.gov/centralcoast/water_issues/programs/401wqcert/docs/instruct_401_wq_cert_app.pdf.

[412] The Supreme Court held that the EPA's interpretation is consistent with the CWA in *PUD No. 1*.

[413] 40 CFR § 121.2(a)(3); *PUD No. 1* at 712.

standards, or it does not.[414] Furthermore, as confirmed by the U.S. Supreme Court in *PUD No. 1 of Jefferson County v. Washington Department of Ecology* (*PUD No. 1)*, CWA Section 401 certification considers the impacts of the *entire* activity – not just the impacts of the particular discharge that triggers Section 401.[415] ***Therefore, for the BDCP to receive Section 401 certification, the entire BDCP project must be conducted in such a way as to meet all water quality standards. This it does not do, as water quality standards cannot be met given BDCP's modeling results based on currently-proposed BDCP flow regimes.***

The CWA states that water quality standards "shall consist of the designated uses of the navigable waters involved *and* the water quality criteria for such waters based upon such uses."[416] In other words, "a project that does not comply with a designated use of the water does not comply with the applicable water quality standards."[417] This fundamental CWA mandate does not change when the impact on beneficial uses arises from altered flow. The CWA was established specifically to "restore and maintain the chemical, *physical*, and biological integrity of the Nation's waters"—not solely to regulate "pollutants."[418] The U.S. Supreme Court addressed this issue directly in *PUD No. 1*, stating that:

> Petitioners also assert more generally that the Clean Water Act is only concerned with water 'quality,' and does not allow the regulation of water 'quantity.' This is an artificial distinction.

In *PUD No. 1*, Supreme Court took up the question of whether Washington state had properly issued a CWA Section 401 certification imposing a minimum stream flow requirement to protect fish populations. The Supreme Court held that conditioning the certification on minimum stream flows was proper, as the condition was needed to enforce a designated use contained in a state water quality standard.[419] In reaching this decision, the court noted that the project as proposed did not comply with the designated use of "[s]almonid [and other fish] migration, rearing, spawning, and harvesting," and so did not comply with the applicable water quality standards.[420] Similar reasoning

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[414] 40 CFR § 131.11 ("For waters with multiple use designations, the criteria shall support the most sensitive use"); *see also* 40 CFR § 131.6. As noted by the state Supreme Court, Porter-Cologne "cannot authorize what federal law forbids"; that is, California cannot allow for the "balancing away" of the most sensitive beneficial uses in a reliance on Porter-Cologne rather than the Clean Water Act. *City of Burbank v. State Water Resources Control Bd*., 35 Cal.4th 613, 626, 108 P.3d 862 (2005).

[415] *PUD No. 1 of Jefferson County v. Washington Department of Ecology*, 511 U.S. 700 (1994). *PUD No. 1* established that so long as there is a discharge, the state can regulate an activity as a whole under § 401. *PUD No. 1* at 711-712.

[416] 33 U.S.C. 1313(c)(2)(A) (emphasis added); *PUD No. 1* at 704. In addition to the uses to be protected and the criteria to protect those uses, water quality standards include an anti-degradation policy to ensure that the standards are "sufficient to maintain existing beneficial uses of navigable waters, preventing their further degradation." *PUD No. 1* at 705; 33 U.S.C. 1313(d)(4)(B); 40 CFR § 131.6. EPA regulations add that "[e]xisting instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." 40 CFR § 131.12.

[417] *PUD No. 1,* 511 U.S. at 715. *See also* 40 CFR § 131.3(b) (U.S. EPA stating that "[w]hen criteria are met, water quality will *generally* protect the designated use," (emphasis added) indicating that numerical criteria do not always by themselves protect a designated use).

[418] 33 U.S.C. § 1251(a) (emphasis added).

[419] *PUD No. 1,* 511 U.S. at 723.

[420] *Id*. at 714.

must be applied to open water beneficial uses like Delta smelt and longfin smelt, as well as other listed, covered, and non-covered species alike.

The U.S. Supreme Court specifically took note of CWA Sections 101(g) and 510(2), which address state authority over the allocation of water as between users. The Court found that these provisions "do not limit the scope of water pollution controls that may be imposed on users who have obtained, pursuant to state law, a water allocation."[421] This conclusion is supported by the "except as expressly provided in this Act" language of Section 510(2), which conditions state water authority; and by the legislative history of Section 101(g), which allows for impacts to individual water rights as a result of state action under the CWA when "prompted by legitimate and necessary water quality considerations."[422] Accordingly, these CWA provisions are not impediments to California's implementation of its CWA mandate to ensure compliance with water quality standards, *including* within the context of flows.

As noted above, in its August 2010 flow criteria report, the State Water Board found that "[t]he best available science suggests that current flows are insufficient to protect public trust resources," and that "[r]ecent Delta flows are insufficient to support native Delta fishes for today's habitats."[423] However, the flow regimes incorporated by the current BDCP are largely equivalent to those that have been failing to protect Delta ecosystems and species for years. These include: Water Right Decision 1641 (D-1641)[424]; the 2006 San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality Control Plan; the 2009 NMFS Biological Opinion (BiOp)[425]; and the 2008 USFWS BiOp.[426]

The BDCP not only fails to increase flows, it actually on average ***reduces*** Delta outflow and ***increases*** exports when compared to both the No Action alternative and existing conditions (see Sections II and VII above). The U.S. EPA expressed serious concerns about the EIR/EIS Administrative Draft's (ADEIS) proposed decrease in outflow "despite the fact that several key

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[421] *Id*. at 720.

[422] *Id*. "*See* 3 Legislative History of the Clean Water Act of 1977 (Committee Print compiled for the Committee on Environment and Public Works by the Library of Congress), Ser. No. 95–14, p. 532 (1978) ('The requirements[of the Act] may incidentally affect individual water rights. . . . It is not the purpose of this amendment to prohibit those incidental effects. It is the purpose of this amendment to insure that State allocation systems are not subverted and that effects on individual rights, if any, are prompted by legitimate and necessary water quality considerations')." *See also* Memorandum from U.S. EPA Water and Waste Management and General Counsel to U.S. EPA Regional Administrators, "State Authority to Allocate Water Quantities – Section 101(g) of the Clean Water Act" (Nov. 7, 1978), available at: http://water.epa.gov/scitech/swguidance/standards/upload/1999_11_03_standards_waterquantities.pdf.

[423] SWRCB, 2010 Flow Report, pp. 2, 5.

[424] Public Draft EIR/EIS, § 5B.1.1.2 (Nov. 2013), available at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Public_Draft_BDCP_EIR-EIS_Appendix_5B_-_Responses_to_Reduced_South_of_Delta_Water_Supplies.sflb.ashx. D-1641 requires the SWP and CVP to meet flow and water quality objectives, including specific outflow requirements, an export/import ratio, spring export reductions, salinity requirements, and, in the absence of other controlling restrictions, a limit to Delta exports of 35 percent total inflow from February through June and 65 percent inflow from July through January. Public Draft EIR/EIS § 5B.1.1.2.

[425] Public Draft EIR/EIS § 5.3.3.1 (Nov. 2013), available at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Public_Draft_BDCP_Chapter_5_-_Effects_Analysis.sflb.ashx.

[426] *Id.*.

scientific evaluations by the federal and State agencies indicate that more outflow is necessary to protect aquatic resources and fish populations."[427]

Further, the BDCP notably incorporates "bypass flows" that ostensibly establish the minimum amount of water that must flow downstream of the planned north Delta intake; this "minimum" amount, however, falls well below that needed to meet beneficial uses. Rather than protecting Delta flow, the BDCP reduces Sacramento River flow south of the North Delta intakes by up to 9,000 cfs for parts of the year.[428] Chinook salmon, Central Valley steelhead, sturgeon and lamprey all migrate and spawn in this area, with Delta smelt and longfin smelt likely spawning in the lower Sacramento River, as well.[429]

In sum, because it fails to put needed flows back into failing waterways, the BDCP will violate water quality standards by failing to protect sensitive beneficial uses. These include "rare, threatened or endangered species habitat," "estuarine habitat," "spawning, reproduction, and/or early development," and other sensitive beneficial uses.[430] The State Water Board has indicated tentative interest in designating subsistence fishing as a beneficial use statewide, including in the Delta.[431] It will thus fail as a set of flow regimes that could support Section 401 certification for necessary Section 404 permits.

Without this regulatory context, the EIR/EIS improperly defeats its own purpose under NEPA and CEQA to disclose fully the setting as a baseline for evaluating water quality impacts and recommending mitigation measures for BDCP alternatives.

7. The EIR/EIS fails to include an adequate description of state and federal water quality anti-degradation policies in Chapter 8, *Water Quality.*

National water quality policy since 1972 obligates the states, including California, to improve water quality, whatever its current condition, and since 1987 requires satisfaction of anti-degradation requirements that EPA established in Clean Water Act regulations.[432] US EPA established a regulatory framework for anti-degradation policy that requires states to develop anti-degradation policies. The heart of EPA anti-degradation criteria includes existing instream water

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[427] U.S. EPA, "EPA Comments on Administrative Draft EIR/EIS, III Aquatic Species and Scientific Uncertainty, Federal Agency Release," p. 4 (July 18, 2013) (emphasis added), available at: http://www2.epa.gov/sites/production/files/documents/july3-2013-epa-comments-bdcp-adeis.pdf.

[428] Public Draft Plan § 5.3.1.1, available at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Public_Draft_BDCP_Chapter_5_-_Effects_Analysis.sflb.ashx.

[429] *Id.* § 3.4.1.3.5, available at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Public_Draft_BDCP_Chapter_3_-_Part_2_-_Conservation_Strategy.sflb.ashx.

[430] SWRCB, "Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary," p. 9 (Dec. 13, 2006), available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/docs/2006_plan_final.pdf.

[431] Email from Esther Tracy of State Water Resources Control Board, Office of Public Participation, to Andria Ventura, Clean Water Action, "State Water Resources Control Board Beneficial Uses," May 6, 2014, forwarded to Colin Bailey of Environmental Justice Coalition for Water, thence to Tim Stroshane, Environmental Water Caucus consultant. Tracy's message primarily concerns subsistence fishing by California Indian Tribes.

[432] 33 U.S.C. 1313 (d)(4)(B).

uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

Lowering of water quality may only be tolerated in instances where it "is necessary to accommodate important economic or social development in the area in which the waters are located...after full satisfaction of the intergovernmental coordination and public participation provisions of the State's continuing planning processes." The Bay Delta Conservation Plan will worsen water quality in the Delta, as the EIR/EIS shows (more on this in Section VII of these comments). BDCP's modeling of operating conditions for the Tunnels assumes that the State Water Board acts to adopt BDCP modeling assumptions. The Board can only proceed with lowering water quality objectives where it provides and sustains a clearly supported and convincing argument about the economic and social development in the area. The EIR/EIS indicates there will be adverse effects on water quality, agriculture, land use, socioeconomics, recreation, public health and environmental justice. The Board will have difficulty supporting such an argument; it is never necessary to destroy a region's water quality in order to supposedly improve it.

Moreover, the state must still assure water quality adequate to protect existing agricultural uses fully even if it proceeds with relaxing the South Delta salinity objectives. Further, the state shall assure that there shall be achieved the "highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control."[433]

Anti-Degradation analysis under federal policy must assure that "existing instream water uses and the level of water quality necessary to protect the existing uses" is "maintained and protected."[434]

The State Water Resources Control Board's own "Statement of Policy with Respect to Maintaining High Quality of Waters in California" states:

> Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies."[435]

By failing to disclose state and federal anti-degradation policies adequately in the regulatory setting section of BDCP's EIR/EIS, Chapter 8, the EIR/EIS improperly defeats its own purpose under NEPA and CEQA to disclose fully the regulatory setting as a baseline for evaluating water quality impacts of BDCP alternatives and recommending appropriate mitigation measures. The EIR/EIS must be recirculated to ensure BDCP complies with this legal requirement.

8. The BDCP EIR/EIS fails to describe adequately the land use, agricultural, and socio-economic setting in the Delta.

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[433] 40 CFR Part 131.12(a)(1) and (2).

[434] 40 CFR 131.12(a)(1). This *only* allows consideration of lowering water quality "where it is necessary to accommodate important economic or social development *in the area in which the waters are located.*"

[435] State Water Resources Control Board, Resolution No. 68-16 (Oct. 28, 1968), Part 1. Accessible online at http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/laws_regs_policies/rs68-016.pdf.

There is confusion in BDCP's setting description of lands that would become part of the BDCP. It claims anticipated benefits to habitat and species under the plan, specifying activities involving over 148,000 acres within four Restoration Opportunity Areas (ROAs). The ROAs include Suisun Marsh. The EIR/EIS treats the Marsh as separate from the statutory Delta while including it in the Plan Area.[436] BDCP's proposed activities must be considered within the context of how much land in the Delta and Suisun Marsh is already dedicated to habitat and to restoration projects that will go forward even if BDCP is not permitted. ***The EIR/EIS in Chapter 13 fails to describe this ongoing record of habitat restoration activity adequately.*** Taking these activities into consideration, BDCP offers readers and decision makers who would use the EIR/EIS little or nothing in the way of conservation that cannot be accomplished by other means.

It is difficult to recognize the land use setting that Chapter 13 assembles in the actual Delta.

The BDCP EIR/EIS defines a total area of 872,000 acres in seven counties for its study area,[437] including parts of Sutter (for Yolo Bypass areas) and Alameda counties that are not part of the statutory Delta or Suisun Marsh. BDCP asserts that the statutory Delta alone has 538,000 acres of "agricultural land uses" but does not define "agricultural land uses."[438] Using classifications by the California Department of Conservation's Farmland Mapping and Monitoring Program (FMMP), BDCP identifies 585,000 acres in its total study area used for agricultural purposes.[439]

This picture contrasts with the Delta Stewardship Council's *Draft Delta Plan Environmental Impact Report*, Section 4, Biological Resources, Table 4-4, which lists the area of natural community types in the Delta and Suisun Marsh. This 2013 report gives a total of 838,250 acres for the whole region (which includes 106,620 acres for Suisun Marsh), of which 480,320 acres are agricultural lands (57 percent) and 81,910 are identified as "developed" (10 percent). The remainder—276,020 acres, 33 percent of the Delta and Suisun Marsh—are already open water and natural community areas.

These numbers are similar to those used in the Delta Protection Commission's 2012 *Economic Sustainability Plan (ESP)*, which identified 738,000 acres in the statutory Delta (*ESP* page 20) and found agricultural acreage in production in 2010 to be 461,380 acres, out of a total of 500,383 acres of available farmland.[440]

The principal land use in the Delta is agriculture. FMMP surveys are updated every two years, so one explanation for these discrepancies is that BDCP and the ESP used surveys from different years. However, it is worth noting that BDCP's estimate of acreage for "agricultural land uses" in the statutory Delta alone is 77,000 acres greater than the estimate in the *ESP* of land actually in agricultural production. This is significant because BDCP's habitat proposals depend to a significant degree on taking agricultural land out of production. After all, the percentage impact of conservation measures on land use appears to be less if the amount of agricultural land available is asserted to be greater.

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[436] BDCP EIR/EIS, Chapter 13, *Land Use*, Section 13.1.1.1, p. 13-2, lines 2-4 and page 13-3, lines 18-40. See also Figure 13-1.

[437] *Ibid.*, Chapter 14, *Agriculture*, Section 14.1.1, page 14-2, lines 4-6.

[438] *Ibid.*, Chapter 13, *Land Use*, Section 13.1.1.1, page 13-2, line 2.

[439] *Ibid.*, Chapter 14, *Agriculture*, Section 14.1.1, page 14-2, lines 7-8.

[440] Delta Protection Commission, *Public Draft Economic Sustainability Plan*, October 10, 2011, page 115.

9. The EIR/EIS fails to describe economic conditions of the Delta adequately.

From the perspective of Delta as Place, the fundamental weakness in the socioeconomic analysis arises from a decision not to distinguish, or to distinguish inconsistently, between the statutory Delta (sometimes referred to in the document as the interior Delta) and the five-county Delta region. The rationale for this decision is that "socioeconomic conditions [. . .] would potentially affect not only the statutory Delta, but also a larger area that covers parts of the Delta counties surrounding the statutory Delta."[441] However, conflating the statutory Delta with the larger Delta region misrepresents the situation in the statutory Delta -- the Delta as Place.

The EIR/EIS notes that the Delta Reform Act of 2009 specifically identified the following unincorporated "Legacy Communities" as exemplifying the Delta's unique cultural history and contributing to the sense of the Delta as a place: Bethel Island, Clarksburg, Courtland, Freeport, Hood, Isleton, Knightsen, Rio Vista, Ryde, Locke, and Walnut Grove.[442] "In addition to recognized cities and communities, the Delta also includes numerous small, recreational areas (including campgrounds, marinas, recreational vehicle parks, and vacation homes) that are popular throughout the spring and summer months."

The EIR/EIS distinguishes between "small towns and dispersed rural residences in the interior of the Delta, and large urban areas on the periphery." "The population in the interior of the Delta is centered around several rural communities, including Clarksburg, Courtland, Hood, Isleton, and Walnut Grove/Locke/Ryde (Delta Protection Commission 2012)."[443]

However, for several important socioeconomic indicators (Table 16-4, Housing Units; Table 16-5, Housing Type Trends; and Table 16-6, Housing Vacancy Rates), the EIR/EIS uses data from the California Department of Finance that is available for incorporated communities only; of the eleven communities identified above as exemplifying the Delta as Place, only Isleton and Rio Vista, neither of them in the primary zone, are included in the table. For other important indicators of socioeconomic well-being (including employment trends, income and poverty levels, and revenues and expenditures), Delta as Place communities are subsumed under Delta counties.

As a consequence, the analysis fails to capture data that the EIR/EIS itself identifies as important. For example, the EIR/EIS says that the economy of the interior Delta generally revolves around agriculture and tourism/recreation.[444] But because the analysis uses data for the Delta counties, the importance of agriculture and tourism are not reflected in Annual Employment and Shares by Industry, which shows Government to have the largest employment share and Agriculture to have the smallest.[445]

Regarding tourism/recreation, the EIR/EIS uses AECOM data for SICs (standard industrial classifications) for its Table 6-11, Employment Conditions for Delta Region Recreation-Related Industries.[446] The EIR/EIS has not included the SIC code for marinas or boat-building and repair,

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[441] BDCP EIR/EIS, Chapter 16, 16.1.1.1, lines 6-9.

[442] *Ibid.*, page 16-2, lines 21-27.

[443] *Ibid.*, page 16-3, lines 2-3; lines 8-10.

[444] *Ibid.*, page 16-4, line 2.

[445] *Ibid.*, Table 16-8, page 16-16.

[446] *Ibid.*, page 16-22.

although it has included the code for zoos, of which there are none in the interior Delta. According to the comment letter prepared by the Delta Protection Commission, the BDCP undercounts recreation spending in the Delta by $76 million as compared to recreational spending estimated in the Commission's *ESP* ($236 million in the EIR/EIS versus $312 million in the *ESP*).

In the interest of evaluating impacts of BDCP on the Delta as Place, the EIR/EIS should have made a greater effort to address the challenge of separating data regarding the statutory Delta from data for the five counties that include the Delta region. This task was tackled in the *Economic Sustainability Plan for the Sacramento-San Joaquin Delta* (ESP), published in January 2012, which was produced by the Delta Protection Commission for the Delta Stewardship Council in response to the Delta Reform legislation. The EIR/EIS appears not to have taken full advantage of this resource for its socioeconomic analysis.

The EIR/EIS alludes to the difficulty of doing justice to the socioeconomic role of Delta agriculture.

> Agriculture is one of the more important sectors of the Delta economy. [. . .] the aggregate employment data presented earlier in this section (see Table 16-8) suggest that agriculture is a fairly small employment sector relative to other sectors at the county level, such as government and retail trade. Part of the explanation for this is that the counties include cities such as Sacramento, Stockton, and Antioch. By their nature, cities are concentrations of non-rural economic activity. County-level data summaries that include the cities tend to diminish the important role of agriculture in more rural areas of the counties, such as the statutory Delta. Commercial agriculture and the associated agricultural services, packing, processing, marketing, insuring, and transportation activities are critical components of the Delta region's economic and social character.[447]

But recent agricultural data for the statutory Delta was available to the EIR/EIS. The *Economic Sustainability Plan* shows total Delta farmland acreage in 2008 (500,383 acres), as distinct from farmland acreage in the Delta counties.[448] It identifies the top 20 Delta crops by acreage in 2009, with the top five being corn, alfalfa, processing tomatoes, wheat, and wine grapes.[449] It identifies the top 20 Delta crops by value in 2009, with the top five being processing tomatoes, wine grapes, corn alfalfa, and asparagus and calculates a total of $702 million in revenues from Delta agriculture in 2009. It estimates the total animal output in the Delta at $93,388,000. It forecasts growth in truck, deciduous, and vineyard crops and decline in grain and pasture crops, with an increase in revenue resulting from the planting of more high-value crop.[450] The *Economic Sustainability Plan's* estimates of crop revenues and animal output together total over $795 million.

Using California Department of Food and Agriculture crop reports for the five Delta counties, the EIR/EIS looks at crop yields, prices, and value per acres and finds the top crops to be corn, alfalfa, grain and hay, safflower, and pasture.[451] Tomatoes, asparagus, and grapes—major crops for the statutory Delta and crops for which growth is forecast—are farther down the list. This is significant because it is farmland in the statutory Delta, not farmland in the five-county region generally, that is targeted for conversion to habitat by BDCP. The EIR/EIS thus gives a misleading picture of the likely impact of farmland conversion.

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[447] *Ibid.*, page 16-23, line 4, lines 7-15.

[448] *Draft Economic Sustainability Plan*, page 115.

[449] *Ibid.,* Table 8, page 116.

[450] *Ibid.*, Table 10, page 119, page 121, and page 130.

[451] BDCP EIR/EIS, Chapter 16, Table 16-13, page 16-25.

Moreover, the EIR/EIS estimates the combined value of crops and livestock "in the Delta" (using the controversial *Delta Risk Management Strategy Phase 1 Report*) as $697 million—almost $100 million less than the *Economic Sustainability Plan* estimates.[452] Since BDCP is including the Yolo Bypass in the Plan Area, the BDCP Applicants ought to be including its agricultural contributions to the Delta economy. We suspect they may not be.Plan

Having relied on data at the level of the five-county region for its background analysis of socioeconomics, the EIR/EIS switches to a focus on the statutory Delta for its evaluation of environmental consequences, including effects on community character and cohesion, population, housing employment and income.[453] "This assessment [of environmental consequences] focused on communities in the statutory Delta, where the direct effects of the BDCP would occur and where social and community effects would be greatest. Social and community effects elsewhere in the larger five-county Delta region are anticipated to be minor because they would be spread over a large, heavily populated area and among many communities."[454]

In other words, the EIR/EIS uses a region-focused analysis to effectively minimize the socioeconomic role of the Delta as Place, and it uses an analysis focused on the statutory Delta to minimize environmental effects of BDCP on the wider region.

10. The EIR/EIS fails to disclose adequately the cultural resource setting of the Delta Plan Area.

We find the EIR/EIS is unclear whether the reconnaissance conducted on cultural resources of the Plan Area (consisting of the legal Delta in the Water Code, Suisun Marsh, and Yolo Bypass) is focused on just the alignments of the BDCP alternatives within the Plan Area, or whether it is really generalized to the Plan Area as a whole. It should be both. Chapter 18 should have a set of location maps that show locations and densities of cultural resources by type: archaeological, historic, potential sites for human remains, and the like. This forms the initial basis for estimating the number and types of impacts to cultural resources.

We also note that the regulatory setting of Chapter 18 has identified Section 106 of the National Historic Preservation Act as an important regulatory framework for the identification, treatment, and protection of historic and archaeological resources that might merit inclusion in the National Register of Historic Places. Section 106 requires Applicants to declare an "area of potential effect" within which potential cultural resources are to be identified for treatment in the Section 106 process. The setting/affected environment section of the BDCP EIR/EIS fails to describe in map form or via narrative the size and vicinity of the area of potential effects of the Bay Delta Conservation Plan as an "undertaking" under Section 106. This is a serious deficiency because it is the basis for determining impacts on resources that may be ripe for inclusion in the NRHP.

Chapter 18 also fails to just summarize the number and type of cultural resources by alternative. A simple table that characterized how many of which type of cultural resource, sorted by BDCP alternative alignment and habitat restoration conservation measure/Conservation Zone/ Restoration Opportunity Area, would suffice and assist lay readers and decision makers greatly.

We also support the County of Sacramento's comments on the incomplete discussion of Chapter 18's regulatory setting section. The EIR/EIS omits regulatory information regarding special

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[452] *Ibid.*, page 16-24, line 29.

[453] *Ibid.*, page 16-38, lines 20-21.

[454] *Ibid.*, page 16-40, lines 9-13.

planning and neighborhood preservation areas found in the Zoning Code of Sacramento County, and the EIR/EIS should be revised and recirculated to include regulatory information regarding these areas, which are subject to additional protective measures because of their unique historic and cultural resources.[455]

11. The EIR/EIS fails to disclose land subsidence problems associated with normal activities of state and federal aqueducts in relation to groundwater overdraft in the San Joaquin Valley.

Land subsidence along the Delta Mendota Canal (DMC) is well-documented. The intertie between the DMC and the California Aqueduct became necessary because subsidence from groundwater overdraft reduced the capacity of the DMC. Groundwater overdraft continues rampantly along and near the route of the DMC and California Aqueduct. However, BDCP and its DEIS/EIR do not disclose this risk in the "Subsidence" section nor are there any policies or recommendations or plans to regulate the risk of aqueduct failure or reduced capacity from subsidence as a result of ongoing groundwater overdraft (**need to verify this**).

How can it be that the risk section of the BDCP completely omits the risks of San Luis Dam failure and aqueduct subsidence to central and southern California's Delta water supply reliability? We can only conclude that the focus on earthquake risk to Delta levees is part of the scare tactics to promote the Twin Tunnels. However, it is not supported by existing scientific information.

The Geology Chapter of the EIR/EIS must include the relative risks to reliable water supplies from hazards such as San Luis Dam failure and aqueduct subsidence. We also recommend policies and recommendations to reduce those risks such as mandatory groundwater regulation for areas adjacent to important water conveyance facilities such as the DMC and California Aqueduct.

Overall the seismic risk analysis of the EIR/?EIS is woefully inadequate. This is exemplified by its omission of evaluating all risks to Delta water supplies, failure to consider in any alternative a minimum PL 84-99 levee standard and a reduced emphasis on levee protection for many Delta lands. We conclude that BDCP and its EIR/EIS are not intended to evaluate and reduce Delta risks, but instead is intended to promote the Twin Tunnels project. To do so, the Plan relies on unsubstantiated scare tactics about Delta levee failure from earthquakes and flooding from sea level rise. The real risks to south of Delta water supplies are not disclosed. They are inconvenient truths that might distract from the push to build the Twin Tunnels.

Omission of these other risks from the BDCP EIR/EIS means the EIR/EIS fails to fulfill its purpose of providing adequate context for lay public readers and decision makers to understand relative and absolute seismic and other risks California's CVP and SWP systems beyond Delta levees.

G. The EIR/EIS fails to provide adequate impact analysis and analysis of effects and consequences.

The enormous size of the EIR/EIS is an obstacle to finding impact analyses, let alone discerning whether any given impact analysis provides adequate disclosure of project and plan impacts of the Bay Delta Conservation Plan. In addition to the Executive Summary table of impacts (Table ES-9, which in Chapter ES is itself 62 pages long) there should be at the opening of each environmental

[455] Comments of Sacramento County on Bay Delta Conservation Plan and Draft EIR/EIS, May 28, 2014, p. 69 to 74.

issue chapter an executive summary of the chapter that summarizes the impacts of the proposed project by alternative and identifies the key areas of controversy. This is especially important when the issue chapters can be themselves hundreds or, truly, thousands of pages long—as long as any typical project-specific EIS/EIR on a discreet project. BDCP's water quality chapter exceeds 800 pages. Fish and Aquatic Systems exceeds 3,000 pages; Recreation exceeds 400 pages. Other chapters routinely exceed 100 to 200 pages. Careful review for lay and professional readers alike is burdensome, time-consuming, and ultimately, frustrating and off-putting. The consequence of such a review burden is that BDCP and its documentation confound the purposes of NEPA and CEQA, and in the confounding, violate these two laws.

Lost in this conflict are the impacts that Delta water policy decisions are having on low-income communities of color. Some of the hydraulic effects of enclosure will affect people and communities that rely on subsistence fishing in Delta channels.

1) Sacramento River inflow below Freeport (a few miles south of the city of Sacramento) will decrease with operation of the Twin Tunnels. This decreased flow will extend from Freeport through Walnut Grove all the way to Suisun Bay. This means that water flows will slow down and there will be water quality problems, including the potential for increased selenium contamination. To the extent that people fishing the river shores catch sturgeon or other fish species that feed on bottom-dwelling organisms, e.g., invasive clams which biomagnify selenium or mercury and other contaminants, they could experience increased exposures, if and when the Twin Tunnels go into operation.

2) Related to this, residence times of water in the west Delta and other parts of the Delta increase under the BDCP by about 25 percent. This means that any contaminants will persist in the water longer and will therefore increase human exposure and public health consequences of the operation of the Twin Tunnels.

3) The land use, noise, circulation/transportation, and air quality issues associated with construction of the Twin Tunnels are significant locally in the Delta, due to periodic intensive use of roads and land for a decade. Chapter 28 of the BDCP EIR/EIS documents the location of racial/ethnic minority residents of the area as well as low income/poverty rate populations in the Delta on which there would be imposed a significant impact.

4) The water rights of Delta farming enterprises are the economic foundation of the Delta's modern agricultural economy, and farm workers participate in that economy. To the extent that the Twin Tunnels may harm existing Delta water rights, particularly along the lower Sacramento River, there is an environmental justice impact if businesses and their employees, even temporary laborers, are harmed by the loss of water for producing crops in the Delta.

5) The loss of agricultural land to conversion to habitat restoration may also be an environmental justice impact for reasons similar to point #4, above. This involves the loss of land for economic production in the Delta. Habitat restoration impacts, both construction and inundation of formerly dry land areas, also could mobilize legacy methyl mercury and selenium in sediments into food webs that could directly affect human health.

6) Cumulative upstream reservoir operations will likely work to maximize storage. In terms of cumulative impacts of the BDCP and Twin Tunnels, this prospect links the BDCP and Twin

Tunnels to the proposal to raise Shasta Dam and expand Shasta Lake, and all the consequence that would follow from that expansion.[456]

The EIR/S must acknowledge and evaluate the effects of expanding storage supplies at Shasta, Sites Reservoir, and Temperance Flat, all of which are on the state and federal governments' drawing boards and are reasonably foreseeable projects and must therefore be analyzed. The Winnemem Wintu Tribe has expressed its concerns about the impact of raising Shasta Dam on the McCloud River and the inundation of its last remaining sacred cultural sites. Construction of Temperance Flat reservoir on the San Joaquin River would likely flood the Western Mono Tribe's communities and lands upstream of Millerton Lake near Fresno.

1. The EIR/EIS fails to disclose environmental justice impacts of enclosing the Delta common pool, reduced salmonid survival rates, and increased risks to environmental justice communities of subsistence fishing when mercury and selenium in fish tissues are projected in BDCP modeling results to increase by 2060.

Subsistence fishing is an important beneficial use of water in the Delta common pool. Subsistence fishers do so informally but frequently. Flows for fish and fish habitat are crucial to the ongoing health and protection of the public trust resources that support this beneficial use. Many are low-income residents of the Delta from a variety of racial and ethnic backgrounds. Many members of these environmental justice communities may speak English only to a limited degree. It is already unfortunate and well known that these communities are poorly served by state-issued health advisories about contaminants, particularly mercury, in the tissue of fish commonly caught in the Delta.[457]

As showed elsewhere in our comments, BDCP modeling results report that salmon smolt survival rates are expected to decrease by 2060 as a result of BDCP Twin Tunnels operations. With regard to EWC's Indian Tribe members, the Bay Delta Conservation Plan's modeling results show the project will decrease long-term survival rates of salmon smolts through the Delta, when habitat conservation plans are supposed to contribute to survival and recovery of listed species. Salmonids are central to the religion and cosmology of the Winnemem Wintu, Hoopa, Karuk, and Yurok Tribes of northern California. Threats to the survival of salmon are threats to the cultural survival of these Indian Tribes. In addition, the omission of long-planned major storage projects like the raising of Shasta Dam to expand that reservoir and the proposed Temperance Flat storage project from the BDCP EIR/EIS obscures the cumulative impact of BDCP from the public and decision makers. Both projects would flood sacred sites and lands that are vital to the Winnemem Wintu's and Western Mono's connections to the Earth and to their religion. These effects are adverse, and must be avoided. But they are ignored by the EIR/EIS's cumulative impacts analysis.

There are adverse effects associated with methylmercury contamination of fish, increases of selenium concentration in fish tissues long-term in sturgeon, and subsistence fishers along the lower Sacramento River will have to find other places to fish. These impacts are indicated by the

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[456] Environmental Water Caucus Response Letter to the U.S. Bureau of Reclamation for the Shasta lake Water Resources Investigation Draft Environmental Impact Statement, September 30, 2013, 48 pages, Accessible online 8 May 2014 at http://ewccalifornia.org/reports/shastadeiscomments.pdf.

[457] Jay A. Davis, Ben K. Greenfield, Gary Ichikawa, and Mark Stephenson, "Mercury in sport fish from the Sacramento-San Joaquin Delta region, California, USA," *Science of the Total Environment* 391(2008) 66-75; and Fraser Shilling, Aubrey White, Lucas Lippert, and Mark Lubell, "Contaminated fish consumption in California's Central Valley Delta," *Environmental Research* (2010), doi:10.1016/j.envres.2010.02.002.

modeling results presented in BDCP documents on top of the cumulative contamination that already exists, but are not analyzed adequately in the EIR/EIS.

2. The EIR/EIS fails to disclose fully the water supply benefits of North Delta Intake diversions by focusing on wet and above normal year reliability benefits and failing to analyze water transfer benefits of the diversions in drier types of water years.

BDCP's true underlying purpose and need is not only to increase diversions for Delta export from the North Delta Intake diversions in wet and above normal years, but also to increase the supply reliability of cross-Delta water transfers (i.e., from north of Delta to south of Delta locations) in drier and drought years. This is not disclosed in the Purpose and Need Statement of Chapter 2 in the EIR/EIS. The underlying purpose and need of BDCP and its North Delta Intake diversions is more fully disclosed in the modeling results in EIR/EIS Chapter 5, *Water Supply*, and in accompanying analysis of water transfers in that chapter and related appendices.

All nine/twelve BDCP alternatives will have little to no effect on federal Central Valley Project reservoirs relative to the No Action Alternative condition, according to BDCP EIR/EIS modeling results.[458]

The operational modeling criteria for BDCP, however, have noteworthy effects on Oroville reservoir storage, the State Water Project's largest reservoir located on the Feather River. Figures 5-9 and 5-10 show real differences in exceedance probabilities for the BDCP alternatives relative to the No Action Alternative (essentially a with/without BDCP comparison in 2060). With few changes occurring in the federal reservoirs, it appears that most if not all operational changes of the North Delta Diversions are "paid for" with flow releases from Oroville. In Figure 5-9, Alternative 4 H2 and H4 scenarios reveal that in about 60 percent of all years, spring X2 flows will be supplied ("paid for") from Lake Oroville, as reflected in their "end of May" storage levels falling below those of the No Action Alternative. By the end of September (Figure 5-10), Oroville storage levels are nearly all above the No Action Alternative (with limited exceptions for Alternative 4/H4 [i.e., the operational scenario paying extra Delta outflow for *both* Delta smelt and longfin smelt]. Alternative 4 for scenarios H2 and H4 would lower Oroville storage relative to the No Action Alternative levels in the range of years between 20% and 80% exceedance probability—the middle 60 percent of all water years. At the drier end of the spectrum, however, most alternatives differ little from conditions under the No Action Alternative at Oroville at the end of September.

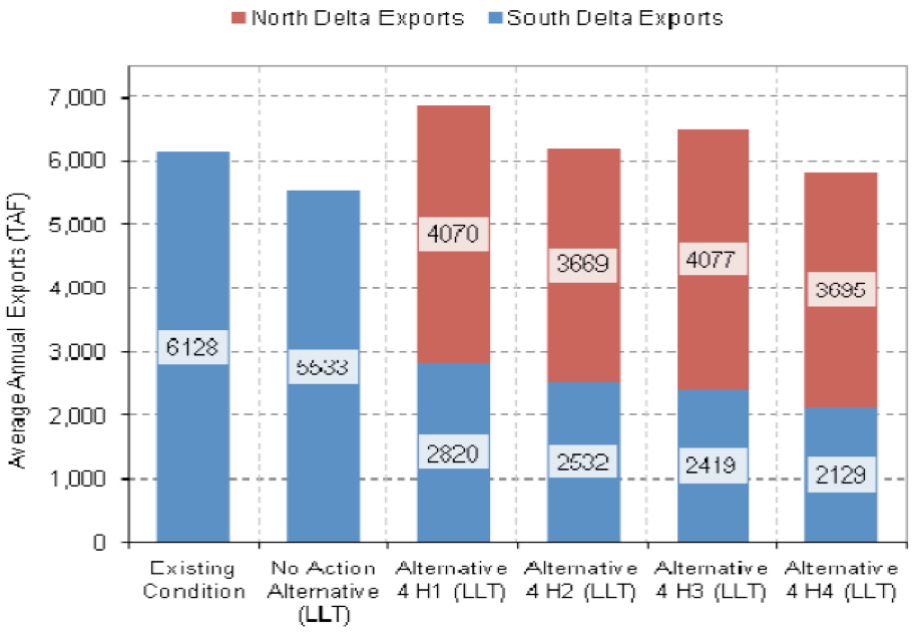
Figures 18 and 19 below illustrate the manner in which BDCP anticipates employing the North Delta intakes (shown in red) primarily in wet years, when they will divert the majority of Delta exports. During dry and critical years, on the other hand, North Delta diversions would decrease dramatically, relative to South Delta export diversions.[459]

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[458] See Figures 5-6, 5-7, 5-8, 5-11, and 5-12 for modeling results showing effects of BDCP alternatives on storage levels on Trinity, Shasta, and Folsom reservoirs.

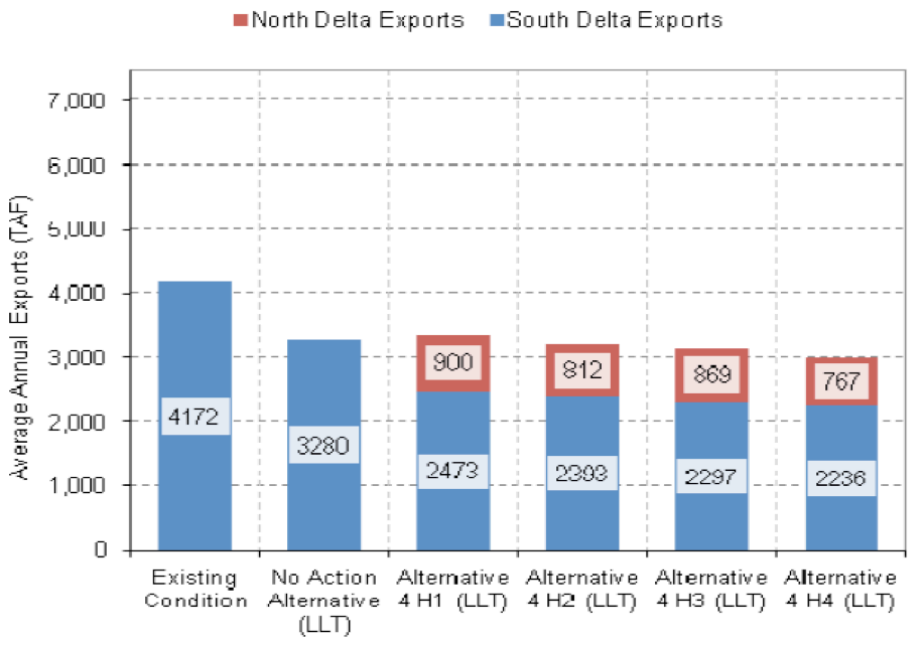
[459] The need to protect "bypass flows" in the lower Sacramento are the ostensible reason, according to BDCP operational modeling assumptions/criteria, though the North Delta Intakes' prospective but as yet unapproved junior diversion rights on the lower Sacramento may be another.

Figure 18
North and South Delta Exports
Wet Year Average



Source: BDCP EIR/EIS, Chapter 5, *Water Supply,* Figure 5-18.

Figure 19
North and South Delta Exports
Dry and Critical Year Average



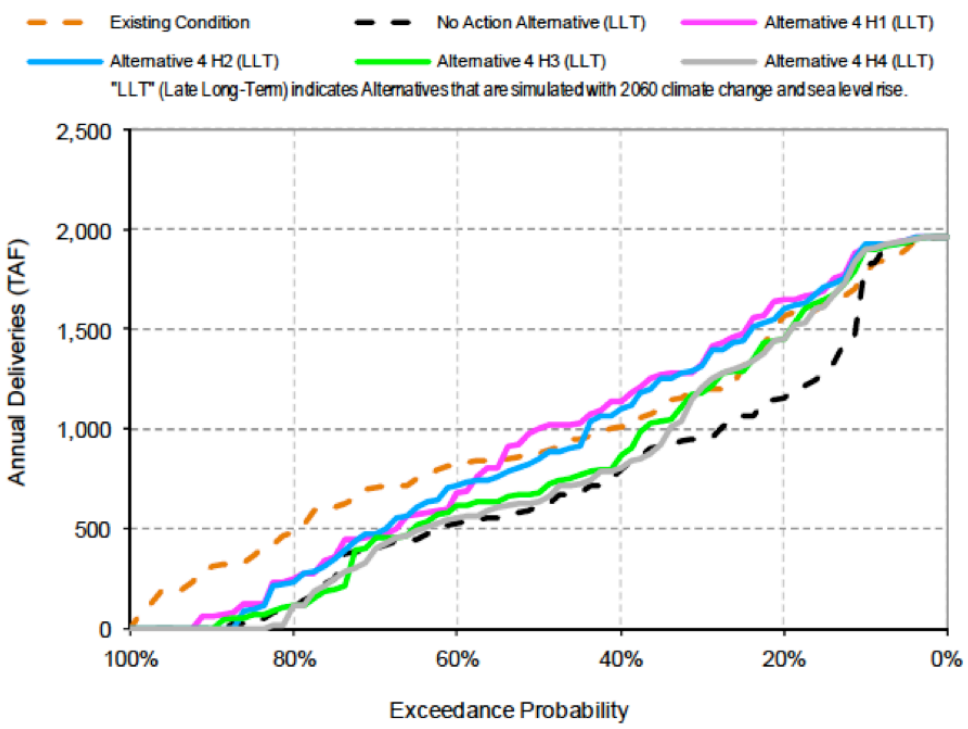
Source: BDCP EIR/EIS, Chapter 5, *Water Supply,* Figure 5-19.

This makes some sense when we recall that the North Delta Diversions are to be owned and operated by the California Department of Water Resources as part of the State Water Project, which will have lower priority water rights at the North Delta Diversions.[460]

Below we excerpt in Figure 20 three figures showing modeling results for water supply effects of Alternative 4, the proposed action alternative. According to the excerpt from Figure 5-31 of the EIR/EIS, Alternative 4's scenarios all "out-deliver" the No Action Alternative for South of Delta agricultural water service contractors, except for having to deliver increased outflows in the driest 15 percent of years. With Westlands Water District being the largest CVP agricultural south-of-Delta contractor, this chart surely keeps Westlands interested in the North Delta Intakes and Tunnels project.

Figure 20
BDCP Water Supply
Beneficial Effects

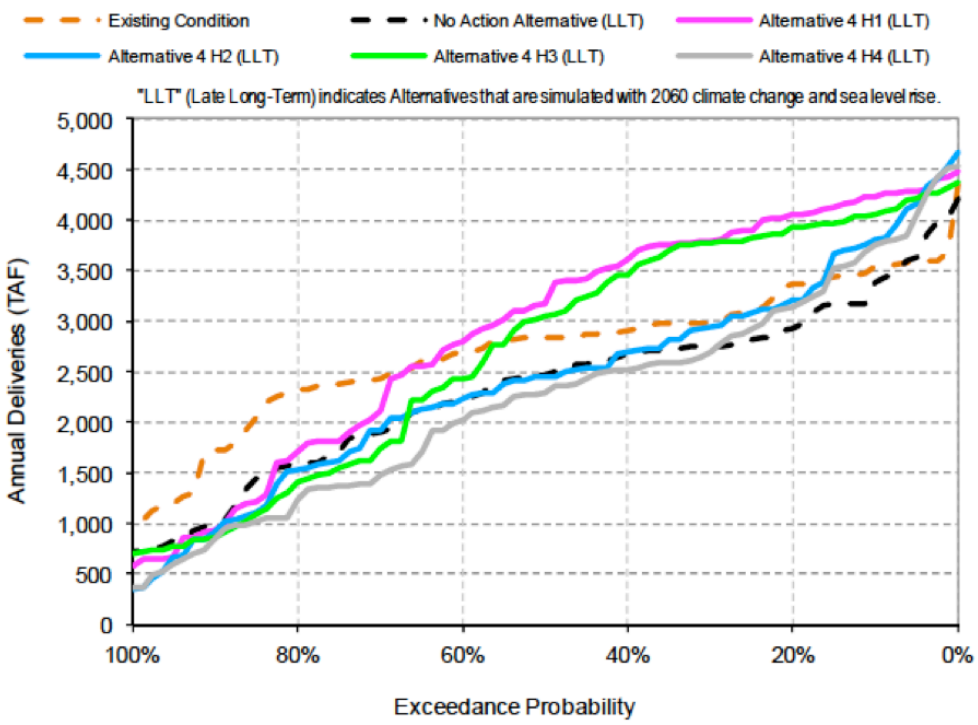
Excerpt from Figure -5-31.



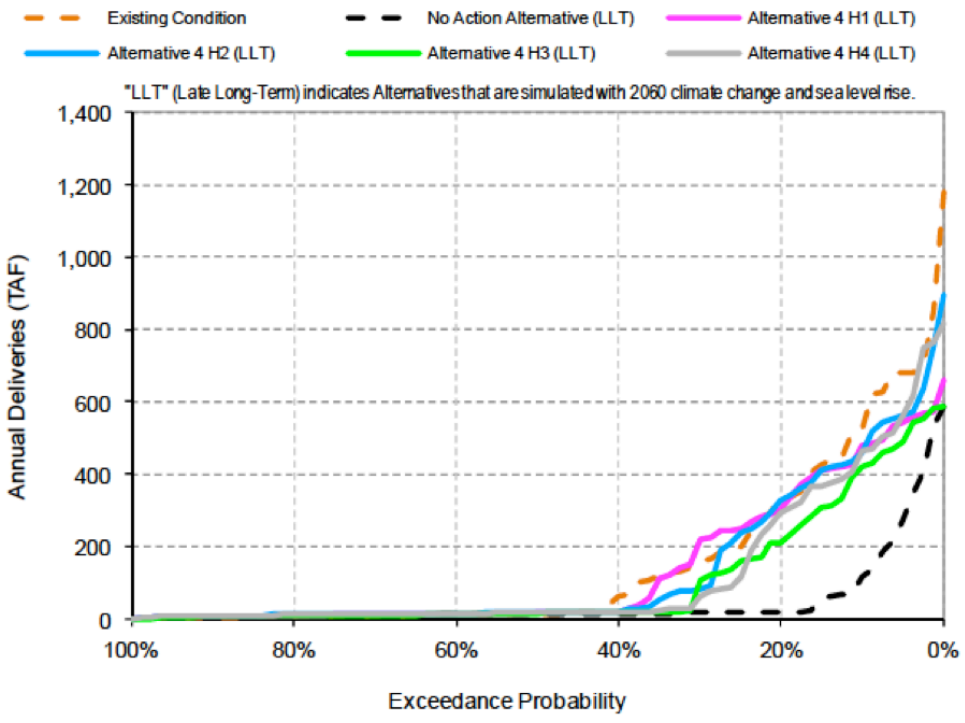
[460] BDCP, Chapter 7, *Implementation Structure*, Section 7.1.2.1.1, p. 7-10, lines 2-6.

Figure 20
BDCP Water Supply
Beneficial Effects

Excerpt from Figure 5-34.



Excerpt from Figure 5-36.



Source: BDCP EIR/EIS, Chapter 5, *Water Supply*.

The excerpt from Figure 5-34 depicts a similar analysis for annual south of Delta SWP deliveries (including Table A contract amounts as well as potential "surplus waters" via Articles 21 and 56 of SWP contracts). This chart shows that for Alternative 4's scenarios South of Delta deliveries perform no worse (and some better) than the No Action Alternative. Only the Alternative 4/H4 scenario benefiting both longfin smelt and Delta smelt with extra spring and fall Delta outflows provides deliveries lower than the No Action Alternative in almost 70 percent of years (including all of the driest). The other alternatives are lower than the No Action Alternative in only about 20 to 35 percent of the driest years.

The excerpt from Figure 5-36 illustrates SWP Article 21 surplus water deliveries for all BDCP Alternatives. We show the frame for each of the four Alternative 4 scenarios. It is important to note that SWP Article 21 deliveries to South of Delta contractors nearly approximates "existing conditions, and greatly exceeds the No Action Alternative. ***It is an underlying purpose of BDCP to use conveyance changes to "restore" surplus Article 21 water deliveries to South of Delta SWP contractors relative to their reduced No Action Alternative prospect.*** The No Action Alternative envisions near zero Article 21 deliveries except in about the wettest 15 to 20 percent of years in the future. The Twin Tunnels project (Alternative 4) would about double the frequency of Article 21 deliveries to State Water Project south-of-Delta water contractors.

Table ES-9 of the EIR/EIS in Impact WS-2 coyly designates water supply changes in SWP and CVP deliveries as "no determination," when clearly they are beneficial. This is one manner in which BDCP's underlying purpose and need statement obscures its likely benefits. The water supply benefits in wet and above normal years extend to additional Article 21 supplies for SWP contractors, and a generally more consistent increased supply of imported Delta water for CVP contractors (primarily Westlands Water District) most of the time with a Tunnels project in place.

The Twin Tunnels' benefit to water transfers is also obscured from the BDCP purpose and need statement. We read in Chapter 7, *Implementation Structure*, of the Bay Delta Conservation Plan that "Reclamation will likely enter into an agreement with DWR to "wheel" CVP water through a new conveyance facility."[461] Why is it that the CVP would want to "wheel" water from the North Delta Intakes when it may do so already at Banks Pumping Plant?

In drier years, BDCP expects there will be extra capacity in North Delta Intakes and Tunnels.[462] In drier years, full CVP contract amounts and SWP Table A amounts will not be available to contractors. While these "contractual" supplies may not be available, the contractors may still have what BDCP refers to as "supplemental demand" for water.

Many of the numerous, similar BDCP alternatives will have intakes sized to carry 15,000 cfs, not just 9,000 cfs as with Alternative 4's intake design. Water transfers[463] are often "wheeled" at times when one project's pumping capacity is insufficient while the other may have extra capacity to divert and lift water out of the Delta for the other. An expanded Clifton Court Forebay will also be able to store extra waters awaiting pumping capacity prior to export to complete such transfers. Indeed, currently, the "Four Pumps Agreement" between the California Department of Water Resources and the California Department of Fish and Wildlife idles four Banks Pumping Plant units so that the

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[461] *Ibid.*, lines 11-12. "Wheeling" water occurs when one water project's water—say deliveries to be made by the Central Valley Project—is actually pumped from the Delta by the State's facilities near Tracy (currently). Under BDCP, "wheeling" could occur further north, at the North Delta Intakes, where water quality is better.

[462] *Ibid.*, Chapter 5, *Water Supply,* p. 5-29, lines 1-2; Appendix 5D, p. 5D-1, lines 28-31; pp. 5D-2, lines 18-23; and p. 5D-3, lines 29-33.

[463] Water transfers are defined by BDCP EIR/EIS in Appendix 1E, *Water Transfers in California: Types, Recent History and General Regulatory Setting*, p. 1E-1, lines 13-18.

State Water Project complies with both fishery mitigations for DFW and navigability limits under US Army Corps of Engineers Public Notice 5820A (from October 1981). Will these pumps be rendered usable in proportion to water arriving at Banks Pumping Plant directly from the North Delta Intakes via the Twin Tunnels?[464]

The EIR/EIS fails to provide a quantitative analysis in Chapter 5 of water transfer behavior even though CalSIM II is perfectly capable of modeling it. But the EIR/EIS does provide a "spreadsheet model" analysis in Appendix 5D that brackets two potential water market volumes in periods of "supplemental demand," one of up to 600,000 acre-feet, and the other of up to 1 million acre-feet, each for single-year time spans.[465]

Chapter 5 claims that "any transfers conveyed through BDCP facilities will need to satisfy all of the applicable requirements in force at the time of the transfer's approval" and states that

> Alternative 4 provides a separate cross-Delta facility *with additional capacity to move transfer water from areas upstream of the Delta to export service areas and provides a longer transfer window than allowed under current regulatory constraints*. In addition, the facility provides conveyance that would not be restricted by Delta reverse flow concerns or south Delta water level concerns. *As a result of avoiding those restrictions, transfer water could be moved at any time of the year that capacity exists* in the combined cross-Delta channels, the new cross-Delta facility and the export pumps, depending on operational regulatory constrains including BDCP permit terms discussed in Alternative 1A.[466]

The decision to omit quantitative analysis of water transfers in Chapter 5 is not for lack of data or modeling methodologies. EIR/EIS Appendix 5D provides ample data cataloguing historic water transfers back into the 1990s. Appendix 5D specifically notes that "supplemental demand" for water transfers is triggered typically when SWP allocations go below 50 percent, and CVP allocations below 40 percent.[467] Such insights are the very stuff of modeling assumptions. BDCP's Chapter 5 Effects Analysis proudly catalogues and totals up its use of models assembled to create these 40,000

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[464] *Agreement Between the Department of Water Resources and the Department of Fish and Game To Offset Fish Losses In Relation To the Harvey O. Banks Pumping Plant*, p. 4, Recital E. which states that USACE Public Notice 5820A "limits exports to the amount of water that can be diverted by the existing [seven] pumps, except during winter months when additional amounts can be diverted during high San Joaquin River flow periods." Executed December 30, 1986. Accessible online 7 June 2014 at http://www.water.ca.gov/environmentalservices/fourpumps.cfm. See also California Department of Water Resources, *California State Water Project Atlas*, 1999, p. 80, where it states, "During [Banks] construction (1963-1969) seven pumps were installed. In 1986, four more were added to divert and pump more water during the wet months to fill offstream storage reservoirs and groundwater basins south of the Delta to improve water supply reliability." The four newer pumps, according to the *Atlas*, have a combined capacity to pump 4,368 cfs, and at full throttle could export nearly 780,000 acre-feet during the summer irrigating season (July 1 through September 30) for water transfers potentially independent of USACE constraints. The source of water to the pumps via the Twin Tunnels would be the Sacramento River and not the San Joaquin.

[465] See also BDCP EIR/EIS, Appendix 5C, *Historical Background of Cross-Delta Water Transfers and Potential Source Regions*.

[466] *Ibid.*, Chapter 5, *Water Supply*, p. 5-108, lines 32-39. Emphasis added.

[467] "Comparing the years when cross-Delta transfer activity picks up with allocations, and considering Delta export constraints on transfers, SWP demand for cross-Delta transfers increases noticeably at allocations below 50 percent and DVP demand for cross-Delta transfers increases below 40 percent." *Ibid.*, EIR/EIS, Appendix 5D, *Water Transfer Analysis Methodology and Results*, p. 5D-3, lines 29-33.

pages of spew on BDCP—68 different models in all.[468] But ***the lack of a modeling effort on water transfers is disingenuous, and ultimately renders the water supply impact analysis deficient and incomplete, and betrays an underlying desire among the BDCP Applicants to make cross-Delta water transfers an unspoken purpose and need for BDCP Delta facilities.***

Chapter 5, *Water Supply*, of the EIR/EIS fails to disclose that the Twin Tunnels project could increase deliveries of "surplus" water relative to the No Action Alternative, not merely "restore" such deliveries; and fails to disclose that the Twin Tunnels project would increase "wheeling" activity to support water transfers during most if not all drier years, which presently occur at least 60 percent of the time. Drier years are likely to increase under conditions of climate change. ***These omissions of impact analysis render the EIR/EIS fatally deficient and misleading. If the project continues, the Draft EIR/EIS must be revised and recirculated.***

3. The EIR/EIS fails to disclose groundwater impacts to the Sacramento Valley that would result from expanded cross-Delta water transfer activity involving groundwater substitution.

Chapter 7 is lengthy and would benefit from a summary of impacts and anticipated mitigation measures. Such a meaningful summary would be helpful when BDCP states:

> There could be minor decreases in water supply availability to CVP water users in the Sacramento Valley service area due to the implementation of the alternatives. These minor changes have been estimated at approximately 50,000 acre-feet per year, which is approximately 2% of the current annual average groundwater production quantity in the Sacramento Valley.[469]

However one slices it, 50,000 acre-feet is still a great deal of water. At current levels of water use for rice production in the Sacramento Valley, This section of the EIR/EIS does not disclose why this 50,000 acre-feet would be the general impact on the valley's groundwater. This much surface water would irrigate 10,000 to 15,000 acres for much of the year. Depending on the crop grown this much groundwater substitution would affect 300 to 400 farmers, depending on average farm size of those affected (e.g., at 40 to 50 acre production units). Withdrawing it from particular locations (such as in the Sacramento Valley's rice districts between Yuba City and Chico) could cause significant local effects on groundwater elevations in the regions. Many smaller and larger towns and cities in this area are dependent on groundwater supplies for municipal and domestic use, as well as irrigation. We believe for this reason that the impacts to groundwater of the Bay Delta Conservation Plan are significant and the EIR/EIS is deficient in excluding the Sacramento Valley from its impact analysis.

Expansion of the water transfers market as an underlying purpose and need for the Twin Tunnels Project and its associated Delta facilities in BDCP would expand the number and frequency of groundwater substitution transfers in a large number of years. Since 1996, the State Water Project allocation has been at 50 percent of less of Table A contract amounts for contractors. Over that same period, the federal Central Valley Project has seen just two years where agricultural allocations of contract maximums have been 40 percent or less. (These two thresholds were identified by BDCP as triggers for "supplemental demand" to be met by cross-Delta water transfers by the state and federal projects.) BDCP also identifies three types of transfers: crop fallowing, crop shifting, and groundwater substitution transfers. Most transfers in recent years have involved groundwater substitution transfers. Despite this inchoate feature of the Bay Delta Conservation Plan (that is, disclosed in Chapter 5 appendices but not elsewhere in the BDCP documents) Chapter 7 attempts to justify omission of groundwater impact discussions of the Sacramento Valley in the following way:

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[468] BDCP, Chapter 5, *Effects Analysis*, Table 5.2-5, pp. 5.2-17 through 5.2-21.

[469] BDCP EIR/EIS, Chapter 7, *Groundwater*, p. 7-32, lines 30-33.

> The Sacramento Valley Groundwater Basin is "full" in most areas, except during drought and in a few locales where drawdown has been observed over the years. In most areas groundwater levels recover to pre-irrigation season levels each spring. A 2% increase in groundwater use in the Sacramento Valley to make up for any shortfalls in surface water supply is not anticipated to substantially impact the groundwater resources as long as the additional pumping is not concentrated in a particular area of the valley. Therefore the Sacramento Valley Groundwater Basin is not included in the groundwater analysis presented in this chapter.[470]

BDCP's claim that the Sacramento Valley is "full" is inaccurate. According to DWR's Northern District Branch Chief Dan McManus,

> The above statement characterizing the Sacramento Valley Groundwater Basin as being "full" in most areas is not accurate. Our work on the CWP 2013 Update indicates that groundwater storage in the Sacramento Valley groundwater basin was reduced by approximately 700 – 1,700 TAF, between 2005 and 2010. In many areas of the Sacramento Valley groundwater levels are at all-time lows and preliminary information from our Spring 2014 groundwater level measurements indicate that groundwater level declines are continuing.[471]

BDCP would directly obtain surface water sold by "willing sellers" as part of water transfers occurring when there is conveyance capacity in the Twin Tunnels Delta facilities. That capacity would reasonably be expected to occur in below normal, dry, and critically dry water years. These water year types can reasonably be expected to occur about 60 percent of the time in the future. It is likely that a significant fraction of these water year types will result in SWP allocations at or below 50 percent, and CVP agricultural allocations at or below 40 percent of contractual amounts. BDCP also indicates that in the first years of a series of dry years, water transfers could be arranged in aggregate amounts up to between 600,000 and 1,000,000 acre-feet. (Second and third years of drought sequences, probably less.) It is also reasonable to expect that a significant portion of those water transfers that could be arranged would include groundwater substitution by willing sellers in order to bring crops in and avoid local and regional economic dislocations from water transfer activity. BDCP has, but has not disclosed, what percentage of water transfers involved groundwater substitution in the Sacramento Valley in recent experience.

Groundwater substitution risks reducing surface river flow in the Sacramento Valley. Additional pumping to fulfill surface supplies foregone to transfers would have a direct and significant impact on instream Sacramento River and other tributary flows. Depletion factors vary with hydrology and geology of specific areas in the Valley. DWR places this passage beneath a subheading that reads: "Potential Increase in Water Supply":

> Reoperation of the existing groundwater storage system could significantly increase annual water deliveries throughout California. Conservative estimates of potential conjunctive management indicate that average annual water deliveries could be increased by 0.5 MAF (DWR 2009). More aggressive estimates indicate a potential increase in annual water deliveries by 2 MAF. However, more aggressive estimates of potential increases in water deliveries depend upon predictable and reliable exports of surface water from the Delta to provide a source of groundwater recharge.[472]

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[470] *Ibid*., p. 7-32, lines 33-40.

[471] Email of Don McManus, Branch Chief in DWR's Norther Region Office, to BDCP.comments@noaa.gov, March 25, 2014. Accessible online 8 June 2014 at http://www.friendsoftheriver.org/site/DocServer/Cmt_698.pdf?docID=8475.

[472] *BDCP.*, Chapter 1, *Introduction*, Appendix 1B, *Water Storage*, p. 1B-6, lines 19-24.

This statement in BDCP's EIR/EIS is vague about what comprises the "existing groundwater storage system" but we suspect it refers to a combination of the Sacramento Valley and the San Joaquin Valley. One valley has groundwater naturally recharging from streams that still flow to the sea (the Sacramento Valley), while the other imports allegedly surplus supplies from the Sacramento Valley to spread water for percolation into "conjunctive use" facilities like the Kern Water Bank, Semitropic Water Storage District, and potentially others.

We conclude that the Twin Tunnels project of BDCP's Conservation Measure 1 is intended to facilitate the potential increase in water supplies to Kern Water Bank and Semitropic as well as expanding California's cross-Delta water transfers market. The overall strategy of using the Sacramento Valley to continue boosting conjunctive use of groundwater basins and increasing Delta exports is outlined in DWR's Bulletin 160-98, *California Water Plan Update*:

> This section reviews *the potential for groundwater development and conjunctive use as elements of statewide water management*, concentrating on the potential for augmenting supplies of the major State or federal water projects….
>
> ***Sacramento Valley.*** *…[T[he Sacramento River Basin constitutes most of the potential for additional water development to meet statewide demands.* Just as surface storage reservoirs are being evaluated to develop a portion of the basin's surplus runoff (about 9 maf), managed conjunctive use programs are being evaluated to the same end.
> …
> ...In concept, *Sacramento Valley conjunctive use programs would operate by encouraging existing surface water diverters to make greater use of groundwater resources during drought periods. The undiverted surface water would become available for other users, and groundwater extractions would be replaced during subsequent wetter periods through natural recharge, direct artificial recharge, or in-lieu recharge (supply of additional surface water to permit a reduction of normal groundwater pumping)*.
>
> The [Drought Water Bank] provides an example of conjunctive use in the Sacramento Valley. In 1991, 1992, and 1994, the DWB executed contracts to compensate Sacramento Valley agricultural water districts for reducing their diversions of surface water. *Most of the reduced surface water diversions were made up by increased groundwater extractions from existing wells.* The 1994 program in this area was the largest, amounting to approximately 100 taf. The DWB program included a groundwater monitoring component to evaluate the effects of increased extractions on neighboring non-participating groundwater users. Such monitoring programs would be an important component of future conjunctive use programs.[473]

The question that results from this chain of effects is, ***what would be the near-term and long-term impacts of groundwater substitution transfers? BDCP has failed to identify, disclose, and analyze the potential impacts of cross-Delta groundwater substitution water transfers on the Sacramento Valley and its groundwater resources. This is a serious deficiency of the BDCP EIR/EIS.***

4. The EIR/EIS fails to analyze whether Delta lands employing sub-irrigation techniques would be affected, or adversely affected, by construction and operation of the proposed Twin Tunnels Facilities of Conservation Measure 1.

As noted above, the BDCP EIR/EIS included no description of subirrigation practices by Delta farmers on Delta lands. These lands do occur in the vicinity of all types of alignments (see maps

[473] California Department of Water Resources, *Bulletin 160-98: California Water Plan Update,* p. 6-22. "taf" refers to "thousands of acre-feet" and "maf" refers to "millions of acre-feet." Emphasis added.

from water quality control plans, above) of BDCP alternatives. No analysis of the effects of Twin Tunnels facilities described in Conservation Measure 1 of BDCP has been performed or disclosed in the EIR/EIS.

This is a serious deficiency of the EIR/EIS. Failure to analyze and recognize this water management practice in the Delta could lead to adverse effects like locally-specific rising water tables and salinization of soil horizons that could damage crops or force premature retirement of land from agricultural production.

5. The EIR/EIS fails to adequately disclose and analyze the potential impacts of methylmercury disturbance, bioaccumulation, and its entry into the Delta's benthic food web and connect them to public health and environmental justice impacts.

Please refer to our analysis of methylmercury, Section III above.

6. The EIR/EIS fails to adequately disclose and analyze the potential impacts of changes in Delta water quality and interior flow regime on selenium partition, sediment disturbance, bioaccumulation, and selenium's entry into the Delta's benthic food web.

Please refer to our analysis of selenium issues concerning the mechanisms by which selenium becomes bioavailable and bioaccumulates in the benthic pathway of the Delta's aquatic food web, Section III, above.

7. The EIR/EIS fails to integrate for impact analysis purposes water quality impacts from habitat restoration actions and Twin Tunnels construction and operation with impacts on predators, food webs, and invasive bivalves.

Please refer to our discussion of predators, food webs, and invasive nonnative clams in the Delta Section III, above.

8. The EIR/EIS fails to disclose that the BDCP will violate water quality standards established for flow, preventing necessary Clean Water Act 401 certification.

As described above in Sections VI and VII, implementation of the BDCP will require a CWA Section 404 permit from the Army Corps of Engineers, which it cannot receive unless the state issues a CWA Section 401 certification, which in turn cannot be legally issued unless the BDCP project as a whole (i.e., rather than the individual discharge mandating the 404 permit) meets water quality standards, including by meeting beneficial uses designed to protect Delta species and ecosystems. As written, the BDCP modeling results show it will fail this test, since designated uses cannot be met under the proposed flow scenarios. ***Accordingly, to be implemented, the BDCP must include alternatives' flow regimes that will ensure that beneficial uses protecting Delta ecosystems and species are met.***

To obtain CWA Section 401 certification for the necessary Section 404 permit, implementation of the BDCP must not violate applicable water quality standards under the Clean Water Act.

The fishery agencies would abuse their discretion under Section 10 of the federal Endangered Species Act and the California Natural Communities Conservation Planning Act to issue incidental take permits for BDCP when it demonstrably fails to comply with federal water quality control law.

The EIR/EIS fails to analyze this impact of the Bay Delta Conservation Plan and is therefore inadequate under the National Environmental Policy Act and the California Environmental Quality Act.

9. The EIR/EIS fails to disclose that if BDCP is integrated into the Bay-Delta Water Quality Control Plan, the resultant flow regime modeled under the current BDCP will fail to protect the most sensitive beneficial uses, as required by the Clean Water Act.

In addition to the BDCP not meeting requirements for Section401 certification, the EIR/EIS's Chapter 8, *Water Quality*, contains a "regulatory setting" discussion that omits description of actual water quality objectives adopted by the State Water Resources Control Board in the Bay-Delta Water Quality Control Plan. This is important because BDCP modeling criteria presume some of these water quality objectives as Twin Tunnels operational criteria, and employ other newly designed and operationalized criteria to model the performance of the North Delta intakes and related facilities. In short, ***to model the effects of BDCP, the EIR/EIS presumes—but fails to disclose the presumption—that the State Water Board will adopt and implement BDCP's modeling criteria as legal water quality objectives for the Bay-Delta Estuary, fails to describe the degree to which Delta water quality regulation would be altered by such an action, and fails to analyze whether these amendments could be legally accomplished under the federal Clean Water Act and Porter-Cologne Water Quality Control Act***.

Some of the key modeling criteria for BDCP options that fit this description are Old and Middle River/San Joaquin River inflow-export ratio; North Delta Bypass flows; Head of Old River gate operations; new spring outflow criteria for March through May; new fall outflow criteria for September through November; and a thoroughly revised calculation for determining export to inflow ratio. For the Delta facilities contained in Conservation Measure 1 of BDCP to legally operate in the Delta, the State Water Board would have to amend the Bay-Delta Plan.

The State Water Board is in the process of updating the Bay-Delta Water Quality Control Plan, last updated eight years ago. As noted above, the CWA requires the state to adopt water quality standards that "shall consist of the designated uses of the navigable waters involved and the water quality criteria for such waters based upon such uses."[474] In setting criteria to protect the beneficial uses, U.S. EPA regulations require states to "*protect* the designated use."[475] ***Actions that "reasonably protect"[476] rather than "protect" the beneficial use are insufficient. If multiple beneficial uses are at stake, adopted flow criteria must protect the most sensitive beneficial***

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[474] 33 U.S.C. 1313(c)(2)(A); *PUD No. 1* at 704.

[475] 40 CFR § 131.11 (emphasis added); *see also* 40 CFR § 131.6.

[476] SWRCB, "Comments on the Second Administrative Draft Environmental Impact Report/Environmental Impact Statement for the Bay Delta Conservation Plan," p. 1 (July 05, 2013), available at: baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/State_Water_Resouces_Control_Board_Comments_on_BDCP_EIR-EIS_7-5-2013.sflb.ashx Emphasis added.

use (i.e., they cannot "balance" away uses) and must be based on science.[477] As the state Supreme Court found, Porter-Cologne balancing provisions[478] "cannot authorize what federal law forbids."[479] The more protective federal CWA water quality standard requirements take precedence over weaker Porter-Cologne language; ecosystem and species needs cannot be balanced away.

As described earlier, the BDCP is based on levels of instream flow that are widely considered to be inadequate for Delta fish and habitat. For example, the Department of Interior stated that it "remains concerned that the San Joaquin Basin salmonid populations continue to decline and believes that flow increases are needed to improve salmonid survival and habitat."[480] A comparison of flow regimes established under the BDCP, current flows, the State Water Board's August 2010 flow criteria report, and other flow data demonstrates that flow regimes proposed under the BDCP are at best similar to existing, deeply inadequate flows—and often less than that, particularly in the Sacramento River below the North Delta intakes.

10. The EIR/EIS fails to comply with federal and state anti-degradation policy to protect beneficial uses in the Delta from unjustified degradation of salinity conditions, and failure to provide an anti-degradation analysis at all.

The EIR/EIS fails to provide an analysis of the Bay Delta Conservation Plan's compliance (or likely noncompliance) with state and federal anti-degradation policies.

The BDCP and its EIR/EIS acknowledges (factoring in climate change effects) that residence time of water in the Delta will increase under Tunnels operations, Delta outflow will decrease, mercury and selenium in fish tissues will increase, raising public health concerns as a consequence of BDCP and Twin Tunnels project implementation, as we describe elsewhere in Section VII. Salinity levels will increase throughout the Delta, creating water quality problems for boaters, agricultural irrigators, sport fishing anglers, and subsistence fishers. ***In this light, under state and federal Clean Water Act anti-degradation policy the fishery agencies would abuse their discretion by signing the Implementing Agreement and issuing incidental take permits for activities that would decrease water quality throughout the Delta.***

US EPA Region 1, consistent with *PUD No. 1 of Jefferson County v. Washington Department of Ecology*, 511 U.S. 700 (1994), has found that a state's anti-degradation program "must obviously address

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[477] EPA regulations state that "criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use. For waters with multiple use designations, the criteria shall support the most sensitive use." *See* 40 CFR § 131.11; *see also* 40 CFR § 131.6.

[478] Calif. Water Code § 13000.

[479] *City of Burbank v. State Water Resources Control Bd*., 35 Cal.4th 613, 626, 108 P.3d 862 (2005) (citing the Supremacy Clause).

[480] U.S. FWS, "Comments on the Revised Notice of Preparation and Notice of Additional Scoping Meeting for the State Water Resources Control Board Review of the Southern Delta Salinity and San Joaquin River Flow Objectives in the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary," p. 1 (May 23, 2011). Accessible online 9 June 2014 at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/cmmnts052311/amy_aufdemberge.pdf. . See above for other statements of scientists and agencies on Delta flow.

water withdrawals" as well as discharges.[481][1] California's anti-degradation policy (Resolution 68-16, Oct. 1968) contemplates the policy's application to water rights permits, reading in part:

> WHEREAS the California Legislature has declared that it is the policy of the State that *the granting of permits and licenses for unappropriated water* and the disposal of wastes into the waters of the State *shall be so regulated as to achieve highest water quality consistent with maximum benefit to the people of the State*....[482]

Anti-Degradation analysis of water withdrawals has particular importance in California given a recent decision of the Third Appellate Court. In the *Asociacion de Gente Unida* decision, the Court found that "[t]he anti-degradation policy measures the baseline water quality as that existing in 1968 and defines high quality waters as the *best quality achieved since that date."*[483] It further finds that any actions to lower water quality below that level trigger the anti-degradation policy, unless those levels are consistent with state-adopted water quality objectives.[484] By this definition, the proposed actions trigger preparation of an adequate anti-degradation analysis, which must include findings to support the above requirements if lowering of water quality is to be legally allowed. Water quality lowering almost invariably accompanies water diversions, in the form of changes in flow-related parameters such as dissolved oxygen, temperature, sediment, bacteria, and other pollutants.

As summarized by US EPA, all three water quality law components—designated uses, criteria to protect the designated uses, and the state's anti-degradation requirements—are "relevant and vital tools to protect and restore healthy hydrology."[485] BDCP and the Twin Tunnels' EIR/EIS must consider hydrology impacts in its anti-degradation analysis, and perform the assessments necessary to justify any concomitant degradation consistent with state and federal anti-degradation policies. Their absence in this EIR/EIS means this document must be revised to include anti-degradation analysis. The EIR/EIS should then be recirculated, should the project continue.

11. The EIR/EIS fails to analyze adequately impacts of the habitat conservation elements of BDCP on Delta Plan Area land use, agriculture, and the Delta economy.

In 2012, the Delta Protection Commission's *ESP* found several economic impacts from those BDCP proposals. (): The potential impact of policy changes on Delta salinity is highly uncertain at this time. Water supply in the Delta is a direct consequence of water quality. The better the quality, the more reliable are in-Delta water supplies. Potential changes to Delta salinity depend on decisions on water quality objectives and the resulting effect of isolated conveyance from BDCP. A preliminary estimate of losses due to increased salinity of Delta waters is between $20 million and

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[481] Letter from John DeVillars, US EPA Region 1, to Timothy Keeney, Rhode Island Department of Environmental Management (June 25, 1996), p. 3 (available upon request).

[482] State Water Board Resolution No. 68-16, *op. cit*., note 73 above.

[483] *Asociacion de Gente Unida por el Agua v. Central Valley Regional Water Quality Control Board* (Cal. App. 3d, Nov. 6, 2012), No. C066410, p. 22. Emphasis added.

[484] *Ibid*., pp. 21-22.

[485] Letter from James Giattina, US EPA Region 4 to Lance LeFleur, Alabama Department of Environmental Management, "Alabama Water Agencies Working Group: EPA Region 4 Stakeholder Comments," p. 9 (Nov. 19, 2012) (available upon request).

$80 million per year. The loss of farmland to construct the conveyance facility is estimated to generate an additional $10 to $15 million in crop losses per year.

The agricultural impacts of most of the BDCP conservation measures are difficult to quantify due to the lack of precision in site specification and other details, a direct result of the restoration conservation measures being pitched at only a "program" or conceptual level in the Bay Delta Conservation Plan. Broad ranges of still more potential annual crop losses have been estimated from the land requirements and descriptions of easement costs in the draft BDCP.

- Tidal habitat restoration losses range from $18 to $77 million annually with losses at the lower end of the range occurring when restoration is targeted to Suisun Marsh.
- Natural Communities Protection losses are estimated to range from $5 to $25 million annually.
- San Joaquin River Floodplain crop losses are estimated at $5 to $20 million annually and could be reduced significantly by implementing an alternative proposal to expand an exiting bypass at Paradise Cut.
- Yolo Bypass Fishery Enhancements could generate crop losses between $7 and $10 million annually.[486]

In addition to reduced opportunities for agricultural production and the potential for increased salinity due to habitat restoration, the *ESP* identified the following negative effects on land use (*ESP* page 39):

- Increased mosquito/vector problems from marsh restoration increases the risk of disease and creates a nuisance that makes the Delta less desirable for living, recreation, and tourism.
- Some marsh restoration could increase seepage and risk for levees on nearby islands.

The BDCP EIR/EIS itself identifies four Significant and Unavoidable Adverse Impacts to agriculture in the Delta as a result of constructing and operating the proposed water conveyance facility and implementing the proposed conservation measures.[487] The EIR/EIS Executive Summary indicates that all or most impacts on agriculture from the BDCP alternatives are adverse. The mitigation proposed is a "stewardship program." This appears to be wholly inadequate to the damage BDCP will cause to the Delta's agricultural economy.

The EIR/EIS also acknowledges that salinity will increase in Delta waters, discussed above in Section VII of these comments, which is an adverse water quality impact and injury to Delta water rights which depend on adequate water quality. Along with the land conversion planned with the other 21 "conservation measures" the EWC regards BDCP as an attack on Delta agriculture. The lack of levee investments, the potential to disrupt drainage patterns of the islands by introducing a tunnel, dewatering of lands around Delta facilities—they all amount to death to Delta agriculture by a thousand cuts.

The EWC is also concerned that BDCP, through its Implementation Office, will consolidate control over various DWR and DFW and other conservation/restoration projects under its umbrella. Would DWR turn the conservation easement on Staten Island over to BDCP? Would DFW durn the Yolo Bypass Wildlife Area over to BDCP? Is it the Resource Agency's intention that everything related to habitat will become part of BDCP?

The EIR/EIS also notes that "Implementation of CM2-CM21 would take place on land governed by policies designed to avoid or mitigate environmental effects, as identified in the Delta Protection

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[486] *ESP* pages 112-113.

[487] BDCP EIR/EIS, Chapter 31, *Growth Inducement*, Table 31-1, page 31-10.

Commission Land Use and Resources Management Plan and in the Delta Stewardship Council draft Delta Plan." Among Delta Plan policies associated with land use, the EIR/EIS mentions DP P2 (Respect Local Land Use When Siting Water or Flood Facilities or Restoring Habitats). "Policy DP P2 requires that parties responsible for proposed action avoid or reduce incompatibilities with existing or planned uses **when feasible**"[488] "However, avoidance of all incompatibilities is likely to be considered infeasible; thus activities associated with CM2-CM21 would be compatible with Policy DP P2."[489]

We find there is poor definition of the BDCP Natural Reserve System. There already is a Delta Conservancy. There are other local conservancies in the region. We are very concerned too that having the Implementation Office run a reserve system will likely give it a low priority relative to Delta water operations, real-time fish protection operations, and the inevitable adaptive management dustbin where, we fear, challenging problems will be sent to die. We are concerned that BDCP uses bureaucratic commitment to "consensus" and other governance ploys to strangle the Delta region, and push its ecosystems and listed fish species over the edge.

We find this statement Orwellian. It claims for DWR and BDCP Applicants an implicitly authorized discretion over what is "feasible" for purposes of determining land use compatibility. BDCP arrogates to itself the power to determine under Delta Plan policy DP P2 that land uses of BDCP that may be incompatible would be conveniently found compatible. The EWC and its member groups demand that BDCP define how the Applicants define "feasible" in this land use context, and by what authority it would make such a determination.

BDCP's habitat proposals are redundant. Compared with several types of existing habitat identified in the Delta Plan EIR's Table 4.4, BDCP's habitat proposals seem redundant at best and therefore difficult to justify in view of the costs to existing land uses associated with their implementation.

BDCP says that CM4 would *restore* 65,000 acres of freshwater and brackish tidal habitat.[490] Table 4.4 of the Delta Plan EIR identified over ***83,000 acres*** *of* ***existing*** *tidal and nontidal brackish and freshwater marsh*: 8,330 acres of tidal brackish marsh; 6,980 acres of tidal freshwater marsh; 50, 180 acres of managed nontidal brackish marsh; 3,260 acres of unmanaged nontidal freshwater marsh; and 14,300 acres of managed nontidal freshwater marsh.

BDCP says that CM7 would restore 5,000 acres of riparian forest and scrub. Table 4.4 identified over **16,000 acres** of **existing** riparian forest (8,980 acres) and riparian scrub (7,180 acres).[491]

BDCP says that CM8 would restore 2,000 acres of grassland and protect 8,000 additional acres.[492] Table 4.4 identified **69,200** acres of **existing** grassland.

BDCP says that CM9 would restore vernal pool complexes and alkali seasonal wetlands within a larger matrix of grasslands; no acreage is specified.[493] Table 4.4 identified **15,610 acres** of **existing** grasslands with vernal pools (10,080 acres) and alkali seasonal wetlands (5,530 acres).

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[488] *Ibid.*, lines 24-26. Emphasis added.

[489] *Ibid.*, Chapter 13, page 13-64, lines 10-16 and lines 30-31.

[490] BDCP, Chapter 3, *Conservation Strategy*, Section 3.4.4.

[491] *Ibid*., Section 3.4.7.

[492] *Ibid.*, Section 3.4.8.

[493] *Ibid.*, Section 3.4.9.

BDCP's CM3 proposes to acquire 69,275 acres to establish a habitat reserve system to protect existing natural communities and covered species habitat.[494] Major portions of the Delta are already owned or managed by public agencies or conservancies for the benefit of natural communities. Identifying and quantifying areas set aside for these purposes is complicated by the fact that land changes hands, collaborative efforts are continually being undertaken, and projects are initiated in response to changing conditions. Following is a discussion of some of the projects currently underway and land set aside primarily for habitat purposes, along with estimates of acreage. This list is by no means comprehensive. Where a project lists ranges of acreage, the most conservative numbers are listed here.

In the area identified by BDCP as Suisun Marsh ROA, the California Department of Fish and Wildlife (CDFW) oversees a long-term joint state-federal plan to restore ecological health and improve water management on non-tidal and tidal wetlands and grassland. The primary management zone alone is 89,000 acres, and a 30-year-plan now in place covers **52,000 acres** of wetland and upland habitats.

In the area identified by BDCP as Cache Slough ROA, a Fish Restoration Program Agreement (FRPA) is already in place to satisfy requirements of the Biological Opinions for SWP and CVP operations. FRPA is a joint effort between DWR and CDFW to implement habitat restoration in partial mitigation for the State Water Project's (SWP) impacts on sensitive fish species in the Delta. FRPA is also intended to address the habitat restoration requirements of the 2009 CDFW Longfin Smelt Incidental Take Permit (ITP) for SWP Delta operations (an incidental take permit separate and distinct from those sought by BDCP Applicants).

A variety of activities are associated with FRPA, including restoration and enhancement work on over **14,000 acres** in Yolo and Solano Counties.[495] It includes land formerly owned by the Trust for Public Land (Liberty Island) and The Nature Conservancy (McCormack-Williamson Tract). It incorporates several earlier efforts, including Prospect Island Tidal Habitat Restoration Project and the Cache Slough Complex project. DWR awarded a grant for the Cache Slough Complex project to support a conservation vision jointly devised by the Solano Resource Conservation District, Dixon Resource Conservation District, Reclamation District 2068, and the local landowners. The project has two main components: non-native invasive species removal and habitat enhancement and restoration.

The Department of Fish and Wildlife's Yolo Bypass Wildlife Area encompasses **17,770 acres**. BDCP CM2, Yolo Bypass Fisheries Enhancement (3.4.2), proposes to modify operations of the Yolo Bypass to benefit covered fish species. (No proposed acreage is specified.)

Already underway in the Yolo Bypass is the Knaggs Ranch Agricultural Floodplain Study, a collaborative effort of landowners, UC Davis, and CalTrout that has already shown some success providing salmon habitat on seasonally flooded agricultural land. The long-term goal is to expand the project to 2,500 acres.

Substantial amounts of agricultural acreage are managed for habitat. For example, Staten Island, over **9,100 acres**, is owned by The Nature Conservancy, which is required under a conservation easement owned by DWR to protect wildlife-friendly agriculture on the island. Staten Island is managed in particular for the protection of sandhill cranes. Additional sandhill crane

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[494] *Ibid.*, Section 3.4.3.

[495] "FRPA and Other Habitat Restoration Projects for BiOps and ITP Compliance in the Delta and Suisun Marsh." Map edited by DWR, May 2013.

habitat is provided by the **147-acre** Woodbridge Ecological Reserve (also known as the Isenberg Crane Reserve) in San Joaquin County. The California Department of Fish and Wildlife (CDFW) manages this reserve consisting of low freshwater marsh, grassland, and flooded pasture. BDCP says that CM10[496] would restore 1,200 acres of nontidal freshwater wetlands and create 500 acres of managed wetlands for greater sandhill cranes.

The Delta Wetlands Project, a public-private partnership between Kern County's Semitropic Water Storage District and Delta Wetlands, a private landowner, owns four islands in the Central Delta that it manages for water supply and habitat restoration: Bacon Island (5,625 acres), Webb Tract (5,490 acres), Bouldin Island (6,006 acres) and Holland Tract (about 3,500 acres). Total: **20,621 acres**.

Portions of the 46,000 acre Cosumnes River Preserve (parts of which are in BDCP's Cosumnes/ Mokelumne ROA) and the USFWS's Stone Lakes National Wildlife Refuge (the latter with about 11,500 acres currently owned or managed) lie within the statutory Delta.

The Dutch Slough Tidal Marsh Restoration Project in eastern Contra Costa County is a joint state-local-nonprofit project to restore **1,200 acres** of tidal marshland, riparian, and upland habitats. Sherman Island, 9,937 acres almost entirely owned by DWR, includes the **3,115 acre** Lower Sherman Island Wildlife Area in Sacramento County, managed by DFW; Decker Island Wildlife Area in Solano County, managed by DFW, is **33 acres.** Miner Slough Wildlife Area, also in Solano County and managed by DFW is **37 acres.**

All five Delta counties have their own habitat conservation plans that include Delta lands. In addition, local land conservancies have several hundred acres of land within habitat easements. And although exact information about owners and acreage is not available, the USDA's Natural Resources Conservation Service provides technical assistance on habitat projects to private landowners in the Delta.

Clearly, there is no lack of land currently owned and already managed for habitat in the Delta by a variety of project sponsors. These activities represent an evolution of land uses that is already underway in the Delta in response to concerns about the adequacy of habitat. Intensive farming of the Delta islands goes back over 100 years. Island configuration and new land converted to farms have essentially not changed since the early 1900s, while habitat acreage has increased significantly over time.

Precipitous species decline began in the 1960s, concurrently with increased project exports. If habitat were the solution to species declines, then we would not be seeing the collapse of Delta fisheries that has occurred since the state and federal export facilities began operating, reducing freshwater flows. Habitat restoration efforts have in some cases made matters worse by inadvertently creating habitat for undesirable species, predators, and noxious weeds.

Existing habitat could be managed far more efficiently as a more interconnected system to improve fishery benefits. There are amounts of land already in habitats of various types that are benefiting covered fish already. For fish species, however, whether covered by BDCP or not, Delta inflows are a crucial component of Delta habitat values. BDCP cannot meet its primary goal of export reliability without removing water that fish need. Adding more wetland and other natural community habitat by taking agricultural land out of production will not compensate for this loss of flows.

The disconnect between BDCP's advertised habitat goals, its water supply reliability purposes, and its deletion of flows to benefit fish is on full display in BDCP's designs for the South Delta ROA.

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[496] BDCP, Chapter 3, Conservation Strategy, Section 3.4.10.

The Problem Statement for CM5 acknowledges that "[c]hannel straightening and levee construction have disconnected river channels from their historical floodplain over much of the Plan Area, resulting in the reduction, degradation, and fragmentation of seasonally inundated floodplain and its associated natural communities."[497] This has resulted in a decline in the abundance of species including Sacramento splittail, Chinook salmon, and slough thistle.[498] A few lines later, this assertion is moderated: "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."[499] Nevertheless, we see here the crux of BDCP's case for habitat restoration: Loss of habitat, rather than dramatic changes in quality and timing of flows of water due to increased water exports, is the pre-eminent cause of species declines.

Despite this Problem Statement's focus on seasonally inundated floodplains in the north and east portions of the Plan Area, BDCP says that "the most promising opportunities for large-scale floodplain restoration are in the south Delta."[500]

Selection of the south Delta for the creation of new floodplain habitat only makes sense if the Delta is viewed entirely from the perspective of topography, without respect to existing land use, which is agriculture.

The South Delta ROA is not subsided land; BDCP identifies it as "intertidal" (2 to 5.5 feet in elevation), "sea level rise accommodation" (5.5 to 8.5 feet in elevation), and two levels of "transitional habitat" (8.5 to 15 feet in elevation) (BDCP Figure EA.2.1.1: South Delta Physical Setting, page EA.2-2). Thus, built into the identification of this as a Restoration Opportunity Area is the assumption that subsided areas adjacent to it will become tidal as a consequence of sea level rise. The terminology used to describe this ROA represents an implicit policy decision NOT to commit to maintaining existing land uses in the area.

Significantly, the habitat project on four south Delta corridors that is described in Chapter 3 as "Conservation Measure 5 Seasonally Inundated Floodplain Restoration" is described in Appendix 5E Habitat Restoration (Attachment 5E.A) as "BDCP South Delta Habitat and Flood Corridor Planning." This difference in description represents an accommodation to the South Delta Habitat Working Group, which insisted that flood management objectives be integrated into habitat objectives.[501]

EWC does not expect that flood management will be a guiding principle in implementation of CM5. BDCP is straightforward about the primary goal of CM5: "Restored floodplains may maintain

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[497] Bay Delta Conservation Plan, Chapter 3, *Conservation Strategy*, Section 3.4.5.2, page 3.4-146, lines 28-30.

[498] *Ibid.*, lines 32-33.

[499] *Ibid.*, p. 3.4-147, lines 10-12. Emphasis added. The Problem Statement continues with discussion of changes to habitat for splittail in floodplains in the Yolo and Sutter Bypasses and along the Cosumnes River (lines 38-39), as well as loss of splittail habitat and floodplain connectivity downstream from Sacramento as a result of USACE projects to decrease flooding in the lower Sacramento River (lines 1-5). Emphasis added.

[500] *Ibid.*, 3.4.5, page 3.4-145, lines 16-17. Any floodplain restoration in the Sacramento or Cosumnes-Mokelumne basins would involve channel margin enhancement (CM6) and would be ***in addition to*** the 10,000 acres planned for the South Delta (3.4.5, page 3.4-150, lines 12-15).

[501] *Ibid.,* Chapter 5, *Effects Analysis,* Attachment 5E.A, page EA.1-2, lines 13-14.

existing agricultural uses that are compatible with the primary goal of restoring habitat for covered fish and wildlife species."[502]

In terms of siting and design, flood conveyance and risk reduction benefits are just one of five considerations. A restoration site must have the "potential to meet or contribute to the applicable biological goals and objectives"; must be adjacent to a channel important "for use by covered species, especially by rearing/migrating juvenile salmonids"; and must have the "potential to provide ecologically relevant flood inundation [to benefit native species] given the anticipated range of flow regimes and sea level conditions influenced by climate change and potential management changes."[503]

This last point encompasses several major uncertainties: the range of BDCP flow regimes, the effects of climate change, and management of the San Joaquin River Restoration Program. In particular, flows in the South Delta will be heavily influenced by how flows in the San Joaquin River are managed for restoration.

Despite the uncertainties, the conservation strategy for CM5 combines hypothesis with resolute optimism: "We think this will work and we're going to try it, and if it doesn't work, we'll try something else." The "something else" may also be dramatically disruptive.

> 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.[504]

This is the essence of adaptive management. It is offensive because it seeks to justify a situation where the proposal is to disrupt existing well-functioning land uses to create new habitat. The habitat restoration conservation measures would strive to "break" the Delta (through conversion of economically and socially productive agriculture) in order to "save" it through habitat restoration that the EWC has shown elsewhere in these comments to be fraught with BDCP optimistic intentions that are not backed by credible readings of the supporting science cited. In the South Delta, the factors most damaging to both habitat and agriculture are poor water quality and inadequate flows of water as a result of the operation of the state and federal water projects, both on the San Joaquin River and in the Delta itself. Nor does CM5 propose to adaptively manage that situation.

Details about the Adaptive Management and Monitoring that is proposed (3.4.5.4) confirm what for the south Delta would be essentially an experiment on a grand scale.

> "Compliance monitoring for this conservation measure will consist of documenting in a GIS database the extent of floodplain *successfully restored*. . . . "[505]

This assumes, rather than demonstrates, that restoration actions will be successful. If they are not, more extensive "recontouring" may be called for; rinse, repeat.

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[502] *Ibid.*, page 3.4-149, lines 16-18.

[503] *Ibid.*, Section 3.4.5.3.2, page 3.4-148, lines 20-26

[504] *Ibid.*, p. 3.4-151, lines 20-22. See also 3.4.5.3.3 on the relationship of CM5 to other conservation measures, pages 3.4-149 to 3.4-150.

[505] *Ibid.*, page 3.4-151, lines 5-6. Emphasis added.

> "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."[506] If they are not, "These monitoring elements may be modified, as necessary . . . ."[507]

If the criteria don't provide the results desired, the criteria can be changed.

> "...[O]ne 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."[508]

At least those doing the monitoring will not have to be uncertain about the ineffectiveness of the conservation measure.

BDCP attempts to reassure readers that we can count on "the Implementation Office [to] address scientific and management uncertainties and ensure that...biological goals and objectives are met" through "effectiveness monitoring, research and adaptive management....."[509] Alas, this too is not reassuring. Description of the Implementation Office at Section 7.1.1.3 makes it clear that "the implementation Office staff will work closely with the Authorized Entity Group on a range of matters, particularly with respect to actions that affect water operations, and will be responsive to the Authorized Entity Group...."[510] "The Authorized Entity Group will consist of the Director of DWR, the Regional Director for Reclamation, and a representative of the participating state contractors and a representative of the participating federal contractors."[511] ***The long experience of people in the Delta suggests that under these circumstances, it is unlikely that implementation of any conservation measure will be allowed to take precedence over water operations.***

It is likely that under CM5, the South Delta will be reconfigured for floodplains, with attendant adverse impacts on land use, mainly through conversion of agricultural land., Then it can be operated exclusively instead for exports.

Note regarding water for wetlands: BDCP proposes 65,000 acres of Tidal Wetland Restoration.[512] However, Table 5.4-3 of the Effects Analysis shows a net *reduction* in "Managed Wetland" acreage over the whole planning area. This is due to the loss of 13,278 acres of managed wetlands in Suisun Marsh, which will become "Tidal Natural Communities." Table 5.4-3 shows a net increase in "Tidal Freshwater Emergent Wetland" of 23,991 acres (a 487% increase over the current acreage for that natural community type). The EIR/EIS is vague regarding where the water for these wetlands—6-7 acre feet for each acre—will come from.

This uncertainty about how and where habitat will be engineered or re-engineered and how much water it will need is particularly troubling given the additional uncertainty about how much water

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[506] *Ibid.*, lines 12-13.

[507] *Ibid.*, lines 16-17. Emphasis added.

[508] *Ibid.*, page 3.4-151, lines 33-35.

[509] *Ibid.*, Section 3.4.5.5, page 3.4-152, lines 6-8.

[510] Bay Delta Conservation Plan, Chapter 7, *Implementation Structure*, page 7-7, lines 8-11.

[511] *Ibid.*, 7.1.3, page 7-10, lines 38-40.

[512] BDCP EIR/EIS, page 3-22.

will actually be available if the system is also being managed for export reliability. BDCP will disrupt existing land uses in the Delta for habitat restoration that is in fact highly speculative.

12. The EIR/EIS fails to analyze socioeconomic impacts of BDCP adequately, especially for environmental justice communities.

Having relied on data at the level of the five-county region for its background analysis of socioeconomics, the EIR/EIS switches to a focus on the statutory Delta for its evaluation of environmental consequences, including effects on community character and cohesion, population, housing employment and income.[513] "This assessment [of environmental consequences] focused on communities in the statutory Delta, where the direct effects of the BDCP would occur and where social and community effects would be greatest. Social and community effects elsewhere in the larger five-county Delta region are anticipated to be minor because they would be spread over a large, heavily populated area and among many communities."[514]

In other words, the EIR/EIS uses a region-focused analysis to effectively minimize the socioeconomic role of the Delta as Place, and it uses an analysis focused on the statutory Delta to minimize environmental effects of BDCP on the wider region.

(Another example of selecting an analytical focus that favors BDCP occurs with Commercial Fishing Effects: "Commercial salmon fishing effects are not addressed for individual alternatives in this chapter because, while speculative, these effects are anticipated to be positive overall and would be spread among coastal regions where commercial lands occur." "As discussed in the *Statewide Economic Impact Analysis*, the overall impacts of the implementation of the BDCP are expected to be positive for both the populations and commercial landings of fall-run chinook salmon." While alluding to uncertainties, the EIR/EIS says "The overall effects, however, are anticipated to be positive." [515] Not mentioned are runs of salmon other than fall-run Chinook or the effect on coastal regions if speculations about positive effects turn out to be wrong.)

The Delta as Place is threatened by the whole range of BDCP conservation measures, from CM1 through CMs associated with habitat restoration. "[Construction] activities, along with the long-term placement of the conveyance facilities, could . . . alter the character of [Delta communities] by reducing the extent of undeveloped land in proximity to communities and by changing the viability or desirability of leading economic and social pursuits, including agricultural activities and water-based recreation." "Implementation of habitat restoration could have some similar effects during the construction period by introducing conditions that would alter and potentially detract from the rural characteristics of Delta communities."[516]

Of particular interest in any consideration of Delta as Place is the NEPA analysis of Changes in Community Character as a Result of Constructing the Proposed Water Conveyance Facilities (Alternative 4).

NEPA effects for Alternative 4 include expansion of population and employment throughout the five-county Delta region as a result of construction but decline of agricultural contributions to the character and culture of the Delta. Agriculture-dependent businesses or those catering to

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[513] *Ibid.*, Chapter 16, page 16-38, lines 20-21.

[514] *Ibid.*, page 16-40, lines 9-13.

[515] *Ibid.*, page 16-47, lines 26-28, lines 33-35, and lines 38-39.

[516] *Ibid.*, page 16-41, lines 21-25 and page 16-61, lines 28-30.

agricultural workers are expected to close. A shift from agriculture toward construction is expected to result in more men and fewer women in the labor force (98 percent men for construction versus 84 percent men for agriculture). More agricultural workers than construction workers in the five-county area report Hispanic origin, (87 percent agricultural versus 54 percent construction), so a shift toward fewer Hispanic workers in the labor force seems likely.[517]

For legacy communities in the Delta, "particularly for those communities in proximity to water conveyance structures, including Clarksburg, Hood, and Walnut Grove",

> Effects associated with construction activities could . . . result in changes to community cohesion if they were to restrict mobility, reduce opportunities for maintaining face-to-face relationships, or disrupt the functions of community organizations or community gathering places (such as schools, libraries, places of worship, and recreational facilities).[518]

The "total population and employment base of the study area would expand during water facility construction," but any benefits from investment in the "study area" are speculative (and would in any case be likely to be temporary for the 8-year construction period). "[Property] values may decline in areas that become less desirable in which to live, work, shop, or participate in recreational activities."[519]

Underlying the discussion of Environmental Setting/Affected Environment in Chapter 15, Recreation, is the assumption that fishing is best classified as a leisure pursuit. Categorizing fishing as a recreational activity obscures its importance as a means of acquiring food for low income residents, and especially for some cultures, including Southeast Asian cultures such as Hmong and Cambodian, which are well-represented in the Delta region.

Table 15-1, "Boat Owners' Participation in Water- and Land Based Recreation Activities in the Delta" (page 15-3) shows that 67% of small-boat owners report fishing as one of their "recreation" activities – the largest percentage for any small-boating activity. Chapter 15 notes that "Shoreline anglers may gain access to Delta waterways at numerous locations along Delta roads," (page 15-5, lines 12-13); "Bank fishing is a year-found activity, with peak seasons varying by fish species" (page 15-5, lines 15-16). Angling (fishing with a hook and line) sounds like a leisure activity, but with the exception of fly fishers, fishermen typically eat what they catch.

Given the acknowledged importance of fishing in the Delta, it is clear that any BDCP activities that make it more difficult for people to fish interfere with their ability to feed themselves.

This will disproportionately impact low-income communities, and in the Delta itself, there is an overlap between low-income and non-White communities. According to the *Economic Sustainability Plan*,

> The residents of the Legacy Communities are primarily White, although other racial groups and ethnicities are also well-represented. Eastern Walnut Grove and Locke are quite diverse, with Asians making up 38 percent of the population and Hispanics making up 40 percent of the population. Courtland also has a notable Hispanic population, with about 66 percent of the population reporting that ethnicity.
>
> Across the Legacy Communities, the Census Bureau reports wide disparities in household income, with average household incomes ranging from less than $30,000 to over $90,000 per year. The highest average

[517] *Ibid.*, page 16-163, lines 36-40, lines 40-41, and page 16-164, lines 8-15.

[518] *Ibid.*, page 16-164, lines 24-29.

[519] *Ibid.*, page 16-164, lines 38-39 and lines 45-46.

> income is found around Ryde (including western Walnut Grove), where the Census Bureau reports an average household income of $92,200 (well above the average of $79,200 in the Legal Delta). However, directly across the Sacramento River in eastern Walnut Grove and Locke, the Census Bureau finds that average household income is significantly lower, at about $28,500.[520]

To the extent that "Recreation Sites" are sites where people fish, impacts from BDCP construction or operation on Recreation must be viewed as having potential environmental justice impacts that have not been fully analyzed.

The Delta as Place is in many ways an aesthetic construct. Chapter 17, Aesthetics and Visual Resources, provides a useful indicator of the predisposition of EIR/EIS consultants to view BDCP as a solution to problems that are by no means universally acknowledged. Description of the No Action Alternative incorporates the various disaster scenarios used to justify BDCP. It illustrates the bias that is fundamental to this whole analysis.

> Land subsidence, sea level rise, catastrophic levee failure, or a combination thereof should they occur, would result in flooding and inundation that could significantly damage existing facilities and infrastructure, uproot and damage vegetation to an unknown extent, permanently flood Delta islands, and drastically alter the visual landscape. Should such events occur**,** as anticipated, natural processes and vegetative succession would restore the visual environment to a certain degree over time. However, permanent scarring or visual remnants of damaged infrastructure could remain on the landscape.[521]

"Catastrophic," as is usual in discussions of the Delta, is undefined, and the assumption that these events are inevitable goes unexamined.

The discussion continues with descriptions of scenic views damaged by permanently flooded islands, and so on. It is significant that BDCP does not propose to correct land subsidence or reinforce levees against levee failure. Therefore, all these adverse aesthetic impacts could happen anyway.

EIR/EIS Chapter 28, Environmental Justice, provides a discussion of subsistence fishing among various cultures and low-income populations. The focus is on health risks associated with mercury contamination of fish. However, recreation impacts, including impacts on fishing, are not analyzed in Chapter 28 relative to Alternative 4. Therefore, the issue of access to fishing for environmental justice communities is not fully addressed.

13. The EIR/EIS fails to disclose potential cultural resource impacts from both BDCP alternative alignments and BDCP habitat restoration measures that would disturb ground surfaces.

We note that the recent case of *Madera Oversight Coalition* clarifies proper treatment in EIRs of archaeological and historic resources under CEQA rules.[522] We found no mention of it in BDCP's EIR/EIS in Chapter 18.

In our comments on Chapter 18, *Cultural Resources*, of the BDCP EIR/EIS above, we noted that the the setting should include a series of maps that show locations of cultural resources identified using the techniques described early in the chapter for the entire Plan Area.

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[520] *Draft Economic Sustainability Plan*, page 234.

[521] BDCP EIR/EIS, Chapter 17, p. 17-46, lines 9-15. Emphasis added.

[522] *Madera Oversight Coalition, Inc. v. County of Madera* (2011) 199 Cal.App.4th 48.

Such a series of map then must be cross-correlated not only with BDCP alternative alignments but with potential areas where habitat restoration conservation measures will be implemented—that is, areas where construction activities related to creating habitat sites could intersect and overlap with cultural resources in the Plan Area. This needs to be conducted even at a "program level" given that the "program" for habitat restoration identifies not only conservation "zones" but also "restoration opportunity areas" throughout the Plan Area. The absence of this is critical, because it provides the basis for lay readers and decision-makers alike to see at a glance the potential for impacts to cultural resources stemming from habitat restoration actions. This is critical information

A subset of these maps must also be generated to reflect the cultural resources that may qualify under Section 106 for inclusion in the National Register of Historic Places. Currently, Chapter 18 fails to disclose even these basic types of impact analysis, making it difficult for readers to quickly understand BDCP's cultural resource effects.

BDCP attempts to turn setting/affected environment deficiencies owing to a lack of direct on-site survey information of cultural resources into "mitigation measures," but this reflects a conceptual confusion: mitigation measures are not allowed to be "studies" and "surveys." They must be actions that actively reduce the effects of a proposed project or undertaking on, in this instance, cultural resources. Time and again, the EIR/EIS in Chapter 18, in Alternative 1A and Alternative 4 at least, implies in discussions of mitigation of the adverse effects of the project on cultural resources that prior to construction, the necessary surveys and studies of cultural resources will be completed.[523] Given the limited seasonal construction schedule of BDCP, we fail to see how this can be accomplished without BDCP's construction schedule slipping, especially if the studies have not been completed as part of a recirculated Draft EIR/EIS for the BDCP. By slipping these surveys and studies into "mitigations" BDCP implies that ***the public should "trust us" to conduct their historic and archaeological due diligence after the incidental take permits, 404 permits and other construction permits are issued for the project. This is illegal and unacceptable.*** Thorough study of cultural resources must be completed ***prior to authorization of the undertaking***, according to CEQA, NEPA, and the National Historic Preservation Act, Section 106. Only recovery of human remains may be allowed and conducted once the project is under construction.

It is only in Table ES-9 of the Executive Summary that one can quickly ascertain that seven of eight impacts identified for the BDCP alternatives are adverse/significant and unavoidable not just for the proposed action alternative (Alternative 4), ***but for all BDCP alternatives. These impacts cannot be reduced to less than significant levels. These effects would be irretrievable, irreversible losses of cultural resources to California's pre-history and history of the Delta Plan Area region. Such losses would be compounded to veritable looting of the Delta's heritage as an evolving place when we recall that DWR has been unsuccessful at obtaining access to Delta lands along the BDCP alternative alignments and that it has failed to disclose the locational proximity of known cultural resources to conservation zones and restoration opportunity areas. At a minimum, this Draft EIR/EIS must be withdrawn as inadequate, new information obtained and analyzed, and the Draft EIR/EIS recirculated for public review and comment.***

14. The EIR/EIS reports a large and unacceptable number and variety of significant unavoidable impacts and adverse effects that would result from the Bay Delta Conservation Plan, including some affecting environmental justice communities.

BDCP EIR/EIS's Executive Summary reports in excess of 55 of adverse effects resulting from BDCP implementation. The range of adverse effects is highly varied, ranging from adverse local and

[523] *Ibid.*, Chapter 18, *Cultural Resources*, p. 18-128, lines 14-41 and 1-11, and p. 18-129, lines 1-11.

regional groundwater effects to adverse effects on water quality, public health, agriculture, land use, recreational, economic, cultural resource, air quality, fish and aquatic ecosystem.

This list does not include the adverse cumulative public health effects identified in Chapter 25 of the EIR/EIS. ***The array of adverse effects identified is a strong indicator that Bay Delta Conservation Plan remains poorly planned after eight years.*** This list includes increased adverse effects of bromide concentrations, particularly at the North Bay Aqueduct Intake, increased mercury concentrations (an adverse cumulative condition that could be disturbed by BDCP construction and operation activities, which could increase mercury bioaccumulation), and potentially increased selenium contamination from reduced Delta outflow, increased residence times of water, and changes in upstream management of selenium sources in the western San Joaquin Valley. None of these cumulative public health effects were included in the Executive Summary of the EIR/EIS, making it more difficult for even the English-speaking public and decision makers to learn of these potential impacts.

15. The EIR/EIS improperly weights seismic risks to the state water system in the setting and affected environment discussions. This bias emphasizing seismic risks in the Delta prevents lay readers and decision makers from arriving at informed judgments and decisions about such risks.

We find the BDCP to be completely inadequate when it comes to reducing risks. Because of the lack of Delta levee improvements in Alternative 4, the Proposed Project does not meet the requirements or intent of Water Code Section 85305(a) to "reduce risks to people, property and state interests in the Delta"… "by promoting"…."strategic levee investments." Economist Rodney T. Smith, after conducting an extensive and meticulous analysis of BDCP's economics and financing in the summer of 2013, concluded:

> *As I think about California's future, I am surprised that the risk and consequences of levee failure in the Delta hasn't received more attention.*[524]

For example, despite a recommendation from the Delta Protection Commission and a policy from CALFED, BDCP does not include a policy, recommendation or proposal for Delta levees to meet the PL 84-99 levee standard, nor does it provide the measures to address seismic risks to levees..

The description of risks includes neither seismic and ground subsidence threats to the California Aqueduct and Delta-Mendota Canal. For instance, the January 2009 Newsletter of the International Water Resources Association[525] stated the following regarding B.F. Sisk Dam (San Luis Dam):

> *"The dam and reservoir are located in an area of high potential for severe earthquake forces from identified active faults, primarily the Ortigalita Fault that crosses the reservoir. It is also near two major seismic faults: 45 kilometers (28 miles) from the San Andreas Rift Fault, and 36 kilometers (23 miles) from the Calaveras-Hayward Fault. Reclamation has identified several conditions that require action to reduce risks. Studies and deformation analysis conducted indicated that during a major earthquake, crest settlement greater than freeboard, or cracking associated with embankment deformation, could occur and lead to dam failure.*

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[524] Rodney T. Smith, "Hydrowonk's Take on the BDCP," *Hydrowonk Blog* 9 October 2013. Emphasis in original. Accessible online 11 April 2014 at http://hydrowonk.com/blog/2013/10/09/hydrowonks-take-on-the-bdcp/. Emphasis added.

[525] "IRWA Update" Newsletter of the International Water Resources Association, January 2009, Volume 22, Issue 1, page 15. http://www.iwra.org/doc/iwraupdatejanuary2009.pdf

Failure of the dam could inundate hundreds of square kilometers including the town of Santa Nella and numerous farms and houses along the San Joaquin River, including some areas of Stockton."

Geologic Fault Maps by the California Geologic Survey[526] clearly show greater fault risks to San Luis Reservoir/Dam and the California Aqueduct than are the fault risks in the Delta.

Catastrophic failure of San Luis Dam would inundate the California Aqueduct, Clifton Court Forebay, the Delta Mendota Canal and other water conveyance facilities. The San Joaquin County Dam Emergency Plan[527] inundation timeline for San Luis Dam failure estimates that it will reach Clifton Court Forebay in 50 hours and Brannan and Staten Islands in 100 hours. It describes the area affected as "San Joaquin River Areas, West Stockton and Delta Islands" with an estimated 165,000 people threatened.

A map of the entire San Luis Dam inundation area[528] shows an inundation zone extending throughout most of the southern and central Delta.

The threat to reliable water supplies from earthquakes causing massive levee failure is greatly overstated and not supported by the BDCP and Draft EIS/EIR. Just as the alleged benefits of habitat restoration have been inflated in the BDCP documents, so has the risk of levee failure from seismic activity been inflated without justification. The case for seismic levee failure does not pass the red-face test and is not supported by the best available information on Delta levees.

The Draft EIS/EIR analysis relies on the discredited Delta Risk Management Study Phase 1 report and utterly fails to mention or reference the most current information on Delta levees, which is the Delta Protection Commission's Delta Final Economic Sustainability Report[529].

The DEIS/EIR's faulty reliance on the DRMS Phase 1 report is further undermined by the EIS/EIR's claim that it could take up to 3 years to flush salt out of the Delta following massive levee failure, yet failing to reference…

"DWR's own findings regarding the time that it would take to flush out the Delta as reported by Dr John McGeorge to a meeting of the BDCP Steering Committee on July 28, 2010, and subsequent studies conducted for the DWR by Dr McGeorge and Dr Martin McCann. These studies suggest that even in a 20 flooded islands scenario, a worse than worst case scenario with an exceedingly low probability of occurrence, the Delta would likely flush out within several months, and at worst within six months. The failure of this draft EIR /EIS to reference these studies is an egregious omission which must cast doubt on" the legal adequacy of the entire document.[530]

We agree that the "Earthquake Bogey" as described by Robert Pyke in his May 26 comments on

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[526] http://www.conservation.ca.gov/cgs/cgs_history/Pages/2010_faultmap.aspx

[527] Page 21 http://www.sjgov.org/oes/getplan/Dam_Emergency_PLAN.pdf

[528]http://www.cityofripon.org/DisasterManagement/Figures/Ripon%20Inundation%20Fig%208A%20A%20size.pdf

[529] http://www.delta.ca.gov/Economic%20Sustainability%20Plan.htm

[530] Comments of Dr. Robert Pyke on BDCP Draft EIS/EIR, May 26, 2014, page 39-49; accessed at http://www.centralvalleybusinesstimes.com/links/Pyke%20comments%20on%20BDCP%20PDEIR-EIS%20-%20Final.pdf

BDCP's DEIS/R is not supported by fact or analysis in the Draft EIS/EIR

The CEQA purpose contains three project objectives and then five "additional project objectives" including this one:

"To make physical improvements to the conveyance system that will minimize the potential for public health and safety impacts resulting from a major earthquake that causes breaching of Delta levees and the inundation of brackish water into the areas in which the SWP and CVP pumping plants operate in the southern Delta.

However, there is a disconnect between the CEQA purpose in Section ES.2.1 and Earthquake risk listed as one of state CEQA objectives, but earthquake risk is not listed as part of the NEPA Purpose and Need in Section ES.2.2.

Section ES-9.2 Land-based Resources and Impact Mechanisms

Table ES-9 on page 61 et seq. does not identify earthquake impacts of any alternatives on water supply, water quality. Are earthquakes then not a problem? If earthquake risk to levees is a key CEQA project objective, then why is it not listed in the summary of impacts table?

References in ES.10 do not include Delta Protection Commission's Delta Sustainability Plan that is necessary for analysis of Delta levee vulnerability to earthquake failure. The DEIS/R does not include the best available information and in this case, it appears that information contradicting the need for new conveyance is not included so as to unfairly exaggerate the "Earthquake Bogey".

The Executive Summary relies improperly on Delta Risk Management Study Phase 1 as stated above.

Chapter 2- While seismic risk and catastrophic levee failure are listed as conflicts between species protection and a reliable water supply, earthquakes are not mentioned in Section 2.5.2 (water supply reliability) and 2.5.3 (Delta Hydrology and Water Quality). There is inadequate justification to support the Earthquake Bogey.

The Delta Independent Science Board also pointed out the lack of adequate justification for the Earthquake Bogey in its May 15, 2014 comments (page 9).[531]

"*Second, although levees receive considerable attention in both documents (as befits their importance to what goes on in the Delta), the coverage is disconnected and incomplete. In particular, neither the consequences of levee failures on the effectiveness of BDCP actions nor the financial implications of demands for levee maintenance receives adequate attention. The assumption that most levee breaches will be repaired seems unrealistic*."

Page A-6 from DISB review:

"Effects of and on levees. Although the DEIR/DEIS cites the threat of levee failures as a justification for new pipelines or canals, the reviewed documents offer no detailed analysis of how levee failures could affect the various alternatives, or of how the alternatives may affect the economics of levee maintenance. We found no part of the DEIR/DEIS, or of the Draft BDCP, that relates Delta levees to the BDCP in more than a piecemeal fashion. We discuss these concerns in our review of Chapter 9 (Appendix B).

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[531] http://deltacouncil.ca.gov/sites/default/files/documents/files/Item_9_Attachment_3.pdf

It can be argued that CEQA guidelines do not identify levees as resources; that BDCP is not a flood-control project; and that levee failure is too speculative for analysis. However, few Delta facilities are more important to its current functions than are its levees, and levee failure has happened too often (and the threat of future failures is invoked too much) to be excluded from thorough analysis in the DEIR/DEIS."

On page B-18, the DISB further recommends a "comprehensive levee chapter" because the Draft EIS/EIR as it currently stands inadequately portrays the levee hazards and the existing information is scattered throughout the document.[532]

The DISB points out on page B-27:

"The depiction of hazard in Figure 9-6 contrasts with that by the DRMS study. For instance, Figure 9-6 of Chapter 9 shows all Sherman Island levees as having high potential for damage from liquefaction, while DRMS Figure 6-37c assigns a majority of Sherman Island's levees to the lowest of three categories of vulnerability to earthquakes (URS Corporation and Jack R. Benjamin & Associates Inc., 2008)."

The EWC agrees with Pyke where he points out that the description of Delta levees in Section 3.5.1 is grossly inaccurate in portraying Delta levees as fragile. He points out that the EIS/EIR should have used Chapter 5 and Appendices C, D and E of the Economic Sustainability Plan for a more correct description of the Delta levee system, but did not.

The BDCP EIS/EIR did not analyze an alternative to bring all Delta levees to the PL 84-99 standard as stated in the Economic Sustainability Plan and the EWC's Responsible Exports Plan, yet Pyke states:

"In fact, improvement of the entire Delta levee system to meet the Delta-specific PL 84-99 standard is now within reach."

Furthermore, we agree with Pyke where he points out that the DPC's Delta Economic Sustainability Plan is the most authoritative accurate and peer-reviewed work to date on the status of Delta levees and what it would take to improve them to the PL 84-99 level, yet the BDCP and its Draft EIS/EIR do not even mention it!

EWC agrees with Pyke (page 39) where he points out the inadequacies of the DRMS Phase 1 assessment and the poor peer reviews.

The EWC agrees with Pyke (page 40) where he states: "The failure of this draft EIR /EIS to reference these studies is an egregious omission which must cast doubt on the validity of the entire document."

The EWC incorporates by reference Appendix B of the May 26 comments on the BDCP Draft EIS/ EIR, including, but not limited to Mr. Pyke's analysis of the following:

- Erroneous information in EIS/EIR about the status of existing Delta levees
- Inadequate emphasis on emergency preparedness to limit interruption of Delta exports due to seismic and flooding events
- Inadequate description of levees in No Action Alternative, including an inflated levee failure

[532] The DISB review comments on B-25/26 are critical of the EIS/EIR not having a "comprehensive assessment of levee-related impacts" and states that " Chapter 9 provides little information, however, about the basis for its liquefaction analysis."

rate
- Lack of seismic risk benefit analysis for the alternatives
- Overstatement of liquefaction risks in Chapter 9 and elsewhere
- Complete failure to mention seismic risks in Chapter 8, Water Quality
- Failure to address risk of levee failure from ground settlement due to tunneling activities
- Unsupported conclusions that levees cannot be protected from sea level rise

H. The EIR/EIS improperly excludes many programs and well-known storage projects from its list of projects considered for cumulative impact analysis of the Bay Delta Conservation Plan.

BDCP wishes to consider the North Delta Intakes and Twin Tunnels facilities as a "stand-alone project" for purposes of CEQA and NEPA "just as future storage projects would be."[533] ***The trouble is, neither type are stand-alone projects.*** Legally, the Twin Tunnels would be owned by the California Department of Water Resources.[534] The facilities in Conservation Measure 1 would become part of the State Water Project, which is itself legally titled the State Water Resources Development System[535], a water storage and conveyance system designed to integrate water supplies from northern California with "supplemental demand" (to which we alluded earlier in our discussion of water transfers above) south of the Delta through use of Delta export pumps at Banks pumping plant and the California Aqueduct system (which includes the State-owned storage space at San Luis Reservoir near Los Banos).

While the State Water Project could theoretically operate by itself, the State of California and the US Bureau of Reclamation (via the US Department of the Interior) have agreed that the SWP and the Central Valley Project, with its own numerous reservoirs, canals and Delta export pumping capacity, shall and do engage in coordinated operations of the two projects together. Both Congress and the California Legislature authorized the projects to coordinate their operations.[536]

Functionally, reservoir storage and water conveyance facilities need each other. Without conveyance facilities, water stored in reservoirs, once released, may not be delivered efficiently or directly to its intended customers. Without storage reservoirs, conveyance facilities may not have enough water to transport to make the investment in conveyance pay off if there are no, or insufficient storage facilities to control surplus flows for diversion, storage, and delivery. Scheduling of deliveries can only be efficiently conducted when both storage and conveyance are directly and efficiently managed. Storage and conveyance are the yin and yang of coordinated water resource development systems.

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[533] BDCP EIR/EIS, Chapter 1, Appendix 1B, *Water Storage*, p. 1B-1, lines 16-18.

[534] BDCP, Chapter 7, *Implementation Structure*, p. 7-10, lines 3-6. "The State of California owns, and DWR manages and operates, the existing SWP Delta facilities, including the Clifton Court Forebay and the Banks Pumping Plant. PUrsuant to the BDCP, DWR seeks state and federal regulatory authorizations to continue to operate such facilities. The State of California, through DWR, will construct, own, and operate any new diversion and conveyance facilities described in this plan."

[535] California Water Code Sections 12930 through 12944, enacted 1959.

[536] *Agreement Between the United States of America and the State of California for Coordinated Operations of the Central Valley Project and the State Water Project*, executed November 24, 1986. Accessible online 12 May 2014 at https://archive.org/details/agreementbetween00wash. Coordinated operations were legislated by Congress in PL 99-546, accessible online 12 May 2014 at http://www.usbr.gov/mp/cvp/docs/pl_99-546.pdf. Coordinated operations may be viewed online http://www.usbr.gov/mp/cvo/vungvari/coanew.pdf.

Despite this reality, BDCP's EIR/EIS argues in Appendix 1B that "while storage is a critically important tool for managing California's water resources, it is not a topic that must be addressed in the EIR/EIS for the BDCP."[537]

> This is because the BDCP, as a proposed habitat conservation plan and natural community conservation plan, does not, and need not, propose storage as a project component. Although the physical facilities contemplated by the BDCP, once up and running, would be part of an overall statewide water system of which new storage could someday be a part, the BDCP is a stand-alone project for purposes of CEQA and NEPA, just as future storage projects would be. *Similarly, although new storage projects are the subject of ongoing discussions, and may well someday be formally proposed and subjected to environmental review, such projects have not reached the stage of planning that would make the "probable future projects for purposes of CEQA or "reasonably foreseeable future actions" for purposes of NEPA.* Any such potential future projects therefore need not be addressed as part of the cumulative impacts analyses in the BDCP EIR/EIS. Nor would additional storage qualify as a viable stand-alone alternative for implementation of the BDCP because it is not capable of meeting the established purpose and need for the BDCP [ ]. In short, this appendix is not required by either CEQA or NEPA, but was prepared for informational purposes.[538]

We certainly appreciate that BDCP prepared Appendix 1B. Essentially this statement argues that BDCP is a "stand-alone project" because it is a habitat conservation plan, not simply a conveyance project. It also argues that storage need not be considered in this EIR/EIS because of this stand-alone character of BDCP and because other storage projects, even if they might someday interact in a cumulative fashion with the Delta facilities described in BDCP's Conservation Measure 1 (what we have called here the North Delta Intakes and Twin Tunnels project), they too should be treated as "stand-alone projects." Storage projects would be inappropriate, the argument goes, for consideration as a BDCP alternative because it fails to meet the purpose and need in the Delta, and they should be excluded from cumulative impact analysis for BDCP as "stand-alone projects."

BDCP offers extraordinarily weak justification for excluding planned or conceptual storage projects from consideration in BDCP's EIR/EIS, particularly from cumulative impacts analysis. Two founders of Jones and Stokes Associates (the company long since absorbed into the major BDCP consultant/ contractor ICF International) Albert Herson and Ronald Bass have written about NEPA compliance that:

> According to EPA, *considering past, present, and reasonably foreseeable future actions provides a needed context for assessing cumulative impacts.* The cumulative analysis should adequately consider whether the environment has been degraded and to what extent ongoing activities in the area are causing impacts. It should also consider trends for activities and impacts in the area. Federal agencies should identify activities occurring outside of their jurisdiction that are affecting the same resources as their own actions are affecting and should consult with other agencies potentially affecting the resources in question. In addition, the federal agency should consider private activities.
>
> The analysis should include the use of trends information and interagency analyses on a regional basis to determine the combined effects of past-present, and future actions. *NEPA documents should only consider those past, present, and future actions that incrementally contribute to the cumulative effects on resources affected by the proposed action*….
>
> To successfully assess cumulative impacts, NEPA documents should consider:
>
> - The proximity of the projects to each other either geographically or temporally.

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[537] BDCP EIR/EIS, Chapter 1, Appendix 1B, *Water Storage*, p. 1B-1, lines 7-9.

[538] *Ibid.*, lines 10-32. Emphasis added.

- The probability of actions affecting the same environmental system, especially systems that are susceptible to development pressures.
- The likelihood that the project will lead to a wide range of effects or to a number of associated projects.
- Whether the effects of other projects are similar to those of the project under review
- The likelihood that the project will occur.[539]

Planned reservoir projects like Sites, Shasta's expansion, and Temperance Flat meet at least four of these five criteria on their faces. The problem with cumulative projects' impacts is that while their individual impacts may be less significant if conceived as a "stand-alone project," their significance may lie in their incremental contribution to impacts from other related, coordinated, and/or similar projects.[540] Similar reasoning applies under the California Environmental Quality Act.[541]

Below we list projects, programs, and other actions that have been omitted from cumulative impact consideration in the BDCP EIR/EIS. No explanations specific to each individual project, program or other action was offered in the Appendix in which the list appears.

Projects, Programs and Other Actions Omitted from Bay Delta Conservation Plan Draft EIR/EIS Cumulative Impact Analysis Consideration

Project, Program, or Other Action	Page Number	Type of Action
Delta Risk Management Strategy	3D-41	Levee Plan
Cache Slough Area Restoration	3D-49	Restoration Plan
Delta Islands and Levees Feasibility Study	3D-88	Levee Plan
Shasta Lake Water Resources Investigation	3D-90	USBR Storage Project - expansion
Sacramento Valley Water Management Plan (Phase 8)	3D-91	Water supply allocation agreement subsequent to D-1641 in 2000
Upper San Joaquin River Basin Storage	3D-92	USBR Storage Project - Temperance Flat Reservoir

[539] Ronald E. Bass, Albert I. Herson, and Kenneth M. Bogdan, *The NEPA Book: A Step-by-Step Guide on How to Comply with the National Environmental Policy Act*, 2nd edition, Point Arena, CA: Solano Avenue Press, 2001, pp. 108-109.

[540] "According to EPA guidance, the combined, incremental effects of human activities, referred to as "cumulative impacts" under NEPA, pose a serious threat to the environment. While they may be insignificant by themselves, cumulative impacts accumulate over time, from one or more sources, and can result in the degradation of important resources." *Ibid.*, p. 105.

[541] "Cumulative impact analysis assesses cumulative damage as a whole greater than the sum of its parts." Michael H. Remy, Tina A. Thomas, James G. Moose, and Whitman F. Manley, *Guide to CEQA: California Environmental Quality Act,* 11th edition, Point Arena, CA: Solano Avenue Press, 2007, p. 466.

Projects, Programs and Other Actions Omitted from Bay Delta Conservation Plan Draft EIR/EIS Cumulative Impact Analysis Consideration		
Project, Program, or Other Action	**Page Number**	**Type of Action**
San Luis Low Point Improvement	3D-98	USBR Storage Project - to address water quality and dead pool issues for San Felipe Unit contractors of CVP, including Santa Clara Valley Water District
California Water Plan - 2013 update	3D-39	state water plan
DWR's FloodSAFE California Program	3D-42	Flood control plan
South Delta Temporary Barriers Project	3D-47	Recurrent installation of temporary channel barriers to improve flow for fish and water levels for agricultural irrigators
CalFED Levee System Integrity Program	3D-56	Levee Plan
Upper Yuba River Studies Program	3D-56	Storage plan
Element2: Release Site Predation Study	3D-57	Predator study
EBMUD Camanche Permit Extension	3D-69	Storage project water rights
Bay Area Regional Desalination Project	3D-70	Desalination supply project in which many Bay Area water agencies participate, including CVP/SWP contractors like Santa Clara Valley Water District
El Dorado Water and Power Agency Supplemental Water Rights project	3D-71	storage and power generation project
Folsom Lake Temperature Control Device	3D-71	Storage project for cold water pool management on American River
South Sacramento Habitat Conservation Plan	3D-77	Restoration Plan
Alameda Watershed Habitat Conservation Plan	3D-80	Restoration Plan
San Joaquin County General Plan Update	3D-82	County General Plan
Delta Wetlands Project	3D-83	Storage project in Plan Area
Lower San Joaquin Feasibility Study	3D-87	Flood Control Study
Delta Mendota Canal Recirculation Study	3D-90	Water operations and water quality study
Water Year 2010 San Joaquin River Restoration Interim flows	3D-93	Restoration Plan and San Joaquin River water rights adjustments by SWRCB
Two-Gates Project	3D-95	In-Delta water flow management project

Projects, Programs and Other Actions Omitted from Bay Delta Conservation Plan Draft EIR/EIS Cumulative Impact Analysis Consideration

Project, Program, or Other Action	Page Number	Type of Action
Lower American River Temperature Reduction	3D-105	Storage study for cold water pool management on American River
Delta Smelt Permanent Refuge	3D-106	Restoration Plan for Delta Smelt refugia
Yolo County Habitat Conservation Plan/Natural Communities Conservation Plan	3D-109	Restoration Plan

Source: BDCP EIR/EIS, Chapter 3, *Description of Alternatives*, Appendix 3D, Attachment 3D-A, pages 3D-27 to 3D-110.

We find it implausibly remarkable that BDCP's justification of itself as a "stand-alone project" extends not only to storage projects but also to other restoration plans and recent levee studies. In concept, without the storage plans and projects that are foreseeable (having been studied at least since the days of the CalFED Record of Decision[542]) ***numerous habitat conservation plans are omitted from cumulative impact consideration, including plans that extend into county-jurisdiction portions of the Delta's BDCP Plan Area. From this list of omissions it is natural for a reader to wonder whether many of BDCP's proposed restoration sites in various Restoration Opportunity Areas are redundant or conflictual with existing habitat conservation plans in the region. We have indicated elsewhere that they are.***

Levee studies and plans are omitted from cumulative impact analysis despite BDCP's professed concerns for seismic risks to levees and water quality resulting from allegedly feared levee breaks. ***It is both unexplained by BDCP and inexplicable to the reader why omission from the EIR/EIS cumulative impacts analysis of levee studies, including the 2008 Delta Risk Management Strategy, occurred. This makes it difficult for readers of BDCP to take the Plan's (and its EIR/EIS's) expressed fears of levee failures seriously since BDCP Applicants propose no relevant mitigating remedies.***

The issue of omitting storage projects like Shasta Dam's raising, Temperance Flat, and Sites Reservoirs are important because their omission flies in the face of BDCP's underlying purpose and need for the Twin Tunnels project to increase not only Table A and CVP contract amounts of water supply deliveries, but also to increase supplies potentially available via water transfers in dry and drought years (i.e., years of low SWP and CVP contract allocations). BDCP makes clear that the "Delta facilities" will increase the state and federal projects capacity to arrange and implement cross-Delta water transfers. Yet, inexplicably, the increased storage that has been planned for at least 14 years is omitted from both the Water Supply analysis of Chapter 5 and here the cumulative impacts analysis.

BDCP's cumulative impact analysis is deficient because it omits many storage, restoration, and levee remediation and improvement studies and plans, and because it fails to explain why so

[542] CalFED Record of Decision, 2000, pp. 42-46. Shasta and upper San Joaquin River storage projects are included at this time as well as Sites Reservoir. Accessible online 12 May 2014 at http://calwater.ca.gov/content/Documents/ROD.pdf. These projects are also spotlighted in recent DWR editions of the California Water Plan.

many key individual projects are omitted from the cumulative impacts analysis, despite being reasonably foreseeable. They are present in already-existing plans developed, approved and implemented in many instances. The BDCP Draft EIR/EIS is therefore deficient in fully disclosing reasonably expected cumulative projects and their cumulative impacts in relation to BDCP. The Draft EIR/EIS should be revised to correct this fatal flaw and then, as a Draft EIR/EIS, recirculated for public comment.

I. The EIR/EIS fails to properly consider the effects of climate change.

The EIR/EIS modeling results suffer the same limitations as those we identified for the Bay Delta Conservation Plan itself, Section III above.

J. The EIR/EIS fails to properly mitigate impacts of the BDCP and its Twin Tunnels project.

Ecological "assurances" are mitigation measures that are ironclad. Our comments here have identified many reasons why the Bay Delta Conservation Plan and its EIR/EIS fail to provide sufficient mitigations to make the Plan and its Twin Tunnels project worthy of statutory findings justifying issuance of incidental take permits.

1. The EIR/EIS fails to mitigate significant adverse effects resulting from methylmercury disturbance, bioavailability, and bioaccumulation in Delta foodwebs resulting from construction and operational activities of BDCP.

Please refer to our discussion of methylmercury management, Section III.

2. The EIR/EIS fails to mitigate and manage nonnative invasive clams who are likely to capitalize on habitat restoration activities, increasing salinity conditions, and low Delta outflows resulting from BDCP implementation.

Please refer to our discussions of these issues, Section III.

3. The EIR/EIS fails to mitigate potential selenium contamination resulting from BDCP construction and operational activities, as well as continued delivery of Delta exports to western San Joaquin Valley irrigated lands containing high levels of selenium.

Please refer to our discussions of these issues, Section III.

4. The EIR/EIS fails to mitigate seismic and sea level rise risks to the facilities of Conservation Measure 1, particularly the Twin Tunnels project by adding Delta levee investments to the BDCP conservation strategy investments.

Please refer to our discussions of these issues, Section VII.

5. The EIR/EIS fails to mitigate the Bay Delta Conservation Plan's clear objective of increasing reliance on the Delta, contrary to the Delta Reform Act.

Please refer to our discussions of these issues, Section VI.

K. The EIR/EIS fails to employ and consider the best available science.

1. The EIR/EIS fails to employ the best available science in its use of CalSIM II operations modeling.

Please refer to our discussions of these issues, Section III

2. The EIR/EIS fails to include among the best available science sources the 2010 Delta Flow Criteria report by the State Water Resources Control Board for what fish need, and ignores State Water Board determinations on the significance of flow versus habitat in listed species recovery.

Please refer to our discussions of these issues, Sections III and VI.

3. The EIR/EIS fails to employ best available science when evaluating the effects of North Delta Intake fish screens on Delta smelt and salmonid smolts.

Please refer to our discussions of these issues, Section III.

Attachment 1 - Social Vulnerability and Environmental Inequality in the California Delta-Suisun Region

by the Environmental Justice Coalition for Water

A recent national level reassessment of the relationship between race, hazardous waste, and a number of economic, political, and land use factors have only reaffirmed what environmentally overburdened communities and environmental justice advocates have been claiming for years. That is, when controlling for other factors, those factors "uniquely associated with race, such as racial targeting, housing discrimination, or other race-related factors are associated with the location of the nation's hazardous waste facilities" (Mohai and Saha 2007). This "continuing significance of race" in the distribution of environmental benefits and burdens has been argued by communities throughout California (http://www.invisible5.org/) and documented in academic literature on "environmental inequality" in the San Francisco Bay Area, Silicon Valley, San Joaquin Valley, and Southern California (Cole and Foster 2001; Morello-Frosch et al. 2002; Pastor et al. 2005; Pellow and Park 2002; Pulido 1996, 2000; Harrison 2008, 2006; and London et al. 2008).

The California data are particularly alarming since California is arguably ahead of many states in the U.S. in developing environmental justice-related legislation, policy and programs. The legislative component of California's approach to environmental justice consists of over 20 laws that have been passed since 1999 that direct state agency practice (London et al. 2008). The first of these measures came in 1999, defining environmental justice in the state as:

> [T]he fair treatment of people of all races, cultures and income with respect to development, adoption and implementation of environmental laws, regulations and policies. Fair treatment means that no population, due to policy or economic disempowerment, is forced to bear a disproportionate share of the negative human health or environmental impacts of pollution or environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal program and policies (CLCD 1999).

While this definition has been incorporated into the workings of numerous state agencies addressing pesticides, air quality, and environmental and public health, it is unclear the extent to which agencies charged with protecting water quality *and* public health have developed environmental justice-related policies, programs, and research agendas. This has been particularly so in the case of the Sacramento-San Joaquin Delta and Suisun area of the state (the "Delta-Suisun" region). This area of California is argued to be the "hub" of the state's water supply, while facing considerable threats to its economic, cultural, and environmental qualities in the face of global warming-induced impacts to its water supply and quality (Lund et al. 2007).

Scientific studies, law suits and court decisions, and restrictive legislative mandates have sought to change the way water is managed in California, particularly the manner in which water is pumped in and

through the Delta-Suisun region south to San Joaquin Valley and to Southern California due to its associated impact on the region's ecosystem.

The current status of environmental justice in the Delta is reminiscent of its treatment in CALFED about which a Little Hoover Report on CALFED concluded that the process was an utter failure when it came to Environmental Justice (Little Hoover Commission, 2006). Perhaps this can be expected, as water policy in California has been controlled by what some claim to be the "Water Industry"—private and public water supply agencies and corporations, who have historically made their decisions about water distribution at the cost of environmental quality and the concerns for equity in decision making and the distribution of benefits and burdens (Gottlieb 1988; EJCW 2005).

We take a different approach in these comments. While informative and important, the traditional approach to Delta policy and research tends to focus on water supply and export policy in relationship to global warming, fish declines, levee failures, flood risk, and economic cost and benefits to businesses from such policy decisions (DWR & DFG 2008; Lund et al. 2007; Lund et al. 2008). These studies, in general, do not attend to how low income communities and communities of color, and other socially vulnerable groups, are experiencing environmental inequality in the region. To contribute a first look at how environmental justice communities are faring in Delta water politics we begin by introducing the concepts of social vulnerability and environmental inequality which help to explicate the specific elements of environmental justice on which we focus this analysis. Once clarified, they will allow the reader to better understand how we constructed our research and why. We turn to these two concepts now.

KEY CONCEPTS: SOCIAL VULNERABILITY AND ENVIRONMENTAL INEQUALITY

In disaster and environmental health research, "vulnerability" is often used to describe places and social groups that are more susceptible to experience some type of loss or adverse impact from some environmental threat because of their social location (Cutter 2003). Some have commented that there are three main premises to vulnerability research (Cutter et al. 2003; Houston et al. 2007):

1. An *exposure* model that seeks to identify conditions that make certain social groups or places vulnerable to environmental threats. An example of this angle of research would be to ask, "Of the people who live near a facility that releases toxic air emissions or near a freeway, what social groups are more at risk to develop asthma or some form of cancer?" (Pastor et al. 2005).

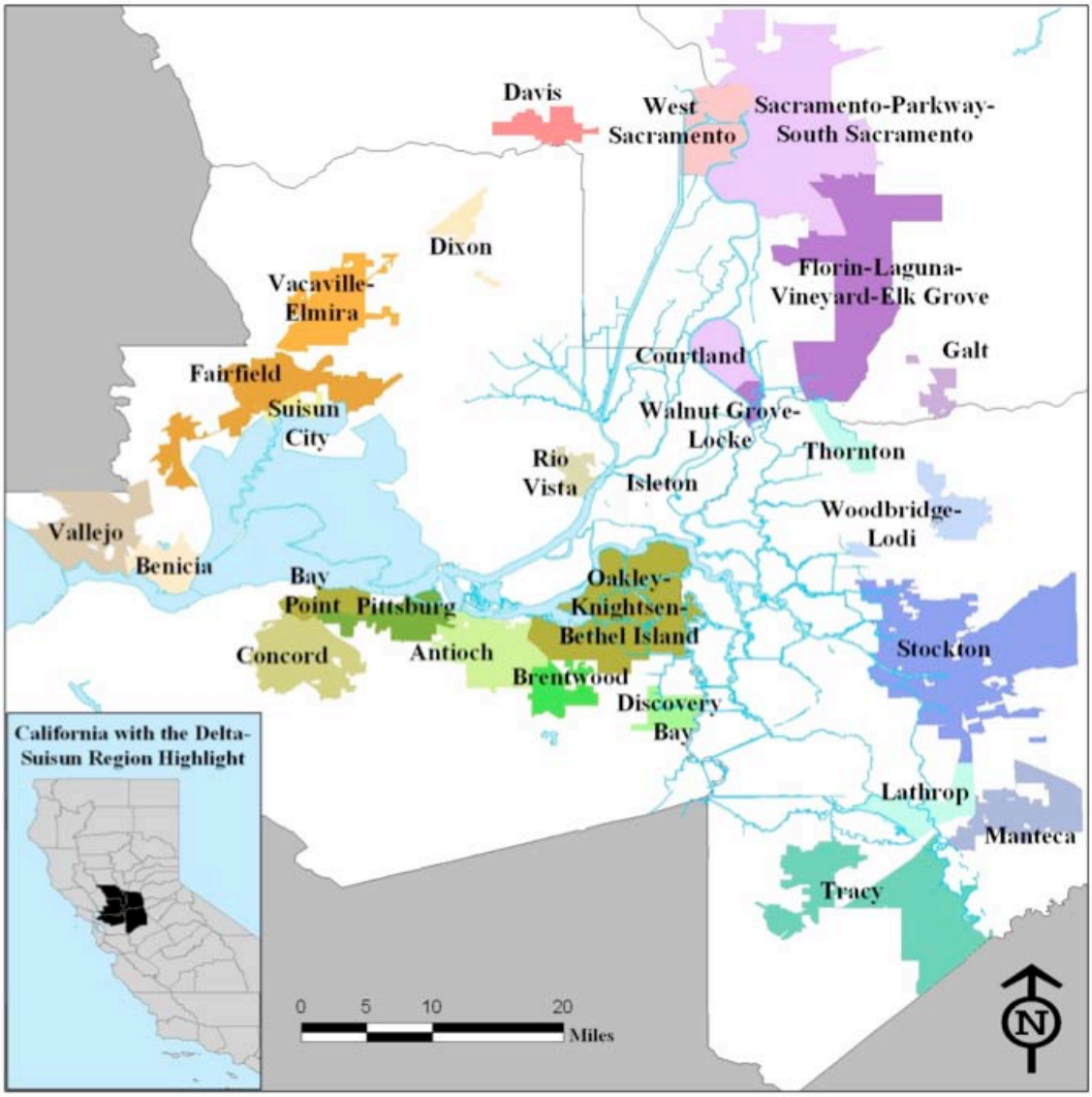
2. A *resistance* model that assesses how potentially impact people and places can withstand an environmental threat. For example, this focus asks, "What characteristics of a community, such as the socioeconomic status and/or the age of their buildings and their standard of upkeep, will allow them to be resistant to a flood?" (Fielding and Burningham 2005)

3. A *resilience* model, which attempts to show how likely people are to recover from some environmental threat. For instance, what type of financial reserves and emergency response measures are in place for an impacted community to recover from a hurricane?" (Houston et al. 2007).

As documented in the introduction, environmental justice advocacy and research have shown that low income communities, people of color, and immigrants are often the disproportionate recipients of environmental burdens and those same communities fail to benefit equitably from environmental policies and programs. Some have called this, "environmental inequality," which seeks to not only show which people and places are vulnerable to an environmental threat, but to identify those communities that already bear a heavier burden. It also "addresses more structural questions that focus on social inequality (the unequal distribution of power and resources in society) *and* environmental burdens…[E] nvironmental inequalities include any form of environmental hazard that burdens a particular social group" (Pellow 2000:582).

In these comments, we are concerned with identifying the socially vulnerable groups (low income, people of color, and immigrants) more likely to be exposed to poor water quality in the Delta-Suisun region. We focus on socially vulnerable groups with high concentrations of contaminants in the fish they eat, the water and land they live near, and in the water they drink, as well as how they cope with these relatively high concentrations of contaminants. While this study establishes social vulnerability without resolving the question of environmental inequality, glimpses of environmental conditions are evident in the words of study participants.

Figure 1
Reference Map of 28 Water Service Areas in the Delta and Suisun Marsh



Reference Map of Water Service Areas in the Delta and Suisun Marsh. Source: Environmental Coalition for Water.

SOCIAL VULNERABILITY AND ENVIRONMENTAL INEQUALITY

IN THE DELTA-SUISUN REGION

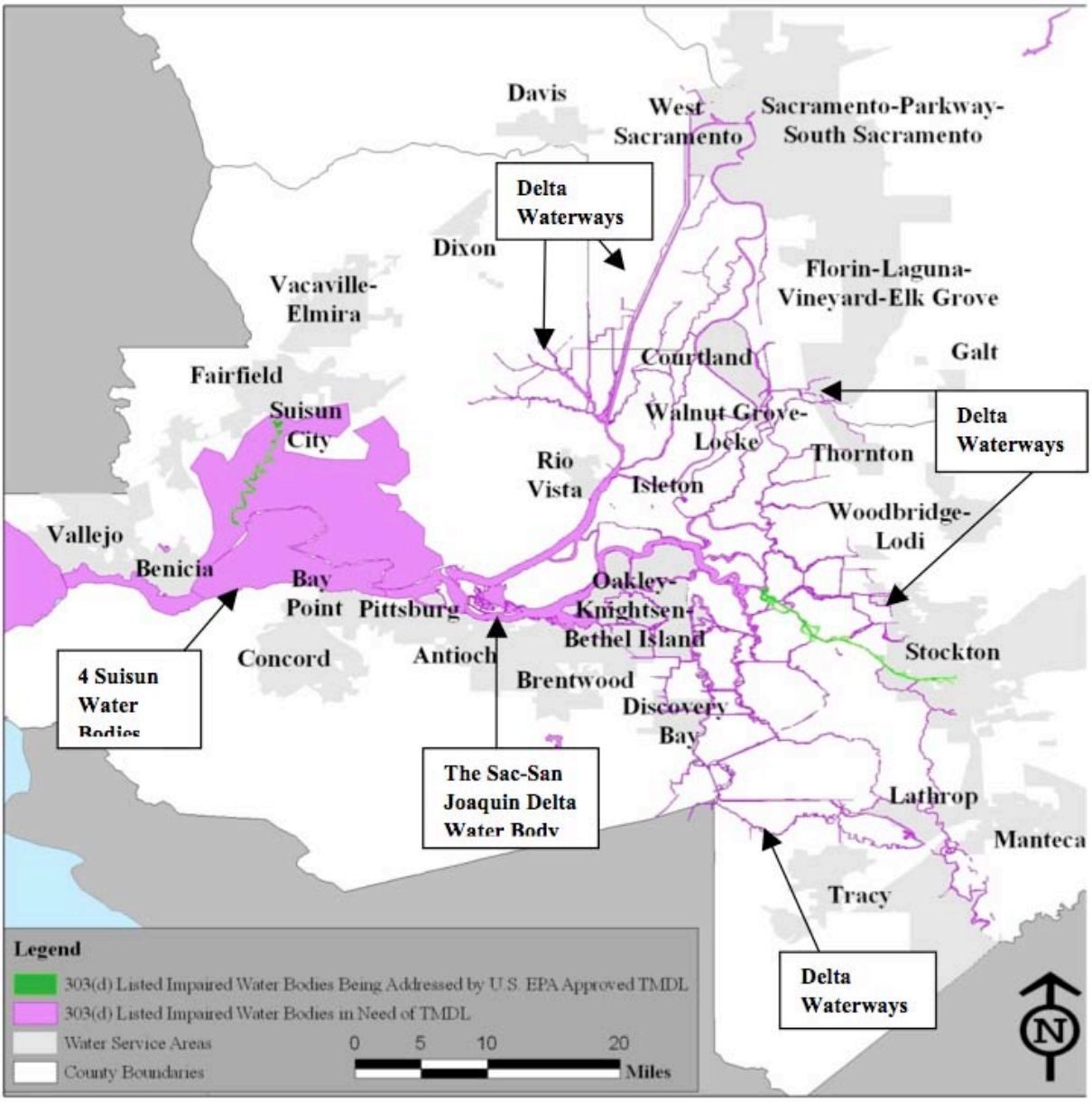
There are four broad themes that emerge from research on social vulnerability and environmental inequality in the Delta-Suisun region. The first subsection below describes the toxins that have been accumulating in the region, their impact on fish, and how people who fish for subsistence in the region

are forced to negotiate these legacies of toxins. The following two sections look at the relationship between social vulnerability and environmental inequality in the local environment and public drinking water systems of water service areas in the Delta-Suisun region. Both sections document the continuing significance of race as a predictor of poor water quality among socially vulnerable groups, as expressed by water contaminant concentration measures we use in our analyses. We then close with an overview of our findings and a discussion of the potential policy implications from our research. First, however, we turn to how socially vulnerable groups are negotiating a legacy of toxins in the Delta-Suisun region.

Negotiating a Legacy of Toxins: Living and Fishing in Impaired Water Bodies

There is an extensive body of literature on the problem of legacy toxins in the Delta-Suisun region. It documents how this decades of gold and mercury mining, agricultural production and the use of harmful pesticides, global trade and shipping patterns, and industrial and urban wastewater is impacting the region's ecosystem (Davis et al. 2003; Davis et al. 2008; Lydy and Austin 2004; O'Neill 2006; Silver et al. 2007; Shilling 2003). Further research suggests there is a potential compounding effect that water diversions from the region have had on the estuary's ability to counteract these legacy toxins, as well as the increasingly high levels of salinity found in the area's surface water (Lund et al. 2007). Few studies have sought to understand what this legacy of toxins means for socially vulnerable communities in the region (Shilling 2003; Silver et al. 2007). We seek to shed some light on the impacts accruing in socially vulnerable delta communities. In this section, we describe the known contaminants that have been accumulating in the region, their potential impact on fish and human health, regulatory responses to this contamination, and how socially vulnerable groups we met in our sample are forced to negotiate these legacies of toxins while they fish for pleasure and subsistence.

Figure 2
Impaired Water Bodies and Water Service Areas in the Delta and Suisun Marsh



Sources: Maps created by lead author with data from the U.S. Census (2000), SWRCB (2008a), and SWRCB (2008b).

Figure 2 shows the impaired water bodies in the Delta-Suisun region, the water service areas near these bodies, and the two water bodies that are being addressed by a U.S. EPA approved TMDLs. The Suisun impaired water bodies include the Suisun Bay, Suisun Marsh, Suisun Slough (highlighted in Figure 2), and the Carquinez Strait. The primary water service areas near the Suisun water bodies are Benicia, Fairfield, Suisun City, Bay Point, and Pittsburg. The Sacramento-San Joaquin Delta impaired water body is primarily located next to Antioch and the Oakley-Knightsen-Bethel Island areas. The Delta waterways run north-to-

south from West Sacramento and Sacramento areas to Tracy and Manteca. They also run west-to-east from portions of Antioch to Woodbridge-Lodi and Stockton.

Table 1: Pollutants found in 303(d) Listed Impaired Water Bodies in the Delta-Suisun Region and Issued Fish Contaminant Goals and Advisory Tissue Levels

Pollutant	Potential Source	Water Bodies Hosting Pollutant	TMDL Status as of 2006	OEHHA Fish Contaminant Goals (FCG) and Advisory Tissue Levels (ATL) in Place for Sport Fish?[1]
Chlordane	Unspecified Nonpoint Source	Suisun Bay, Carquinez Strait; Sacramento-San Joaquin Delta	TMDLs Required	Yes
DDT	Agriculture	Suisun Bay, Carquinez Strait; Sacramento-San Joaquin Delta; all Delta Waterways	TMDLs Required	Yes
Dieldrin	Unspecified Nonpoint Source	Carquinez Strait; Suisun Bay; Sacramento-San Joaquin Delta	TMDL Required	Yes
Mercury	Atmospheric Deposition; Industrial Wastewater; Municipal Wastewater; Unspecified Nonpoint Source; Resource Extraction	Suisun Bay; Carquinez Strait; Sacramento-San Joaquin Delta; all Delta Waterways	TMDLs Required	Yes, for Methylmercury
Polychlor-inated Biphenyls ("PCBs")	Unspecified Point Source	Carquinez Strait; Suisun Bay; Sacramento-San Joaquin Delta; Delta Waterways (Stockton Ship Channel and northern portion, moving towards West Sacramento)	TMDLs Required	Yes
Selenium	Agriculture; Industrial Wastewater; Exotic Species; Natural Sources	Carquinez Strait; Suisun Bay; Sacramento-San Joaquin Delta	TMDL Required	Yes

Source: Water Board (SWRCB 2008a) and OEHHA (2007; 2008). 1 = See OEHHA (2008) for the FCGs and ATLs put in place by OEHHA.

There are a total of 21 pollutants found in these impaired water bodies. Table 1 shows 6 pollutants found in these impaired waters and their potential sources (as identified by U.S. EPA and the Water Board). The table also shows the water bodies where these pollutants are found, their TMDL status, and whether or not they have been assigned fish contaminant goals (FCGs) and advisory tissue levels (ATLs) for fish contamination in the Delta-Suisun region. FCGs were developed by the Office of Environmental Health Hazard Assessment (OEHHA) to estimate the "contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week [32 grams per day], prior to cooking, over a lifetime" (OEHHA 2008:iii). This goal takes into account cancer and non-cancer risks of each contaminant. The ATLs are set to provide advice on what levels of fish consumption, based on cancer and non-cancer risks of a given contaminant, would provide a benefit to the consumer over a lifetime. Rather than documenting each goal and advisory level in Table 1, we show whether there has been an FCG and/or ATL set for each pollutant found in the impaired water bodies. We encourage the reader to see OEHHA (2008, pages 42 and 61) for more on the specifics of each advisory level put in place by the agency.

It is noteworthy here, however, that there are 15 other contaminants listed in section 303(d) of the Federal Clean Water Act and in the Water Board's TMDL program that have not been assessed by OEHHA for their potential impact on fish or the food chain in the Delta-Suisun region. This list includes high concentrations of several pesticides, organic compounds, metals, nutrients, and contaminants that contribute to high levels of salinity, and unspecified pathogens and toxic substances. The sources of these contaminants range from unspecified nonpoint sources and unknown sources, to agriculture, urban runoff and storm sewers, atmospheric deposition, contaminated sediments, water flow regulation and modification, and non-boating recreational and tourism activities. Two of these pollutants have a U.S. EPA approved TMDLs in place as of 2006. These water bodies are highlighted in green in Figure 2. The first is the pesticide, diazinon, which comes from agriculture and urban runoff and storm sewers. It is being addressed in Suisun Slough, which runs into Suisun City. The second TMDL in place is for high levels of nutrients (organic enrichment and low dissolved oxygen). It is highlighted in green in the Stockton Ship Channel, which extends from Stockton into the center of the Delta waterways. Both of these impaired water bodies have been assigned a TMDL due to a combination of political and scientific pressure because of their adverse effects on ecological and human health (Harnly et al. 2005; Schmieder et al. 2008). The massive amounts of contaminants in the Delta-Suisun region have received an uneven treatment from regulatory agencies, as evident in the relative lack of TMDLs designed and implemented in the region and the sparse amount of fish contaminant goals and advisory tissue levels that have been set for pollutants in the impaired water bodies.

Studies are just starting to understand what this legacy of toxins and regulatory ineptitude means for socially vulnerable communities in the region (Shilling 2003; Silver et al. 2007). Silver et al (2007:417) have shown that "fish contamination may have disproportionate impacts on low-income, non-white groups in the Delta." Their study highlighted that this is cause for concern as such groups could be more likely to be disproportionately exposed to the neurodevelopmental problems associated with the highly toxic methylmercury found in the impaired water bodies shown in Figure 2 and Table 1. Silver et al. came

to this conclusion by collecting demographic information and fish consumption patterns at a welfare health clinic in Stockton, California to assess the ethnic differences among low-income women in the Stockton area in their fish consumption rates and their awareness of fish advisories. The typical advisories under scrutiny in the study were similar to the "EAT DELTA FISH SAFELY" sign shown on the front cover to this report. Ultimately, Silver et al. found that African Americans and Asians (Vietnamese and Cambodians) and others not aware of fish advisories in the region are potentially at the highest risk for eating contaminated fish from the Delta. In other research along these lines, Shilling (2003) mapped the zip codes of the Delta-Suisun region that had the highest frequencies of anglers in river locations with high mercury concentrations (those that exceeded the U.S. EPA-recommended 0.3 parts per million) in fish tissue.

Table 2: Selected Demographics of Zip Code Areas with the Highest Frequencies of Anglers in River Locations with High Mercury Concentrations (>0.3 ppm) in Fish Tissue.

Selected Demographic	
People of Color	37.93%
Black or African American	11.76%
Native American	0.95%
Asian/Pacific Islander	15.04%
Some Other Race	10.18%
Hispanic or Latino	21.38%
Linguistically Isolated Households	7.07%
Foreign Born Immigrated to U.S. 1980-2000	73.40%
Below Poverty Level	14.92%
Median Household Income	$42,500

Source: Shilling (2003) and U.S. Census (2000)

Note: Percentages are of the total population for each zip code except for linguistic isolation, foreign born immigrants, and those below poverty level. Linguistic ally isolated households is a percent of households, foreign born immigrated to U.S. 1980-2000 is a percent of foreign born individuals, and below poverty level is of those whose 1999 poverty status has been determined by the Census, which most, but not every time, is equal to the total population in the zip code areas.

Table 2 summarizes the demographics of the zip code areas Shilling found to be the origins of the anglers fishing in high risk areas. The zip codes selected here come from Antioch, Oakley and Pittsburg in the southwest portion of the Delta-Suisun region; and Vacaville in the northwest; Sacramento and Elk Grove in the northeast; and Lodi and Stockton in the southeast. It is not possible to analyze the demographics of the zip codes that are not at risk for high concentrations of mercury contamination to determine if there is disproportionate risk born on these anglers at this time. This is particularly the case since we do not have data on the actual anglers and estimates on how much contaminated fish they are consuming, which contrasts to the Silver et al study. But, it is noteworthy that by deriving the zip codes of origin from

the at risk anglers, Shilling is able to begin painting a picture of the demographics of at risk areas: about 38% are people of color (mostly Black or African American and Asian/Pacific Islander), 21.38% Hispanic or Latino, 7.07% linguistically isolated, 14.92% recent immigrants, about 15% whose 1999 income was below the poverty level, and a median household income of $42,500. These statistics help us understand who might be disproportionately at risk of eating contaminated fish and what areas are associated with high concentrations of mercury and its breakdown products, such as the neurotoxin, methylmercury. But, we have gained little in understanding some of the perspectives of socially vulnerable communities in how they negotiate such potential disproportionate risks.

Social science research into fishing behavior has shown that there are racial, gender, and class meanings behind recreational fishing (Togh and Brown 1997). This was the case in our interviews and focus groups where individuals from a variety of backgrounds attributed their fishing activities to recreation and relaxation. Some describe their fishing spots as "my place of solace out there in that water," where they "sit there…relax and take time away from everybody" (Personal Interview, 2008). Others described their fishing activities in terms of subsistence: 'If you have less money to buy food, you fish more. If you have less work and money, then you will go to the dollar store for food which has food that is worse for you' (Focus Group, 2008). Whether for recreation or subsistence, the people we met in our sample commented on how local polluting sources are responsible for the declining water quality. As an individual who immigrated to the Delta-Suisun during the 1990s told us, "Water affects us when the factories send waste into the river and ocean. This affects fish and all of us because it contaminates the water. There is a drain next to where I fish with liquid that comes I don't know where. I don't know what factories are around there" (Focus Group, 2008).

Some describe this change as an impact on their cultural practices, and wonder what will come of future decisions to export water from the region. As one Native American representative, and long-time resident from San Joaquin County, shared with us:

> [I]t makes my family and I feel sad that our elders and our youth will no longer be able to enjoy the clean water that our ancestors did. My brothers no longer fish to eat as they have seen the deformities and sickness come from the water. Now they fish for the sport of it…[Whatever] Sacramento's decision[s] are on the State's water management will impact our people in many ways. It will impact fishing areas if the water is diverted to other areas, it will dry up our sloughs, gathering areas, and much more. (Personal Communication, 2008)

This individual elaborated on what it means to negotiate the heavily engineered environment, with all its supposed unintended consequences of environmental degradation that has come to characterize the Delta-Suisun region and other industrializing areas. This heavily engineered setting does not resonate with how this individual makes sense of the world. Instead, it is another example of the 'other' world that this person is forced to inhabit:

> [I]t's not an easy thing to live in two different worlds…I leave [home]. I go to work. I'm in their world. I live by their rules. I act like them, ok, to a certain extent. I go out the door, I come home, I'm in my own *world*, you know? I do what *native* people do. I *act* like a Native. I *feel* like a Native. I *eat* like a Native,

> you know? And, it's not easy juggling my life like that, but that's how I have to live because…most people…cannot relate (Personal Interview, 2008)

The statements above resonate throughout our focus groups and interviews: Socially vulnerable groups —racial and ethnic minorities, low income individuals, and immigrants—are being impacted by the water quality of the Delta-Suisun region in a way that forces them to compartmentalize their lives.

How effective have the fish advisories been in addressing the issue of fish contamination in the region? Silver et al. (2007:418) claim that in the Delta-Suisun, it will likely take decades to address the sources of the legacy toxins that permeate the impaired water bodies, so "outreach and education are the only viable methods of immediate exposure reduction," and this must be done in a manner that is sensitive to the different cultures and linguistic capabilities of at risk populations. We interviewed individuals who told us that the fish advisories currently in place are not enough because people who have to choose between starving or eating contaminated fish will eat the contaminated fish (recall the paraphrased quote above: 'If you have less money to buy food, you fish more'). Summing up this point of view, one individual shared with us the following critique of solely relying on outreach, education, and advisories:

> [R]ight now, the only policy option is to tell people to eat different fish or less of the contaminated fish. So, it's totally on the consumer, and it's their personal responsibility to not accumulate toxins. And that's pretty much where it stands. And that's not acceptable. (Personal Interview, 2008)

Instead, advocates working in the region argue that the contamination needs to be cleaned up at the source *while* new exposure reduction strategies are developed and funded. It is not enough to educate people who have no other alternatives or options. Those alternatives and options must be developed to provide these communities with the resources they need to survive both physically and culturally.

What can be done? A publication prepared for the California Department of Public Health and the Central Valley Regional Water Quality Control Board by researchers at UC Davis and staff at the Southeast Asian Assistance Center has proposed some "community-based strategies to reduce mercury exposure in Delta fishing communities" (Shilling et al. 2008). While the strategies identified do not address the socio-economic pressures creating the need for subsistence fishing, the researchers did identify five strategies that resonate with the community perspectives conveyed in this study. The five strategies are:

1. *Monitoring fish and fish consumption:* community organizations lead the design and implementation of fish tissue and fish consumption monitoring, aided by academic and agency scientists.

2. *Assessing mercury exposure:* community organizations, in partnership with agency and academic health professionals calculate or measure actual mercury exposure and community organizations lead communication of findings to communities and individuals.

3. *Effective education and outreach*: community organizations lead the design and implementation of education and outreach programs to communities and individuals eating large amounts of locally-caught fish, aided by academic and agency scientists.

4. *Consumption advisories:* community organizations, in partnership with agency and academic health professionals and scientists, design fish-consumption guidelines that are accessible to the diverse cultures and communities in the Delta region.

5. *Decision-making & implementation model:* to improve the effectiveness of strategic decision-making and implementation, a new model should be developed that moves away from state agencies being funders, recipients of funding, and the primary decision-makers in matters of fish contamination and implementing exposure reduction measures. Rather, the new model should feature organizations from impact communities at the center of decision-making and implementation, partnering with state institutions in support roles (Shilling et al. 2008:5-7).

These recommendations generally depart from what has been a regulatory approach that includes a Water Board that has admitted to not being as efficient in enforcement of water quality standards as it should (Cal/EPA 2008) and a focus on outreach and education as the primary vehicles for exposure reduction because they put the impacted community in a leadership role in making decisions about exposure reduction. If the community perspectives we outlined here resonate with other impacted communities in the region, then perhaps a sixth key strategy for reducing exposure to contaminated fish should be to fully address the source of the contaminants in the Delta-Suisun. We believe the next section provides a step in that direction. It also explores the relationship between socially vulnerable groups and water quality in the region.

Exploring the Murky Waters: Demographics and Water Contaminant Concentration

"The taste of water has changed. I try to use filters. Years ago it felt good to drink water from the spigot or the hose, but not now."

—Focus Group, 2008

This section begins our deeper look at the relationship between social vulnerability and environmental inequality in the local environment and public drinking water systems of water service areas in the Delta-Suisun region. We narrow our focus to using two water contaminant concentration indices to assess the average exposure levels of socially vulnerable groups to poor water quality from 1998-2003. To do so, we draw on data from the Environmental Working Group's national tap water quality study, and data from the Department of Toxic Substance Control's EnviroStor database on water-contaminated hazardous sites to see why, as one of our low income, minority project participants put it, "the taste of water has changed" in the region. We start by providing a map in Figure 4 that shows a visual relationship between the proportion of people of color in each water service area and the presence and frequency of water quality violations. We have retained the layer on the map from the previous section of the impaired water bodies, so that one can also see the visual relationship between the number of water quality violations and the impaired waters.

Figure 4
Water Contaminated Sites, Impaired Water Bodies,
and Percent of People of Color of Water Service Areas in the Delta-Suisun Region

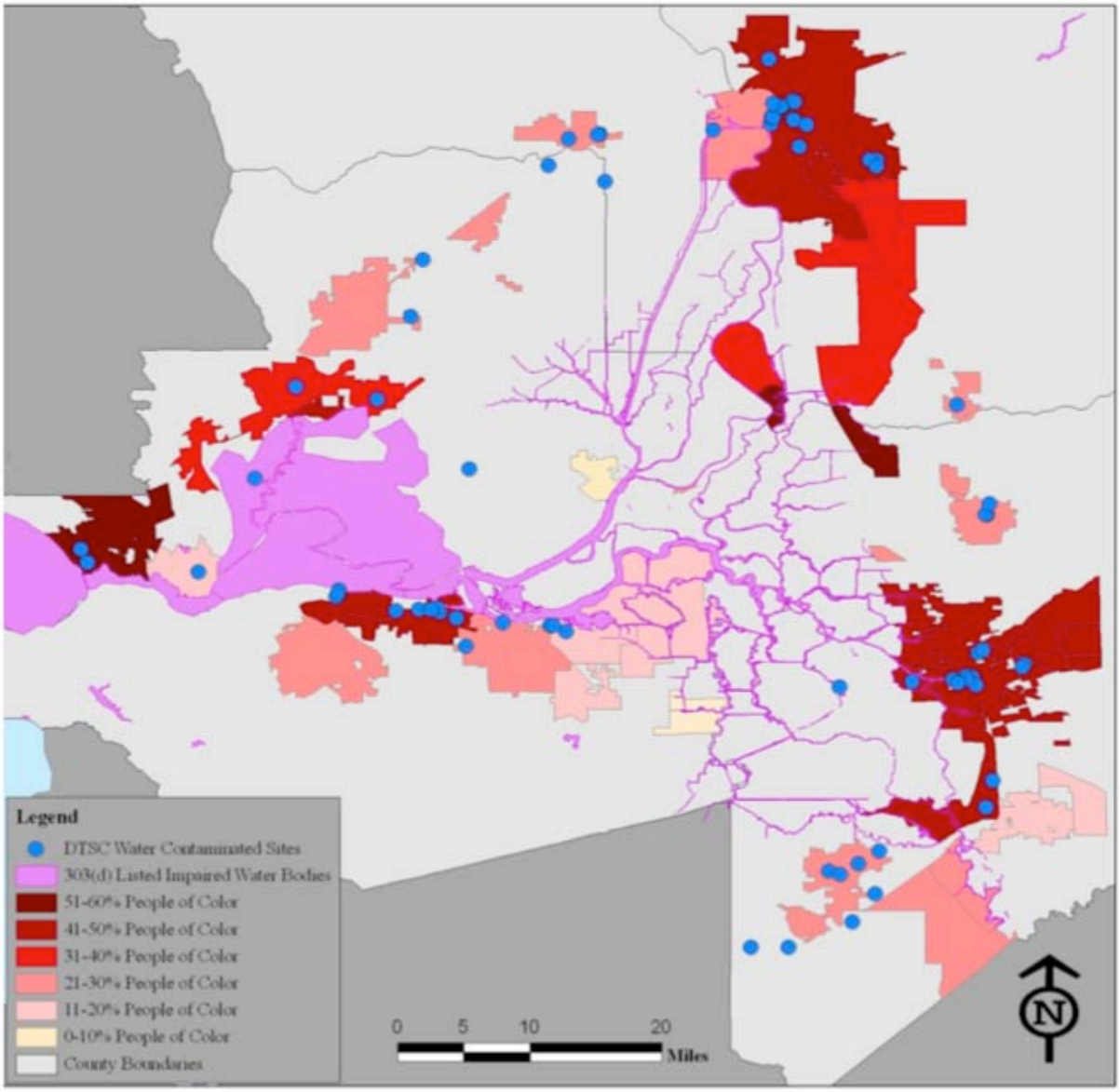


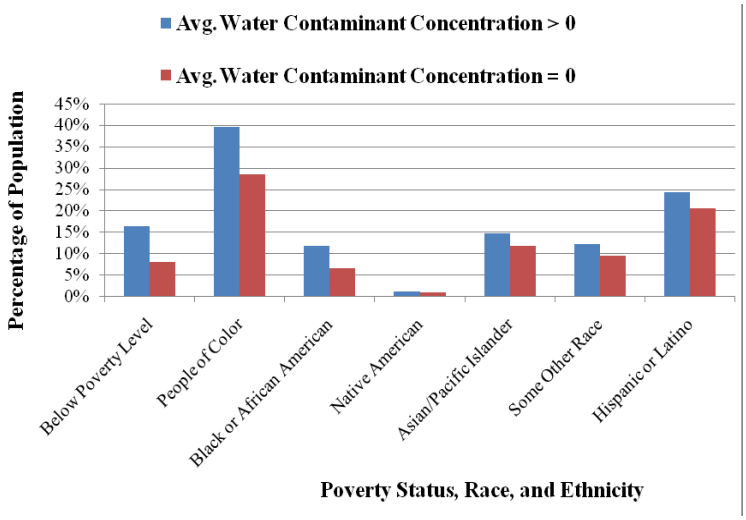
Figure 4: Source: US Census (2000); SWRCB (2008a); SWRCB (2008b); the California Department of Toxic Substances Control EnviroStor Database; and Environmental Justice Coalition for Water.

Figure 4 also shows a visual relationship between race in each water service area and the number of water quality violations: places like Rio Vista, Discovery Bay (both 0-10% people of color), Brentwood, Oakley-Knightsen-Bethel Island, and Manteca (both with 11-20% people of color) have little to no presence of water quality violations. Meanwhile, places that are predominantly people of color (Stockton, Pittsburg, Bay Point, Vallejo, and the Sacramento—Parkway-South Sacramento water service areas) have relatively high numbers of water quality violations.

To further investigate the visual relationships emerging from the data, we examined the level of contamination at each site. Doing so allows for a reflection on the severity of the water quality problem and therefore the likelihood that the water quality problem would negatively impact those being exposed to the water.

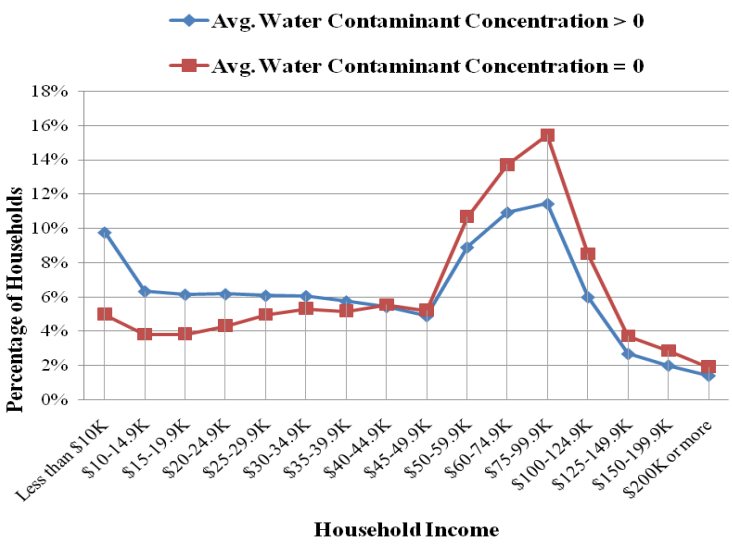
The level of contamination was determined by construction of a new variable we call the "average water contaminant concentration" (WCC). Briefly, the WCC was calculated by taking the sum of potential contaminants of concern from the water-contaminated sites for each water service area, dividing that by the sum of water contaminated sites, then dividing that number by 6 to get the average water contamination concentration from 1998-2003 for each water service area. A high score on the WCC means higher levels of contamination, which suggests worse water quality is present in a water service area's surface, ground, and, potentially, drinking water.

Figure 5: Demographics of Water Service Areas that have an Average Water Contaminant Concentration Level Greater Than Zero versus those Equal to Zero in the Delta-Suisun Region



(a) Poverty Status, Race, and Ethnicity and Average Water Contaminant Concentration

Figure 5: Demographics of Water Service Areas that have an Average Water Contaminant Concentration Level Greater Than Zero versus those Equal to Zero in the Delta-Suisun Region



(b) Percentage of Households and Average Water Contamination Concentration

Source: US Census, 2000.

As seen in Figure 5a, water service areas with an average water contaminant concentration greater than zero differ notably from those whose score equals zero. More specifically, water services areas with a higher proportion of socially vulnerable groups—those below the poverty level, people of color, and Hispanic or Latino— tend to score higher on the WCC. Figure 5b also identifies a relationship between household income and the WCC Score. The median household income of water service areas with an average water contaminant concentration greater than zero is $42,500, while that of the water service areas with a zero WCC score is $55,000.

In isolation, the social vulnerability measures we use thus far suggest that a number of factors are associated with high scores on the WCC. We conducted a regression analysis to explore predictors of poor water quality as measured by the WCC. In Table 3, we report the coefficient signs and their significance levels for each independent variable we use to predict the WCC.[543] As seen in the table, when controlling for the number of water contaminated sites, poverty, percent Hispanic or Latino, linguistic isolation, and percent of foreign born who immigrated to the U.S. between 1980 to 2000, race (as expressed in the percent people of color) is a statistically significant and positive predictor of the

[543] The format we use in Table 3 is modified from Pastor et al. (2007), in which they attempted to provide regression statistics in an accessible manner for the lay reader. Appendix A reports the statistics from this ordinary least squared regression analysis for the technical reader.

WCC. In simpler terms, the higher the proportion of people of color in a water service area the higher the score on the WCC.

Table 3: Coefficient Signs and Significant Levels of a Regression Analysis of the Average Water Contamination Concentration of Water Contaminated Sites on Selected Demographics of 28 Water Service Areas in the Delta-Suisun Region

Model Variables	Coef. Sign	Sig. Level	Coef. Sign	Sig. Level	Coef. Sign	Sig. Level	Coef. Sign	Sig. Level
Number of Water Contaminated Sites	+	*	+		+		+	
% Below Poverty Level	—		—		—		—	
% People of Color			+	*	+	*	+	*
% Hispanic or Latino			—		—		—	
% Linguistically isolated households					—		—	
% Foreign Born Immigrated to U.S. 1980-2000							+	
	N=28		N=28		N=28		N=28	

Notes: * Significant at the p <.05 level

These findings suggest the continuing significance of race in determining environmental inequality. Yet, they are based on a small sample size of only 28 water service areas. Usually this type of statistical analysis is reserved for sample sizes greater than 100 or even 200. To guard against accepting a statistically significant finding when it is actually insignificant, we chose to only report significant levels for our coefficients at the .05 level or higher.

Assessing Vulnerability to Drinking Water Contamination

For this portion of the analysis, we constructed what we call an average drinking water contaminant concentration index (DWCCI). It is similar to the index used in the previous section, except the average DWCCI integrates four characteristics of public drinking water systems found in water service areas (the type of contaminants found and the different violations issued to each system), as well as the number of water-contaminated sites that are known to contaminate drinking water supplies in each water service area. It also averaged over six years and standardized by population of each area, then multiplied by 1000. We then took the natural log of the index, which helped us evenly distribute the index across water service areas (more about this methodology is in Appendix A). This provided us with the opportunity breakdown the index into four rankings classifications, based on standard deviations away from the mean of the transformed average DWCCI. “Low” denotes areas more than one standard deviation below the mean, while “mid-low” signifies that an area was between -1 and zero standard deviations below the mean. “Mid-high” stands for water service areas zero to one standard deviation above the mean, while “high” means that an area was greater than one standard deviation above the mean.

Table 4 describes the demographics of water service areas which fall into each estimated ranking in the average DWCCI. As the table shows, most demographic characteristics of each estimated ranking follow four patterns. First, as is the case for people of color, Native American, Asian/Pacific Islander, linguistically isolated households, and poverty level, we see that percentages of these socially vulnerable groups decrease as we move from low to mid-low rankings or low to mid-high rankings, then they increase across the board at the high ranking level. This pattern breaks, however, for other races and Hispanic or Latino, which steadily increase from low to high ranking levels. This relationship between other race and Hispanic or Latino can be explained by their correlation with each other: the "some other race" category includes people who identify as having some sort of Hispanic origin.

Table 4: Selected Demographics (2000) of Water Service Areas by Their Estimated Rank in the Drinking Water Contaminant Concentration Index (1998-2003)

	Estimated Ranking in the Drinking Water Contaminant Concentration Index			
Selected Demographic	**Low**	**Mid-Low**	**Mid-High**	**High**
People of Color	41.67%	36.21%	25.41%	37.00%
Black or African American	14.41%	9.34%	4.66%	0.48%
Native American	1.14%	0.88%	0.77%	1.49%
Asian/Pacific Islander	15.34%	14.09%	6.30%	13.89%
Some Other Race	10.77%	11.90%	13.69%	21.14%
Hispanic or Latino	21.90%	23.79%	27.51%	39.55%
Linguistically Isolated Households	7.48%	7.04%	5.09%	11.86%
Foreign Born Immigrated to U.S. 1980-2000	73.36%	70.61%	63.65%	59.45%
Below Poverty Level	17.23%	13.95%	7.08%	12.14%
Median Household Income	$42,500	$47,500	$60,000	$37,500

Source: U.S. Census (2000)

Note: Percentages are of the total population for each zip code except for linguistic isolation, foreign born immigrants, and those below poverty level. Linguistically isolated households is a percent of households, foreign born immigrated to U.S. 1980-2000 is a percent of foreign born individuals, and below poverty level is of those whose 1999 poverty status has been determined by the Census, which most, but not every time, is equal to the total population in the zip code areas.

Another small pattern that arises is how the percent foreign born who immigrated to the U.S. between 1980 and 2000 decrease steadily, moving from low to high ranking levels in the average DWCCI. Finally, there is the pattern in which the median household income decreases as we move from low to mid-high ranking, then drops off drastically as we move from mid-high to high rankings. It is difficult to discern from Table 4 if there is any correlation between socially vulnerable groups and the drinking water

contaminant concentration index. Thus, we need to explore this question through another multiple regression analysis, the results of which are displayed in Table 5.

Table 5: Coefficients Signs and Significant Levels from the Regression of the Average Drinking Water Contaminant Concentration Index (1998-2003) on Selected Demographics (2000) of 28 Water Service Areas in the Delta-Suisun Region

Model Variables	Coeff. Sign	Sig. Level	Coeff. Sign	Sig. Level
% Below Poverty Level	—	*	—	*
% Black or African American	—	**	—	**
% Native American	+		+	
% Asian/Pacific Islander	+	*	+	
% Hispanic or Latino	+	**	+	
% Linguistically Isolated Households			+	*
	N=28		N=28	

Note: Standard errors in parentheses, * Significant at the p <.05 level; ** Significant at the p < .01 level

Table 5 shows that, once again, race matters. On average and when controlling for percent below poverty level, percent Black or African American, and percent Native American; an increase in the Asian/ Pacific Islander and in the Hispanic or Latino population is statistically significantly associated with a an increase in the DWCC in water service areas in the Delta-Suisun region. Curiously, on average and when controlling for other demographics in the analysis, the less poverty and the fewer Black or African American residents result in worse water quality conditions as measured by the DWCC.

Finally, linguistic isolation, on average and when holding all other variable constant in the table, becomes a statistically significant predictor of poor drinking water quality for water service areas in the Delta-Suisun region. Interestingly, linguistic isolation is a more powerful predictor of DWCC than Hispanic or Latino population levels and Asian/Pacific Islander population levels as these variables lose their significance once linguistic isolation is added to the model. This finding, paired with the finding about percent below poverty and percent Black or African American suggests households that are linguistically isolated (and most likely speak Spanish or some Asian American or Pacific Islander language) may be those most disproportionately at risk to poor drinking water quality in the Delta-Suisun region.[544] Like the regression results in the previous section, this statistical test used a small sample size of only 28 water service areas. Again, we were conservative and chose to only report significant levels for our coefficients at the .05 level or higher.

DISCUSSION

[544] Once the recent immigrant variable was added to the model, the significance of each variable decreased to not be statistically significant.

The community of Bay Point, California, located on the northeastern edge of Contra Costa County has high percentage of people of color (47.67%), Hispanic or Latinos (39.33%), linguistic isolation (11.79%), poverty (17.23%), and recently-arrived foreign born individuals (78.81%). People from these demographics have been organizing to force a private water company, who has exceeded permissible levels of water treatment chemicals, such as total trihalomethanes, in the water it serves to the community. The community applied and was one of 48 communities in the nation to receive a Community Action for Renewed Environment (CARE) grant from the U.S. EPA in partnership with the University of San Francisco, the Centers for Disease Control and Prevention, and the Contra Costa Health Services' Healthy Neighborhoods Project. The grant has helped them organize and force community hearings to have the private water provider purchase higher quality water treated by the Contra Costa County Water District to provide them with the same drinking water quality enjoyed by the rest of the county's public and privately owned drinking water suppliers. This report has shown that socially vulnerable groups like those in Bay Point are present all throughout the Delta-Suisun region and fighting various forms of environmental inequality: some are forced to fish for subsistence in the impaired water bodies of the region, others are living in communities that have high levels of water contamination in the groundwater and surface water, and others are exposed to high concentrations of contaminants in their drinking water.

Climate science literature suggests that sea level rise will be a result from global warming and that will hit vulnerable groups the hardest. The Delta-Suisun region is an area particularly at risk to such a hazard, as well as at risk to a considerable seismic event that could force flooding throughout the region.

Researchers with the Environmental Justice and Climate Change Initiative and Redefining Progress observe that "[c]limate change is not only an issue of the environment; it is also an issue of justice and human rights, one that dangerously intersects with race and class…An effective policy to address the challenges of global warming cannot be crafted until race and equity are part of the discussion from the outset and an integral part of the solution" (Hoerner and Robinson 2008:1). Research suggests that the global warming could have harmful consequences for drinking water quality, particularly for those already exposed to poor quality water such as Latinos and other vulnerable groups (Levin et al. 2002; Metzger et al. 1995). Recent research on the Delta-Suisun region is vulnerable to a seismic event and global-warming-induced sea level rise that could result in flooding throughout the region, starting in the west and hitting communities like Bay Point first, then cascading to hit other socially vulnerable areas with disastrous consequences for public health and surface and drinking water quality (DWR & DFG 2008; Lund et al. 2007; Lund et al. 2008). In this section, we share some of the perspectives on climate justice in the Delta-Suisun from those we encountered in our research in relation to what they view as equitable flood protection.

Attachment 1, APPENDIX A: TECHNICAL REMARKS

Data Collection and Transformation

Census Data

Environmental justice studies have identified a number of demographic variables that are strong predictors of environmental inequality. We used data from the 2000 U.S. Census Summary File 3, which gives estimates for small groups and areas on a wide variety of topic areas. The goal of this data is to identify large differences among areas or large changes over time. The socio-demographic variables selected allowed us to look at social class, race, ethnicity, linguistic isolation (i.e., households with no household member older than 14 that can speak English "very well"), and immigration status. We downloaded this data electronically from the Census for various geographically-defined areas in the Delta. We also obtained a list of what Census geographies (block groups) reside in the legally-defined Delta and Suisun Marsh to build a sample of "water service areas" used in this analysis (see Figure 1).

Characterizing Water Service Areas

Figure 1 shows the water service areas we constructed for this analysis. We drew on the following to construct a total of 28 water service areas. We started with the systems as they were listed by the EWG database. Water service providers that were specified with fixed populated places in each county were assigned to their corresponding Census populated places by name. For example, the water system for the City of Pittsburg as assigned to the census place, Pittsburg City. We followed this procedure for every system, except for those in jails, correctional facilities, and military operations because much of the Census data we use are not generalizable to these types of exclusive institutions. After each system was initially assigned to a place, we verified that each system actually exists in each place by consulting maps and descriptions of municipal water service providers in the five counties of the Delta; internet searches for systems associated with mobile home parks, businesses, and recreational areas in the Google search engine and in address matching searches for these areas with U.S. Census geographically-coded data in the Census' "American FactFinder" and the list of census geographies that are associated with the legally-defined Delta and Suisun Marsh. We then consulted U.S. EPA's Safe Drinking Water Information System/Federal Version (SDWIS/FED), Census maps of the five counties in the Delta; and geographic information systems software (ArcGIS version 9.2) to select our final set of public water systems (N=144) to assign to water service areas in this analysis.

We were conservative in carrying out this method. We only kept water systems in the analysis if they were located in three of the four following sources: the EWG study, the U.S. EPA SDWIS/FED database, the Google search engine, and county water service provider maps and descriptions. This method provided us the best estimate of what the public drinking water systems and socio-demographics of each service area with the available data. We found that there is considerable discrepancy between these four sources that should be rectified in the future to better facilitate analyses like the one carried out in this report.

Using a Snowball Sampling Method to Explore Community Perspectives

These participants were identified using a "snowball" sampling technique. This is typically used in exploratory social science research in which one starts out with initial contacts and interviewees and builds out to understand a specific group of interest (Lofland et al. 2006). We started with the few contacts EJCW had in the Delta region and eventually spread out to key individuals who had extensive knowledge about the local conditions in environmentally burdened and poor and minority communities. Since this is a non-probability sampling method, we cannot generalize our findings from the sample to the general public of the five counties of the Delta-Suisun Region. But, we do claim that what they shared with us about the water quality and human health concerns are *suggestive* of how socially vulnerable groups cope with such issues.

Selecting Water-Contaminated Sites

The California Environmental Protection Agency's (Cal/EPA) Department of Toxic Substance Control (DTSC) recently created the "EnviroStor" database. It is publicly available[545] and contains data on *known and suspected* contamination and histories for sites located throughout California. We used a number of selection criteria to select sites for this analysis. First, we selected those sites whose longitude and latitude were in the water service areas we constructed for this analysis that are in the legally-defined Delta and Suisun Marsh (discussed below). We then selected sites that were suspected to contribute to some form of water contamination (e.g., an aquifer used for drinking water, ground water not used for drinking water, and surface water). We then obtained our final number of water-contaminated sites (N=82) after an analysis of each site history revealed that some form of water contamination occurred and was being addressed during or before 1998-2003 to ensure that we kept a common time frame for analysis with the drinking water quality data with the EWG drinking water study. Finally, we coded the EnviroStor data on the 82 sites to identify the "potential contaminants of concern"[546] for each site for subsequent analysis of water contamination concentration in the water service areas. We also use contamination data from this database in our analysis of the Drinking Water Contamination Concentration Index, as well as an analysis of what demographics are most strongly associated with the concentration of water-contaminated sites in the Delta-Suisun region.

Data Analysis

Water Contaminant Concentration

We presented simplified versions of the regression results in the text to make the text more accessible to the lay reader. The equation used to derive the average water contaminant concentration is shown below:

Average Water Contaminant Concentration = (Sum of Potential Contaminants of Concern from Water Contaminated Sites / Sum of Water Contaminated Sites) / 6

[545] The DTSC EnviroStor database is found at www.envirostor.dtsc.ca.gov.

[546] DTSC defines these contaminants as potential contaminants that "include hazardous substances that may be present at the site" and cause for concern to human and environmental health (DTSC 2008).

Table A1: Regression of the Average Water Contaminant Concentration of Water Contaminated Sites on Selected Demographics of 28 Water Service Areas in the Delta and Suisun Marsh

Independent Variables	Class Model	Race & Ethnicity Model	Communication Model	Immigration Model
Number of Water Contaminated Sites	0.121* (0.047)	0.082 (0.045)	0.074 (0.049)	0.078 (0.051)
% 1999 income level below the poverty line	- 0.042 (0.030)	- 0.043 (0.032)	- 0.036 (0.036)	- 0.037 (0.037)
% People of Color		0.038* (0.015)	0.040* (0.016)	0.040* (0.016)
% Latino		- 0.033 (0.017)	- 0.026 (0.023)	- 0.024 (0.025)
% Linguistically isolated households			- 0.041 (0.086)	- 0.052 (0.096)
% Foreign born individuals who immigrated to the United States in 1980 or later				0.004 (0.013)
Constant	0.965* (0.386)	0.779 (0.478)	0.720 (0.502)	0.506 (0.866)
R-Squared	0.215	0.402	0.408	0.411
Adjusted R-Squared	0.152	0.298	0.273	0.242
F-Statistic	3.4253*	3.8638*	3.0305*	2.4372
	N=28	N=28	N=28	N=28

Notes: Standard errors in parentheses; * Significant at the p <.05 level

In Table 3, we report the coefficient signs and their significance levels for each independent variable we use to predict the average water contaminant concentration.[547] As seen in the table, when controlling for the number of water contaminated sites, percent of people the population below poverty, percent Hispanic or Latino, percent households linguistically isolated, and percent of foreign born who immigrated to the U.S. between 1980 to 2000, race (as expressed in the percent people of color) is a statistically significant and positive predictor of the average water contaminant concentration levels experienced by water service areas in the sample. That is, an increase in the percent of people of color in a water service area, on average and when controlling for all other variables in the table, is associated with an increase in the level of water contaminant concentration in water service areas in the Delta-

[547] The format we use in Table 3 is modified from Pastor et al. (2007), in which they attempted to provide regression statistics in an accessible manner for the lay reader. Appendix A reports the statistics from this ordinary least squared regression analysis for the technical reader.

Suisun region. Also, while not statistically significant, the on average, increases in the number of water contaminated sites and the percent foreign born who have immigrated to the U.S. between 1980 and 2000 are also associated with increases in a water service area's water contaminant concentration.

Drinking Water Contaminant Concentration

To look at which social groups are associated with poor drinking water quality, we constructed a similar water contaminant concentration index to what we used in the previous section. It differs in that it sums the following characteristics of public drinking water systems in the water service areas of the Delta-Suisun region: the average amount of total contaminants; the average amount of health-limit-exceeding contaminants; the average health-based EPA violations; and the average EPA monitoring, reporting, and other non-health-based EPA violations. It also adds to this sum the number of water-contaminated sites that have been identified to pollute drinking water supplies in each water service area. These summed elements are divided by six to construct an average measure from 1998 to 2003. Finally, this average figure is divided by the population of water service areas then multiplied by 1000 to derive a standardized drinking water contaminant concentration index to compare across water service areas in the region. We then take the natural log value of this index to make it more evenly distributed and ready to conduct another multivariate regression analysis similar to the section on water-contaminated sites.

DWCCI = ((Average Total Contaminants in Public Water Systems + Average Health-Limit-Exceeding Contaminants in Public Water Systems + Average Health-Based EPA Violations in Public Water Systems + Average EPA Monitoring, Reporting, and Other Non-Health-Based EPA Violations in Public Water Systems + DTSC_DW/6) / Population of Water Service Areas) * 1000

Table A2: Coefficients from the Regression of the Average Drinking Water Contaminant Concentration Index (DWCCI) (1998-2003) on Selected Demographics (2000) of 28 Water Service Areas in the Delta-Suisun Region

Independent Variables	Class, Race, Ethnicity Model	Communication Model
% Below Poverty Level	-0.095*	-0.099*
	(0.034)	(0.036)
% Black or African American	-0.147**	-0.145**
	(0.041)	(0.042)
% Native American	0.433	0.382
	(0.434)	(0.453)
% Asian/Pacific Islander	0.091*	0.085
	(0.038)	(0.041)
% Hispanic or Latino	0.066**	0.054
	(0.018)	(0.029)
% Linguistically Isolated Households		0.052
		(0.103)

Table A2: Coefficients from the Regression of the Average Drinking Water Contaminant Concentration Index (DWCCI) (1998-2003) on Selected Demographics (2000) of 28 Water Service Areas in the Delta-Suisun Region		
Constant	-2.091**	-1.979**
	0.641	0.689
R-Squared	0.653	0.657
Adjusted R-Squared	0.574	0.559
F-Statistic	8.2806***	6.7111***
	N=28	N=28
Note: Standard errors in parentheses		
* Significant at the p <.05 level; ** Significant at the p < .01 level; *** Significant at the p < .001 level		

The table shows that, once again, race matters again: on average and when controlling for percent below poverty level, percent Black or African American, and percent Native American; a percent increase in Asian/Pacific Islander and in percent Hispanic or Latino is statistically significantly associated with a percent increase in the average drinking water contaminant concentration levels of water service areas in the Delta-Suisun region. Curiously, on average and when controlling for other demographics in the analysis, a percent *decrease* in percent below poverty level and in percent Black or African American are associated with percent increases in average drinking water contaminant concentration levels. This suggests that as we add the linguistic isolation measure to the analysis, we see that linguistic isolation, on average and when holding all other variable constant in the table, becomes a statistically significant predictor of poor drinking water quality for water service areas in the Delta-Suisun region. In addition, the significance level for percent Hispanic or Latino and percent Asian/Pacific Islander go away. This finding, paired with the finding about percent below poverty and percent Black or African American suggests households that are linguistically isolated (and most likely speak Spanish or some Asian American or Pacific Islander language) may be those most disproportionately at risk to poor drinking water quality in the Delta-Suisun region.[548] Like the regression results in the previous section, this statistical test used a small sample size of only 28 water service areas. Again, we were conservative and chose to only report significant levels for our coefficients at the .05 level or higher.

[548] Once the recent immigrant variable was added to the model, the significance of each variable decreased to not be statistically significant.

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Attachment 2 - Estimating Costs of BDCP Alternatives

BDCP's economic analysis has not presented such an analysis, but it provides the building blocks for it in Table 9.A-2 above. This table shows at the bottom that the "existing" high and low-outflow scenarios are assumed to yield total average annual water deliveries of 3.446 million acre-feet and 3.889 million acre-feet, respectively. The differences between these levels are due to divergent Decision Tree results. Note too that the range of average annual water deliveries of the proposed scenarios and the other alternatives to take are between 3.399 and 5.591 million acre-feet. These represent levels of "preserved water supplies" resulting from the Twin Tunnels, and are thus the difference between these "existing" high and low outflow scenario exports without the Twin Tunnels and the exports expected under the high and low outflow BDCP proposed actions, which include the Twin Tunnels. That difference may be used to calculate the annualized cost of water for purposes of comparison.

Using data and financial assumptions employed in BDCP's analysis of bond financing, Table 6 shows compares a number of incremental cost scenarios for water with and without the proposed Twin Tunnels and for both outcomes of the Decision Tree. This table illustrates the strong effect that baseline water export assumptions have on the perception of BDCP new water costs. First, it presents two "without Tunnels" scenarios, the "Existing Conditions" and "No Action Alternative" from the BDCP Environmental Impact Report/Statement (EIR/S). No capital costs of BDCP are associated with these two alternatives.

Where costs are indicated in Table A2-1, they represent the incremental cost of Twin Tunnels water averaged across all water contractors, regardless of sector (i.e., urban and agricultural water contractors).

BDCP's High Outflow scenario (in Table A2-1) "preserves" a Delta exports level of about 1.26 million acre-feet annually over the "Existing" no-BDCP high-outflow exports scenario (comparing columns B and C) at a per acre-foot annualized cost of $723. The BDCP Low Outflow scenario represents a 1.70 million acre-foot annual average increase over its "Existing" no-BDCP exports scenario at a per acre annualized-foot cost of $536. The difference between these two incremental costs is $187 per acre-foot. This figure represents the cost difference to the Twin Tunnels' Applicants of "winning" or "losing" the Decision Tree processes. Put another way, there is a $187 per acre-foot incentive (i.e., a cost savings of $187 per acre-foot) for the Applicants to have the incidental take permits implement the Low Outflow Scenario. [compare with Rodney T Smith's Hydro Wonk numbers.]

Table A2-1 also shows that several moderate and low-export Twin Tunnels project scenarios become infeasible if lower and very plausible estimates of "preserved" export levels are used. If the existing modeled water cost of the biological opinions is subtracted from average south-of-Delta exports the last 15 years or so, the future without Twin Tunnels' exports could average about 4.66 million acre-feet. This "preserves" about 45,000 acre-feet worth of exports. ***At that reduced level of "supply preservation" the incremental cost of Twin Tunnels water skyrockets from $723 to over $20,200 per acre-foot.*** Other scenarios fail to preserve exports and become infeasible as a result (that is, they have negative incremental costs). In **Table X**, the low outflow (that is, high average exports of 5.591 million acre-feet per year) without-Twin-Tunnels scenario would have an annualized cost per acre-foot of about $979. This is nearly twice the per unit cost of water from the Twin Tunnels project using BDCP assumptions for future exports.

Table A2-1
Sensitivity of Twin Tunnels Costs
to Alternative Increments of "Preserved" Delta Export Levels

Scenario	BDCP Proposed Action Costs ($Millions)	Annualized Capital Cost of Twin Tunnels ($ Millions) (A)	Average Annual BDCP Proposed Action South of Delta Exports (MAF) (B)	Average Annual BDCP "Existing Scenario" South of Delta Exports (MAF) (C)	Annualized Cost per Acre-foot of Delta Exports Under BDCP Assumptions($/AF) (D = A/(B-C)]	Average Annual South of Delta Exports Status Quo (MAF) (E)	Annualized Cost of Delta Exports Preserved Under Status Quo ($/AF) [F = A/(B-E)}
1. Existing Conditions	$0	$0	5.100	NA	NA	NA	NA
2. No Action Alternative	$0	$0	4.400	NA	NA	NA	NA
3. High Outflow BDCP Twin Tunnels	$13,472	$910	4.705	3.446	$723	4.660	$20,232
4. Low Outflow BDCP Twin Tunnels	$13,487	$911	5.591	3.889	$536	4.660	$979
5. Alternative 4 - Tunnel & Through-Delta	$13,472	$910	4.400	3.889	$1,782	4.660	($3,502)
6. Alternative 8 - Tunnel & Through-Delta	$13,472	$910	3.100	3.889	($1,154)	4.660	($584)

Source: Draft Bay Delta Conservation Plan, November 2013; Dayflow. State Water Resources Control Board, *Comments on the Second Administrative Draft Environmental Impact Report/Environmental Impact Statement for the Bay Delta Conservation Plan*, July 5, 2013, Attachment 2. Annualizing assumptions: Bond term = 40 years; interest rate = 6.133 percent per annum. "AF" = acre-feet; "MAF" = million acre-feet. Negative cost figures mean project would be infeasible. Cost figures include capital costs, but annualized capital cost includes interest in annual payment. Both Twin Tunnels scenarios include "through Delta" operation of South Delta pumps.

Suppose the Twin Tunnels project was built, but the Applicants also won their "bet" that regulators would protect the Bay-Delta Estuary to recover listed fish species and protect them as public trust resources: If it was constructed but forced to operate with regulations fully protecting the estuary over Delta exports the State Water Board projected in its Alternative 8 scenario that full protection for the Bay-Delta estuary would result in average annual exports of just 3.1 million acre-feet.[549] The negative incremental cost of water signals the project would quickly become a bad investment in

[549] See footnote 200, above; and BDCP EIR/EIS, Executive Summary, Table ES-11.

that future scenario. Under this circumstance, Table X indicates that the Twin Tunnels would become a stranded asset.

At these incremental cost levels for Twin Tunnels' new water, there will be strong economic incentive for regulators, water contractors, and the owners of the state and federal projects to have the scientific research in the Decision Tree processes come down on the side of low outflow and high exports in order for the Twin Tunnels reduce risk and uncertainty.

The need to make an expensive investment in the Twin Tunnels could create a compelling incentive on the part of water contractors and regulators (both the fishery agencies and the State Water Resources Control Board) alike to avoid protecting the Bay-Delta Estuary. Protecting the Estuary would be contrary to the exposed financial position of water contractors and bondholders. Regulators would be exposed to intense political pressure to support policies that protect these financial commitments, likely at the Bay-Delta Estuary's expense. ***Such a situation would place water and species protection policies for the Delta Estuary secondary to the financial obligations of Twin Tunnels' Applicants.***

In sum, the "business case" for the Twin Tunnels project (CM1) erodes rapidly when other plausible scenarios for future Delta export levels are applied to project incremental cost calculations, such as when continuation of annual export levels under the current biological opinions are used as the baseline to evaluate the project's cost and feasibility. The analysis in **Table XX** shows that there is tremendous uncertainty about the incremental cost of the Twin Tunnels project given risks associated with the future of Delta export levels. The pressure to undertake such a risky investment —and make it pay off—will be intense.

The following Environmental Water Caucus affiliated organizations support the comments and recommendations shown in the attached letter.

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Abstract:
We used the UnTRIM San Francisco Bay–Delta hydrodynamic model to examine the spatial distribution of salinity as a function of freshwater flow in the San Francisco Estuary. Our particular focus was the covariation of flow with the spatial extent of the low-salinity zone (LSZ: salinity = 0.5 to 6), and with the extent of habitat for common species of -nekton as defined by their salinity ranges. The UnTRIM model has an unstructured grid which allowed us to refine earlier estimates of the availability of suitable salinity ranges, particularly for species resident in low salinity. The

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response of the salinity field to flow was influenced by the bathymetry of the estuary. Area and volume of the LSZ were bimodal with X2, the distance up the axis of the estuary to a near-bottom salinity of 2, roughly the middle of the LSZ. The smallest area and volume occurred when the LSZ was in the Delta or Carquinez Strait, moderate values when it was in Suisun Bay, and the highest values when it was in broad, shallow San Pablo Bay. Resource selection functions for the distributions of common nekton species in salinity space were up-dated from previous values and used to calculate salinity-based habitat indices using the UnTRIM results. These indices generally increased with decreasing X2 (increasing flow), but the slopes of these relationships were mostly inconsistent with corresponding relationships of abundance to flow. Thus, although the salinity range used by most nekton expands as flow increases, other mechanisms relating population size to flow are likely more important than the physical extent of suitable salinity.

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SAN FRANCISCO ESTUARY & WATERSHED SCIENCE
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Variation of Fish Habitat and Extent of the Low-Salinity Zone with Freshwater Flow in the San Francisco Estuary

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ABSTRACT

We used the UnTRIM San Francisco Bay–Delta hydrodynamic model to examine the spatial distribution of salinity as a function of freshwater flow in the San Francisco Estuary. Our particular focus was the covariation of flow with the spatial extent of the low-salinity zone (LSZ: salinity = 0.5 to 6), and with the extent of habitat for common species of nekton as defined by their salinity ranges. The UnTRIM model has an unstructured grid which allowed us to refine earlier estimates of the availability of suitable salinity ranges, particularly for species resident in low salinity. The response of the salinity field to flow was influenced by the bathymetry of the estuary. Area and volume of the LSZ were bimodal with X2, the distance up the axis of the estuary to a near-bottom salinity of 2, roughly the middle of the LSZ. The smallest area and volume occurred when the LSZ was in the Delta or Carquinez Strait, moderate values when it was in Suisun Bay, and the highest values when it was in broad, shallow San Pablo Bay. Resource selection functions for the distributions of common nekton species in salinity space were updated from previous values and used to calculate salinity-based habitat indices using the UnTRIM results. These indices generally increased with decreasing X2 (increasing flow), but the slopes of these relationships were mostly inconsistent with corresponding relationships of abundance to flow. Thus, although the salinity range used by most nekton expands as flow increases, other mechanisms relating population size to flow are likely more important than the physical extent of suitable salinity.

KEY WORDS

Salinity, habitat, fish, freshwater flow, resource selection function, delta smelt, longfin smelt, striped bass, threadfin shad

INTRODUCTION

Salinity is crucial in determining the distributions of nearly all species that inhabit estuaries. Although salinity (or conductivity) is but one of many attributes that define habitat, most estuarine species are abundant within a limited range of salinity. As this salinity range moves with freshwater and tidal flows, attributes of this habitat may change, including its spatial extent, local bathymetry, exchange processes, and biotic interactions. These changes may, in turn, alter population dynamics of the species so as to cause abundance to covary with freshwater flow on

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an annual time scale (Kimmerer 2002b). Here we ask how the extent of habitat defined by salinity varies with freshwater flow, and whether this covariation may cause variation in abundance with flow.

A river-dominated estuary can be considered an ecocline with two ecotones, i.e., ecosystem properties such as species composition vary slowly with salinity within the gradient but the ends of the gradient can be a sharp barrier for both freshwater and marine species (Attrill and Rundle 2002; Greenwood 2007). Efforts to classify estuarine salinity ranges into discrete units on the basis of distributions of biota, beginning with the Venice classification system, have met with mixed success (Bulger et al. 1993, Greenwood 2007). Nevertheless, many such systems identify a low-salinity or oligohaline zone as an important region for a variety of physical, chemical, and biological properties (Postma and Kalle 1955; Morris et al. 1978; Baross et al. 1994; North and Houde 2003). Influences of freshwater flow on the biota of estuaries often occur indirectly through the response of salinity and its covariates. For example, salinity stratification can stimulate primary production (Cloern 1984). Shifts in the salinity field can alter the distribution and abundance of benthic filter feeders, resulting in variation of phytoplankton with flow (Nichols 1985; Wilber 1992). In addition the distributions of marsh and submerged plants can shift during long periods of altered salinity (Watson and Byrne 2009).

The salinity field of a tidal estuary with strong river flow is influenced by freshwater flow into the estuary, and by mixing processes that lead to salt intrusion from the ocean. These mixing processes include tidal dispersion (Zimmerman 1986) and gravitational circulation (Monismith et al. 2002). The relative strength of each of these processes varies spatially because of the spatially variable bathymetry of the estuary, and it varies in time and space depending on the location and movement of salinity gradients (Gross et al. 2010). In the vertical direction, turbulent mixing is the dominant mixing process and it interacts strongly with gravitational circulation (Monismith et al. 2002). The result of the interplay between net seaward advection by tributary inflows and horizontal and vertical mixing processes is a complex and time-varying circulation and salinity field that can include both stratified and vertically well-mixed conditions at different times and locations.

The spatial distribution of salinity in a river-dominated tidal estuary is, therefore, difficult to determine using monitoring data alone. This is clearly the case in the San Francisco Estuary (estuary), with its long records of salinity measurement. Continuous monitoring gives good temporal resolution but poor spatial resolution, and measurements can vary with small differences in positions of the sensors. Vessel-based sampling confounds space and time and usually results in a relatively small number of measurements. Although continuous spatial records have been taken (e.g., Powell et al. 1989), they have proved difficult to interpret and have not contributed much to knowledge about the estuary.

Three-dimensional (3-D) hydrodynamic models provide an alternative means to determine patterns of salinity in an estuary. Field measurements are used for calibration but otherwise the model can be run independently of measurements if suitable boundary conditions are available. If the model is calibrated over the range of salinity conditions in the region of interest, the salinity predictions should be as accurate as the calibration.

Previously we used the 3-D version of the TRIM model (Casulli and Cattani 1994; Gross et al. 2010) to examine salinity distributions in the estuary and in particular how the availability of habitat for various species of nekton, based on salinity and depth, varied with freshwater flow (Kimmerer et al. 2009). The principal conclusion was that increases in the extent of this habitat with flow were probably unrelated to increases in population size of most of the species examined. At that time, the TRIM model was the best-calibrated 3-D model of the estuary, but it lacked resolution in narrow channels and represented most of the Sacramento–San Joaquin Delta as a pair of shallow tidal lagoons. This was a drawback for analyzing the habitat of fish species that spend much of their time in freshwater.

In this paper we re-examine the distribution of salinity in the estuary using UnTRIM (Casulli and

Zanolli 2002, 2005), a successor to TRIM that uses an unstructured grid and is therefore capable of representing the network of narrow channels in the Delta. This model has been implemented and calibrated for the Estuary and used in several management-related applications (MacWilliams et al. 2008, unpublished). We ran the model with nine different steady values of Delta outflow, supplemented with output from a 3-year period from April 1994 through March 1997 that included the calibration period (MacWilliams et al. unpublished). Our particular focus was on the low-salinity zone (LSZ), defined here by a salinity range of 0.5 to 6 (Practical Salinity Scale), because of its importance as habitat for delta smelt (Bennett 2005) and because it has been the focus of numerous studies of circulation, organism retention, and plankton dynamics (e.g., Arthur and Ball 1979; Burau 1998; Kimmerer et al. 1998, 2012). We asked how the spatial extent (volume, area, depth) of this zone varied with flow, and whether a better-defined and more extensive analysis of the extent of the salinity ranges of various nekton species would cause us to alter our earlier conclusions (Kimmerer et al. 2009).

We use X2, the distance in km up the axis of the estuary to a near-bottom tidally averaged salinity of 2, as a measure of the physical response of the estuary to freshwater flow. X2 is related to abundance indices of several estuarine nekton species (Jassby et al. 1995; Kimmerer 2002a). The LSZ is centered at a salinity of about 2; thus, X2 is a measure of the position of the LSZ. However, it is important to distinguish between the LSZ as a particular habitat and the numerical value of X2 as a measure of the wide variety of the physical responses of the estuary to flow (Kimmerer 2002b). In particular, abundance of various fish species may respond to X2 or its correlates through mechanisms that are not directly related to LSZ characteristics (Kimmerer 2002b; Kimmerer et al. 2009).

This paper examines the distribution of salinity from several perspectives. We examined the influence of both steady and time-varying flows on the area and volume of the LSZ. Steady flows used to set up this analysis were based on values for summer–fall (July through October) because of current interest in this period in the life cycle of delta smelt (Bennett 2005), but the results apply to the range of flows regardless of season. We also refined the previous analyses of the relationship of resource selection functions to flow and X2 (Manly et al. 2002; Kimmerer et al. 2009) using the finer resolution provided by UnTRIM to investigate the low-salinity end of the system. We analyzed data for species included in the previous study (Table 1), selected because they are abundant or because they have relationships of abundance to X2 as described in Jassby et al. (1995) and Kimmerer et

Table 1 Species analyzed with sampling programs that provided data for each of the habitat indices, and months included in each analysis. Sampling programs are: the 20mm survey (20mm, Dege and Brown 2004), Summer Townet Survey (TNS, Turner and Chadwick 1972), Fall Midwater Trawl Survey (FMWT, Moyle et al. 1992), and the San Francisco Bay Study midwater trawl (Bay MW) and otter trawl (Bay OT, Armor and Herrgesell 1985).

Common name	Scientific name	Sampling program	Months
Bay shrimp	*Crangon franciscorum*	Bay OT	May–Nov
Starry flounder	*Platichthys stellatus*	Bay OT	May–Nov
Northern anchovy	*Engraulis mordax*	MWT, Bay MW	Sep–Dec, Apr–Nov
Longfin smelt	*Spirinchus thaleichthys*	MWT, Bay MW	Sep–Dec, May–Dec
Delta smelt	*Hypomesus transpacificus*	20mm, TNS, MWT	Mar–Jul, Sep–Dec
American shad	*Alosa sapidissima*	MWT, Bay MW	Sep–Dec , May–Nov
Threadfin shad	*Dorosoma petenense*	20mm, TNS, MWT	Mar–Jul, Jun–Aug, Sep–Dec
Striped bass	*Morone saxatilis*	20mm, TNS, MWT, Bay MW, Bay OT	Mar–Jul, Jun–Aug, Sep–Dec, May–Dec

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al. (2009). In this study we included threadfin shad, which could not be analyzed before because its habitat is mainly in freshwater, and omitted Pacific herring, which lacks a significant relationship with X2.

METHODS

Model Summary

UnTRIM (Casulli and Zanolli 2002, 2005) is an extension of the 3-D hydrodynamic model TRIM, which has been widely used in the estuary and elsewhere (Gross et al. 1999, 2010; Kimmerer et al. 2009). UnTRIM uses an unstructured grid, which has several advantages over the Cartesian grid used in TRIM. The grid can be made finer to resolve narrow channels and other small features of interest and coarser elsewhere, focusing computer resources where they are needed. Grid cells can be oriented along the axes of sinuous channels, making the model's representation of spatially continuous flow more accurate. In addition, grid cells can be made narrow enough to represent even small channels with at least a few rows of cells, improving accuracy in narrow channels.

The UnTRIM Bay–Delta model represents the entire San Francisco Estuary from the landward reaches of the Sacramento–San Joaquin Delta to the Gulf of the Farallones (MacWilliams et al. unpublished). In our application of the model, the grid is coarse in the ocean and gradually becomes finer, with the finest resolution in the Delta. The model has been calibrated using water level, velocity, flow, and salinity data collected throughout the estuary (MacWilliams et al. 2008, unpublished). The calibration period of April 1994 through March 1997 was selected because substantial field data on salinity and velocity were available from the Entrapment Zone study (Burau 1998; Kimmerer et al. 1998, 2002; Bennett et al. 2002). This period also encompassed a wide range of freshwater flows, from daily Delta outflow of 20 $m^3 s^{-1}$ in October 1994 to 11,500 $m^3 s^{-1}$ in March 1995.

Following the approach used by Kimmerer et al. (2009), nine steady outflow scenarios were simulated that spanned a range of outflows. Six flows were selected to achieve an approximately even distribution of calculated X2 values, resulting in a roughly log–equal interval of flow spanning 100 to 2,810 $m^3 s^{-1}$. Three additional intermediate flow values (140, 265, and 520 $m^3 s^{-1}$) were added to better represent changes in salinity-based habitat as a function of X2 through Suisun Bay (Table 2). The lowest flow is in the 12th percentile of daily flows from the DAYFLOW[1] data set from water years 1956 through 2011 and the 17th percentile of dry-season (May through November) flows. The high flow is in the 94th percentile of flows for the whole year and the 99.5th percentile of dry-season flows. The times to reach steady state in these model runs were inversely related to outflow (Table 2).

Table 2 Outflow and steady-state X2 for each constant flow scenario and the time (d) for X2 to move halfway from an initial position to its steady-state value.

Outflow ($m^3 s^{-1}$)	X2 (km)	T1/2
100	89.8	25.4
140	84.8	23.1
190	79.4	22.8
265	72.8	18.3
370	67.4	14.6
520	62.5	9.4
730	57.9	7.0
1440	50.6	4.3
2810	42.7	2.1

Boundary Conditions

MacWilliams et al. (unpublished) describe all of the boundary conditions used in the UnTRIM Bay–Delta model. The discussion here summarizes the boundary conditions specific to the steady outflow scenarios. These were designed to use repeating conditions over each day, eliminating the need to average over the spring–neap tidal cycle to represent steady-state conditions. We used a constant salinity of 33.5 at

1 DAYFLOW is a DWR developed program to estimate average daily flows for the Delta and its tributaries through measurements and calculations *http://www.water.ca.gov/dayflow/* [accessed 30 April 2011].

Table 3 Inflows ($m^3 s^{-1}$) from each river for each steady outflow scenario. All values based on DAYFLOW.

	Outflows ($m^3 s^{-1}$)								
River flows	**100**	**140**	**190**	**265**	**370**	**520**	**730**	**1440**	**2810**
Cosumnes	0.8	0.8	0.9	1.1	1.3	1.5	1.9	3.2	5.8
Calaveras	4.0	4.4	4.9	5.7	6.7	8.2	10	17	31
Mokelumne	6.8	7.5	8.4	9.6	11	14.0	18	30	54
Sacramento	332	364	405	467	553	676	848	1431	2555
San Joaquin	56	62	69	79	94	115	144	244	435
Yolo	4.6	5.0	5.6	6.5	7.6	9.3	12	20	35
Total inflow	404	444	494	569	674	824	1034	1744	3114

the ocean boundary and a repeating daily tide comprising the M2 lunar semidiurnal tidal component modified to a 12-hr period and the K1 lunar diurnal component modified to 24 hr. These were phased such that lower low water followed higher high water as in the estuary. Wind and evaporation also varied repetitively over each 24-hr period to represent the average summer daily pattern of meteorological conditions. Historical data from July through October during water years 1980 through 2010 were used except as noted below. Output from the DAYFLOW program for July through October during water years 1980 through 2010 was used to calculate the proportion of total inflow from each river (Table 3), the long-term mean export rate (237 $m^3 s^{-1}$), and the proportion of total water exports attributable to each export facility (Table 4). Export rates for the Contra Costa Water District diversion were apportioned between the Rock Slough (39%) and Old River (61%) intakes. Delta Island Consumptive Use (DICU) was determined for the same period for each of 257 DICU nodes, with a total net withdrawal of 67 $m^3 s^{-1}$. For all scenarios, Delta exports and DICU remained constant, and inflow was calculated to achieve the target outflow. Mean discharges of streams flowing directly into the estuary west of the Delta were estimated from available gage data from July through October of 1990 through 2010, adjusted by the ratio of total-to-gaged watershed area of each stream. The total of these inflows was 6.9 $m^3 s^{-1}$, about 94% of which flows into South Bay and most of the remainder into San Pablo Bay.

Table 4 Average Delta export flows for July through October of water years 1980 to 2010 used in the steady-flow scenarios. Export flows are for water pumped out of the Delta for agricultural and municipal uses.

Export facility	**Average flow ($m^3 s^{-1}$)**	**Percent (%) contribution**
State Water Project	121	51
Central Valley Project	110	46
Contra Costa Water District	5.5	2.3
North Bay Aqueduct	1.7	0.7
Total export flow	237	

For the steady outflow scenarios, we assumed typical summer operating conditions for all control structures in the Delta. The Delta cross-channel and Suisun Marsh salinity control gate were open; the barrier at the head of Old River was open; and the three temporary barriers on Grant Line Canal, Middle River, and Old River at the Delta–Mendota Canal were in place with culverts and weirs operating under typical summer configurations.

Model Runs and Analysis

For each steady flow, the model was run for 180 days to reach steady state. X2 for each steady flow was determined from the distribution of bottom salinity during the steady-state run. Model results were averaged over the last day of each simulation. The distributions of salinity and depth in each of six model regions (one region—the ocean—was not used in most of the calculations) were summarized from

the model as matrices of surface area in the region for each combination of 80 bins of salinity and 56 bins of depth. Salinity bins were in increments of 1 above 5, and 0.1 below 5. Depth bin increments were 1 m from 0 to 40 m (encompassing 97% of the volume of the estuary), and 5 m from 40 m to 100 m.

Areas of each bin in the matrix were multiplied by the midpoint depths of the bins to determine volumes which were summed over all depths in the salinity range. To analyze the characteristics of the LSZ, we summed volumes and areas of all cells in San Pablo Bay, Suisun Bay, and the Delta with salinity between 0.5 and 6, and calculated the mean depth as the ratio of volume to area. A similar calculation using model output from April 1994 through March 1997, which included the calibration period, was used to compare the steady-state and time-varying cases. We also developed a hypsograph of area vs. depth for each region at an intermediate flow (370 $m^3 s^{-1}$).

Resource selection functions to estimate area and volume of the salinity ranges used by species of nekton were updated from Kimmerer et al. (2009) using monitoring data through 2010. Briefly, generalized additive models (GAMs) were fit to data on catch per trawl or frequency of occurrence as a function of salinity. GAMs were fit using a loess smoother with degree = 2 and span = 0.5, and either a Poisson (catch per trawl) or binomial (frequency of occurrence) error distribution. In the previous analysis we used depth as a covariate with data from the Bay Study otter trawl (Kimmerer et al. 2009). We did not do so here because that analysis showed effects only in deep, saline waters (Kimmerer et al. 2009) and here we focused more on the freshwater end of the system. We calculated resource selection functions using data from all stations except that data from the 20-mm Survey and Summer Townet Survey (TNS) were restricted to Suisun Bay and the Delta because of limited coverage in San Pablo Bay. Twenty-five bootstrap samples were taken for each resource selection function to allow for approximate error estimates.

Resource selection functions were standardized to the range (0,1) and used as weighting factors with the data on total volume by salinity to calculate salinity-based habitat indices (hereafter, habitat indices) for the entire estuary for each species at each of the nine steady-flow levels. Combinations of species and sampling programs were included only if the sampling programs covered most of the salinity range of the species; for example, northern anchovy collected by the TNS was excluded since most of the fish occur seaward of the region sampled by this program.

The statistic of interest from this analysis was the slope of the relationship between the log of the habitat index and X2. To the extent that this slope matched that of the corresponding relationship of log of abundance index to X2 (Jassby et al. 1995; Table 2 in Kimmerer et al. 2009), the result would support the flow-based change in extent of suitable salinity (the habitat index) as a mechanism for the response of abundance index to flow (under the assumption that population size would scale with area of suitable salinity). A more negative slope for the log abundance–X2 relationship would imply that other mechanisms besides variation in extent of suitable salinity were contributing to the flow response of abundance. A more negative slope for the log habitat–X2 relationship would imply that fish abundance was unresponsive to volume or area of the habitat as defined by the salinity field.

RESULTS

The hypsographs show the predominance of shallow water in all regions of the estuary (Figure 1). The median depth is 6.3 m in Central Bay and < 4 m in the other regions. Even the Delta is predominantly shallow, although the western Delta near the confluence of the Sacramento and San Joaquin rivers is deeper than farther eastward (not shown).

Spatial distributions of salinity with flow (Figure 2) show both the movement of the salinity field and the change in its shape and characteristics. At a low flow of 140 $m^3 s^{-1}$ (X2 = 85 km) the low-salinity zone is in the western Delta, Suisun Bay has salinity up to ~15, and San Pablo to Central Bay are at salinity close to seawater. At a flow of 1,440 $m^3 s^{-1}$ (X2 = 51 km) Suisun Bay is fresh and the LSZ is in the shoals of San Pablo Bay. Although stratification cannot be seen in these maps of depth-averaged salinity, it can be inferred from the higher salinity in channels than

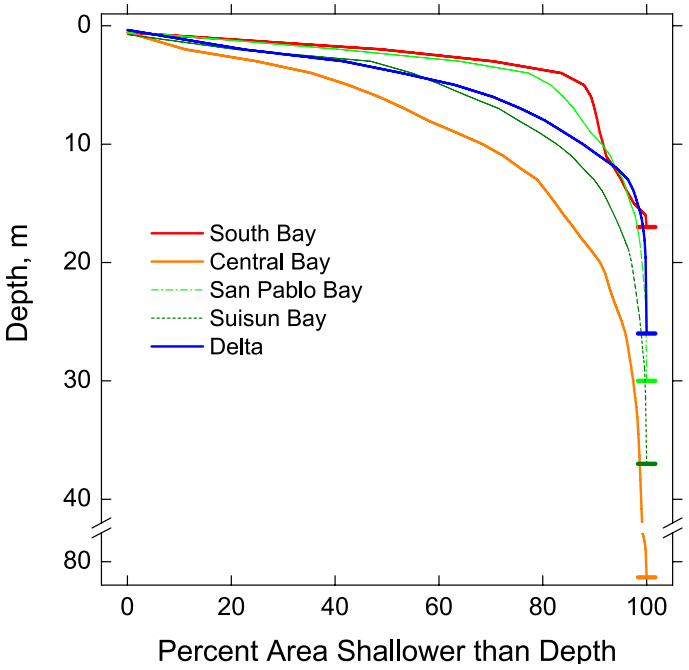


Figure 1 Hypsograph by basin for the San Francisco Estuary, giving cumulative percentage of area deeper than each 0.1-m increment of depth below the NAVD88 datum

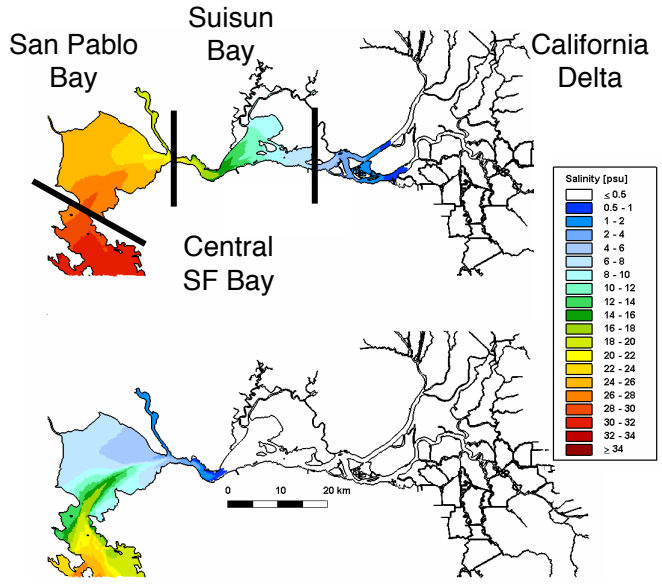


Figure 2 Maps of the northern San Francisco Estuary showing regions and boundaries (black lines). Modeled depth- and daily-averaged salinity for two steady flow scenarios. **Top**: 140 $m^3 s^{-1}$. **Bottom**: 1,440 $m^3 s^{-1}$, close to the 20th and 80th percentiles, respectively, of monthly mean Delta outflow from water years 1956 through 2011.

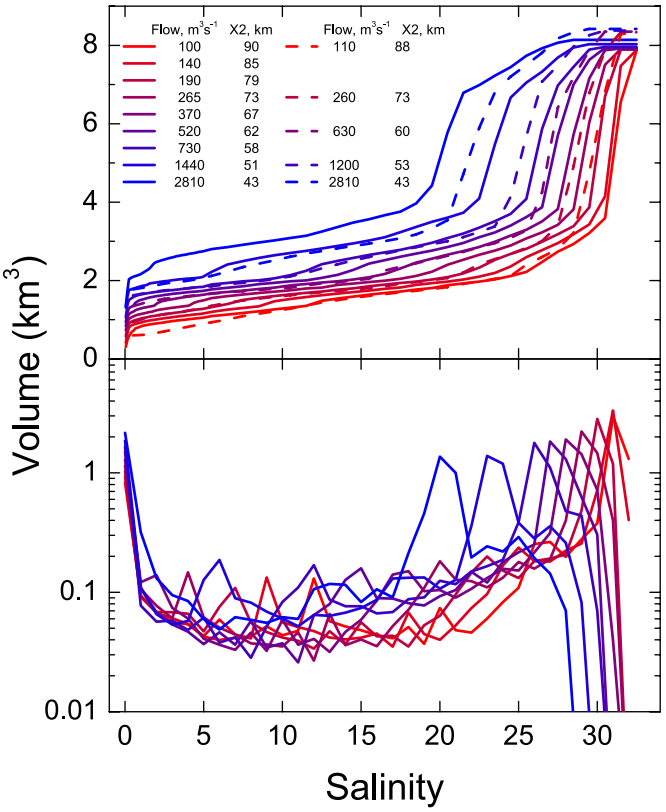


Figure 3 **Top:** cumulative volume by salinity bin from the UnTRIM model at 9 steady flows (solid lines) and the TRIM model at 5 steady flows (dashed lines). **Bottom:** volume by salinity in increments of 1 unit from UnTRIM. Flows and corresponding X2 values are color-coded with red representing the driest and blue the wettest conditions. Volumes are relative to mean sea level, binned according to water-column mean salinity. Lines for TRIM results have an additional volume of 0.6 km^3 added to account for the unresolved portion of the Delta, assumed to be freshwater.

adjacent shoals in southern San Pablo Bay during the high-flow period.

The distribution of volume by salinity throughout the estuary (Figure 3) reveals several key features using both the UnTRIM results and our previous results with TRIM. First, the largest part of the total volume of the estuary is in deep channels of Central Bay, indicated by the peaks in volume in the lower panel of Figure 3. Second, the total volume of the estuary is bimodal with respect to salinity: about half is within 10 of the maximum salinity, 10% to 20% is

fresh, and the remainder is spread over the remaining salinity range. As flow increases the volume of the freshwater pool increases, the maximum salinity in the estuary decreases, and the salinity in the deep channels of Central Bay decreases still further. Third, as flow increases there is no consistent response of volume in salinity between 1 and 10, and a modest increase in volume between 10 and 25. The volume of freshwater grows faster with flow in results using UnTRIM than in those from TRIM because the Delta is fully resolved in UnTRIM.

The distribution of salinity by basin shows the progressive freshening moving down-estuary as X2 decreases (Figure 4). The Delta is essentially freshwater except at very low flows when brackish water intrudes into the western Delta from Suisun Bay. Suisun and San Pablo bays have the widest range of salinity from freshwater during moderate to high-flow periods to polyhaline during low flow periods. Central and South bays have similar salinity patterns consisting primarily of near-oceanic salinity at low to moderate flows with progressive freshening as flow increases.

The relationships of area and volume of the LSZ to flow or X2 are bimodal (Figure 5). As expected, volume and area of the LSZ increase as the LSZ moves from the western Delta (X2 > 75) into the center of Suisun Bay (X2 ~ 65). However, area and volume then decrease as the LSZ moves further westward through Suisun Bay into Carquinez Strait and then increase sharply around X2 < 50 km. Defining the LSZ by bottom salinity instead of depth-averaged salinity makes little difference in these patterns (Figure 5). Mean depth—the ratio of volume to area—shows a roughly inverse pattern to area, which is more variable than volume. The steady-flow and historical model runs corroborate each other at X2 above about 65 km. At higher flows the area and volume of the LSZ vary widely for a given X2 from the historical run, and this variation is greatest and most divergent when X2 is changing rapidly. In addition, there is a sharp discontinuity in area and volume in the historical model output around X2 = 40.

Updated resource selection functions were similar to those developed previously except that the function for threadfin shad was not developed previously (Figure 6). This shows that threadfin shad is the most freshwater-oriented species of the abundant species in the data set. In many cases the resource selection functions based on catch were more tightly confined to a salinity range than those based on frequency of occurrence because of the occasionally high catches in that salinity range.

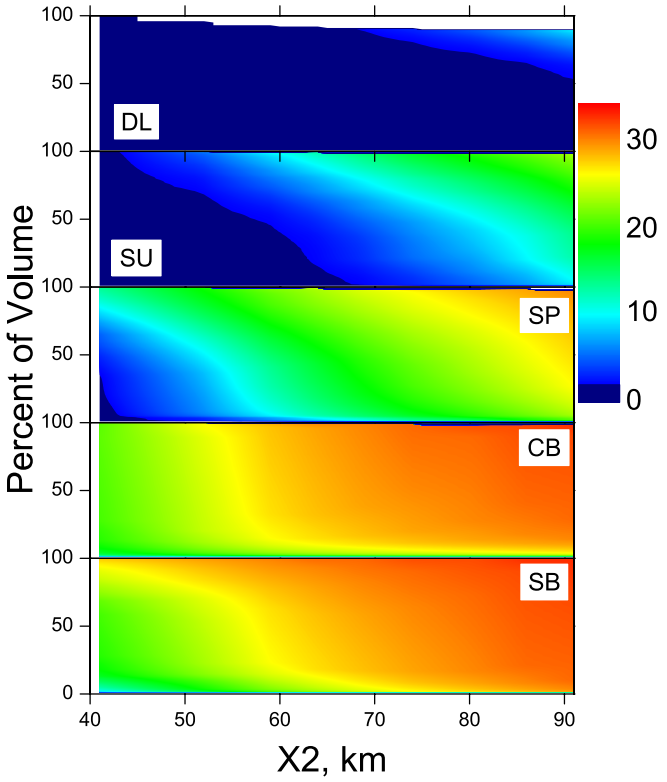


Figure 4 Volume in each region (as percent of the maximum total volume in that region) by X2 with contours indicating depth-averaged salinity. Regions are from northeast to southwest: Delta (DL), Suisun Bay (SU), San Pablo Bay (SP), and Central (CB) and South (SB) San Francisco bays.

Examples of the relationships of salinity-based habitat volume to X2 show a reasonably tight fit (Figure 7). Error bars based on bootstrap resampling of the raw data used to develop the GAM curves were small relative to variability across X2 values for most species.

We compared the slopes of log-transformed habitat volume vs. X2 (examples in Figure 7) to corresponding slopes of log abundance vs. X2 simply by

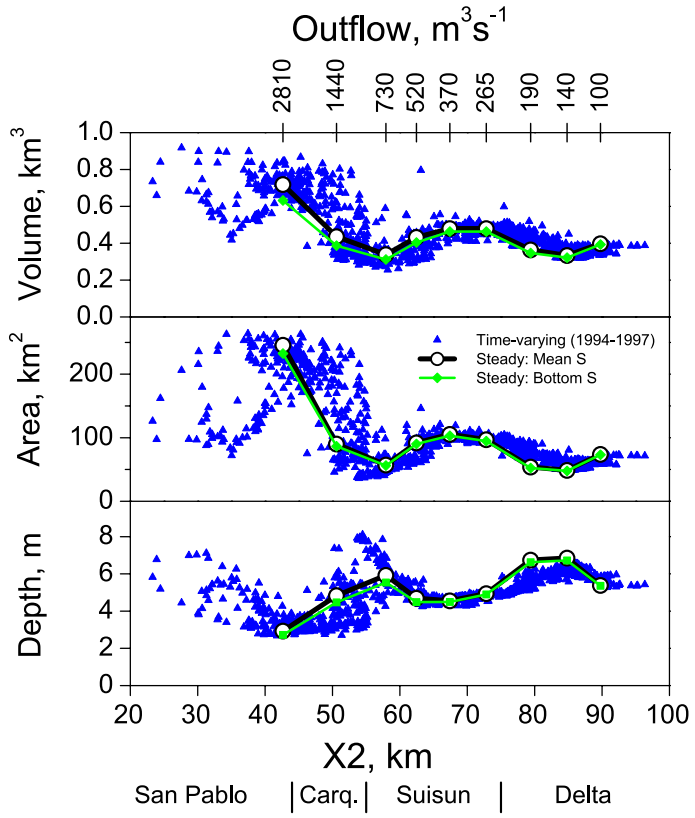


Figure 5 Volume, area, and mean depth (volume * 1000/area) of the Low-Salinity Zone (salinity 0.5 to 6) vs. X2 from the UnTRIM model under nine steady flow scenarios using water-column mean (open circles) or bottom (closed diamonds) salinity. Also shown are daily values based on variable flows during April 1994 through March 1997 (triangles; MacWilliams et al. unpublished). Upper axis gives the Delta outflow corresponding to flow boundary conditions used in the model. Regions of the estuary are indicated at the bottom.

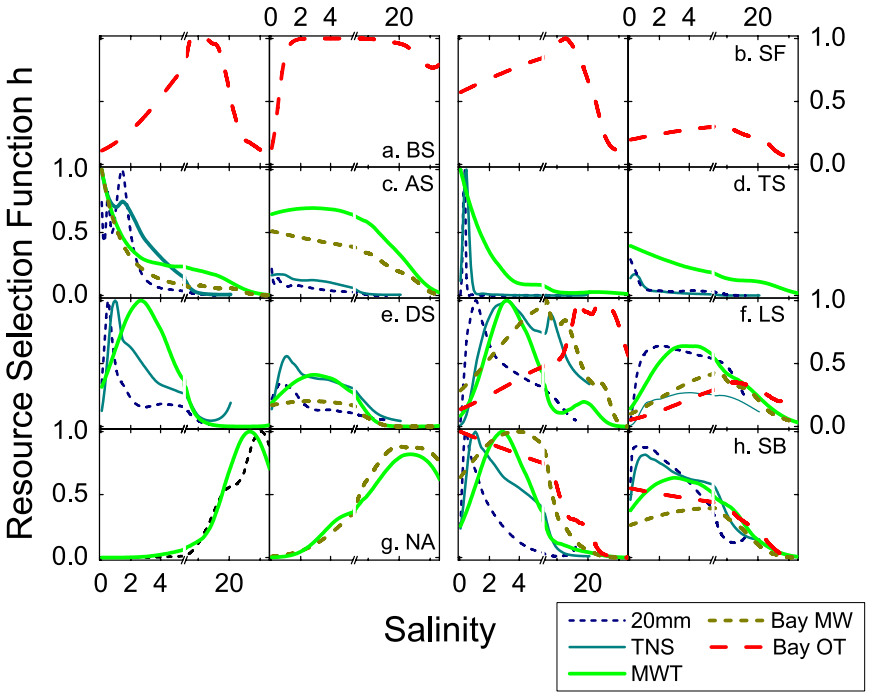


Figure 6 Resource selection functions for abundant species in each of the five sampling programs. The x axis has been broken to emphasize patterns at S < 5.5. Each pair of panels includes lines for a single species based on catch per trawl (left) and frequency of occurrence (right). Species are: a, bay shrimp; b, starry flounder; c, American shad; d, threadfin shad; e, delta smelt; f, longfin smelt; g, northern anchovy; h, striped bass. Sampling programs (legend) are the 20mm Survey, the Summer Townet Survey (TNS), the Fall Midwater Trawl Survey (FMWT), the Bay Study midwater trawl (Bay MW), and the Bay Study otter trawl (Bay OT).

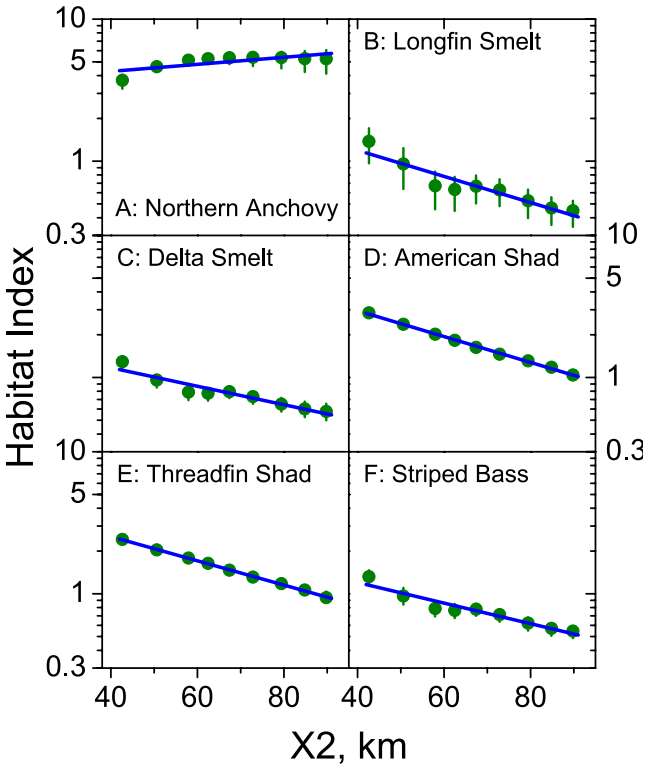


Figure 7 Examples of relationships between X2 and habitat indices. These are for catch per trawl in the Fall Midwater Trawl Survey with salinity averaged through the water column. Each point is the volume by salinity bin, weighted by the resource selection function (Figure 6). Error bars are ranges of each habitat index determined from bootstrap sampling (N = 25) of the raw data in producing the resource selection functions. Lines are least-squares fit to the log-transformed data.

determining whether the habitat slopes fell in or out of the 95% confidence limits of the abundance–X2 slopes (Figure 8). We did not perform statistical tests since the different surveys and different measures (catch vs. frequency of occurrence) have different assumptions and we have no criteria for choosing one over the others. Habitat indices based on the resource selection functions responded to flow as previously observed, i.e., there was a small negative relationship to X2 (positive to flow) for most species in most sampling programs (Figure 7). The principal exception was northern anchovy, because its high-salinity habitat decreases in volume within the estuary as flow increases. Among species known to respond to flow (Kimmerer et al. 2009), habitat–X2 slopes fell within the error bounds of abun-

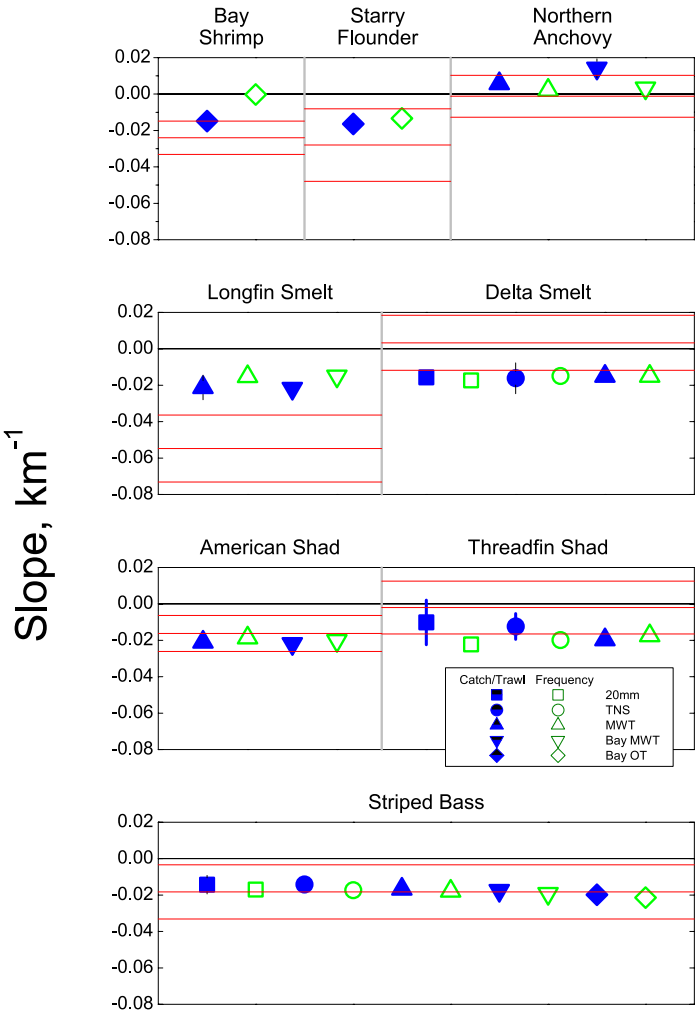


Figure 8 Slopes of relationships between habitat indices based on catch per trawl (blue filled symbols) or frequency of occurrence (green open symbols) vs. X2, from sampling programs indicated by shapes of symbols. The values for catch per trawl from the Fall Midwater Trawl Survey (filled triangles) are the slopes of the lines in Figure 7. Habitat indices were determined by weighting the volume in each salinity interval by the resource selection functions in Figure 6, then calculating total weighted habitat volume for each of the nine steady flows. Confidence limits for slopes of habitat vs. X2 are contained within the symbols except where shown. Red horizontal lines indicate slopes of abundance–X2 relationships with 95% confidence intervals (Kimmerer et al. 2009).

dance–X2 slopes for starry flounder, striped bass, and American shad (Figure 8). Slopes of habitat index to X2 for longfin smelt were much less negative than abundance–X2 slopes. The slopes of habitat index to X2 for delta smelt and threadfin shad were usually lower than the lower 95% confidence limit of the corresponding abundance–X2 relationships, except for those for catch of threadfin shad in the Summer Townet Survey (TNS) and Fall Midwater Trawl Survey (FMWT). Bay shrimp had flatter relationships of habitat index to X2 than abundance to X2.

DISCUSSION

This study may be the first to examine in such detail the distribution of salinity throughout an estuary as a function of freshwater flow, although similar analyses have been conducted for coastal regions (e.g., Lacroix et al. 2004). It is the first to examine the salinity field at sufficient resolution to quantify the extent of suitable salinities for estuarine organisms throughout their ranges. This kind of analysis in a large estuary of complex bathymetry requires the use of a highly resolved hydrodynamic model, because the necessary spatial resolution could not be obtained with any reasonable number of monitoring stations. The excellent calibration of UnTRIM across a wide range of freshwater flows (MacWilliams et al. unpublished) ensures that model results are suitable for this purpose.

All of the figures taken together illustrate the dynamism and complexity of the spatial-temporal distribution of salinity and conditions in the LSZ. The basin-wide distributions of salinity (Figure 4) indicate that at the scale of whole basins the transitions in salinity are smooth, and that both Suisun and San Pablo bays encompass wide ranges of salinity under most flow conditions. The salinity map for high flow (Figure 2 bottom) shows intrusion of saline water into San Pablo Bay, while low-salinity water spreads throughout the shallows. Deep areas are important as conduits for landward movement of high-salinity water and in promoting stratification (Monismith et al. 2002).

Previous views of the relationship of area and volume of the LSZ to X2 have focused on movement of the LSZ into the shallows of Suisun Bay, and a consequent increase in its area and decrease in its mean depth (Cloern et al. 1983). Depth has two key biological consequences. A decrease in mean depth can increase phytoplankton growth rate if turbidity does not change, so that shallow areas can be sources of high phytoplankton productivity (Cloern et al. 1983; Lucas et al. 1999). However, grazing by a given biomass of clams removes a greater fraction of phytoplankton biomass in shallow than in deep water, and, since the introduction of *Potamocorbula*, the relationship of phytoplankton production to depth may be positive or negative (Lucas and Thompson 2012). Phytoplankton primary production and specific growth rate in the LSZ did not change appreciably as flow decreased and X2 moved into central Suisun Bay through spring–summer of 2006–2007 (Kimmerer et al. 2012). Thus, the change in shape of the LSZ with its movement does not appear to result in substantial changes in phytoplankton productivity.

Different estuarine species use shallow and deep habitat differently (e.g., Hobbs et al. 2007; Sommer et al. 2008; Grimaldo et al. 2009). Pelagic organisms orient principally to salinity or its covariates (e.g., turbidity, food availability) and geographic features of the habitat may be less important (Dege and Brown 2004). Benthic or littoral species orient to geographic features and their covariates (e.g., depth distribution, aquatic vegetation), although they may shift positions through movement, or by dying back where salinity becomes unfavorable and colonizing elsewhere. Therefore, movement of a water mass with a given salinity range into a shallow area will alter the feeding and predatory environments for pelagic fish through an increase in average light level in that water mass and changes in the relative abundance of food and predators. Thus it is conceivable, though not actually demonstrated, that some fish species may find more favorable conditions for growth when their salinity range is in a predominantly shallow area.

The possibility of higher fish production in shallow than deep water guided our expectation of an increase in area and volume of the LSZ with decreasing X2. However, the observed relationships were more complex and less monotonic than expected

(Figure 5). As the LSZ moved from the Delta into Suisun Bay, area and volume increased and mean depth decreased as expected. However, further increases in flow moved the LSZ into Carquinez Strait, squeezing the LSZ into narrow, deep channels and increasing its mean depth. At the highest flow, when the LSZ was in San Pablo Bay, the area and volume of the LSZ were substantially higher than when it was in Suisun Bay.

No species of fish occupies the LSZ completely or exclusively, but several are most abundant in the LSZ (Figure 6). If abundance of these fish tracked their available habitat, the relationship of log abundance index to X2 should resemble the graphs of either area or volume vs. X2 (i.e., Figure 5). However, all of the non-zero relationships of log species abundance index to X2 were linear with no indication of a bimodal pattern (Figure 3 in Kimmerer et al. 2009). This may reflect the infrequent occurrence of very low X2 values over long periods in the historical record: daily X2 was <50 km on only 7% of days in January through June of 1967 through 2010. In addition, the months-long averaging periods used in those analyses would have smoothed the X2–abundance relationships. For example, the averaging period used in the X2–abundance relationship for longfin smelt was January through June, over which there were no values <50 km. Nevertheless, the observed X2–abundance relationships are inconsistent with a mechanism that involves extent of low-salinity habitat, which has a strongly nonlinear relationship to X2 (Figure 5).

The steady-state values of area, volume, and depth of the LSZ generally agreed with those based on the 1994 through 1997 historical model simulation (MacWilliams et al. unpublished). The largest differences occurred during large excursions in flow (Figure 5). These differences mainly resulted from the growing responsiveness of the salinity field to flow at higher values of flow, a feature not previously captured in the flow–X2 relationships (Jassby et al. 1995; Monismith et al. 2002; MacWilliams et al. unpublished). There are also differences at lower flow (higher X2) which probably reflect the autocorrelated response of X2 and, therefore, the entire salinity field to unsteady flow.

The refinements provided by UnTRIM include the ability to represent more accurately the movement of water in channels, both because of the smaller cell sizes relative to models with structured grids, and because the cells can be aligned with the principal local axis of the channels. This means that stratification and salt transport should be captured better in UnTRIM than in models such as TRIM. For example, the distribution of salinity in longitudinal profiles is represented considerably better in UnTRIM (MacWilliams et al. unpublished) than in TRIM (Gross et al. 2010; Figures 6 and 7) for similar hydrologic conditions. Nevertheless, it is encouraging that the differences in results of this analysis and those using TRIM (Kimmerer et al. 2009) were fairly subtle. Threadfin shad lives mainly in freshwater regions of the Delta (Figure 6) and could not be analyzed at all using TRIM because of this lack of resolution in the Delta. The other species whose salinity distributions indicated high abundance in freshwater (Figure 6, e.g., delta smelt, American shad, striped bass) had similar slopes of habitat index to X2 to those in the previous analysis except that the values in this analysis varied less across life stages. This likely also resulted from the better resolution in freshwater, since all of these species shift ontogenetically toward brackish water (Figure 6). The slopes for northern anchovy in this analysis were positive, while in the TRIM analysis they were close to zero or slightly negative. This is probably a consequence of better representation of stratification and therefore the geographic distribution of salinity in this analysis than in the previous one (Kimmerer et al. 2009).

The relationships of habitat indices to X2 were remarkably similar among the species with predominantly freshwater or low-salinity affinities (Figure 8). Slopes had 10th and 90th percentiles of −0.1 to −0.22 for species not in the first row of Figure 8. This was a consequence of a general trend toward larger volume of water when volume was weighted using the resource selection functions. This contrasts with the bimodal distribution of volume within the LSZ. These resource–selection functions were either high in freshwater, and therefore responsive to the increase in volume of freshwater with increasing flow; or they were high across a broad range of

salinity, which likely averaged across the pattern observed for the LSZ (Figure 5).

Despite the similarity among the relationships of habitat index to X2, the abundance–X2 relationships (Kimmerer et al. 2009) differed greatly among the species (Figure 8). This finding, together with the lack of correspondence for some species between the habitat–X2 and abundance–X2 relationships (Figure 8), suggest that variation in the volume (or area, not shown) of physical habitat as defined by salinity is not a strong influence on abundance of many of these fish.

The lack of consistent parallels between the availability of salinity-based habitat and abundance could have had several causes. First, our use of salinity as the only variable that defines habitat is clearly inadequate. For example, turbidity is consistently important as a covariate in analyses of delta smelt distributions (Feyrer et al. 2007; Nobriga et al. 2008). Given the difficulty in determining the controls on the delta smelt population, it is not surprising that such a simple descriptor of habitat is inadequate for this species. Threadfin shad is more abundant in clearer water (Feyrer et al. 2009), which may limit its response to increases in freshwater flow and attendant changes in habitat. Other, unmeasured attributes of habitat such as food supply are likely to be important, but were outside the scope of our modeling effort.

Second, the mechanisms relating abundance to X2 may not involve the extent of suitable salinity. For example, longfin smelt are more abundant near the bottom than in the water column at high salinity, but not at low salinity. The mechanism behind this is unknown, but one possible result of this pattern is strong landward movement of the smelt in the deep channels, which may serve to retain the fish against net seaward flow.

As before, striped bass and American shad had relationships of habitat index to X2 that were similar to those for abundance. This is consistent with a mechanism by which abundance responds to quantity of habitat and thereby to flow (Jassby et al. 1995). However, the population of young striped bass does not expand spatially as X2 moves seaward, and several other mechanisms have been proposed for the response of this species to freshwater flow (Kimmerer et al. 2001).

Many aspects of habitat and its response to freshwater flow are missed or ignored by our analysis. As noted above, turbidity is related to abundance or feeding success of many visually-feeding estuarine fishes (e.g., Breitburg 1988; Aksnes and Utne 1997; Feyrer et al. 2007), but we lack a suitable turbidity model. Small-scale features such as fronts and bathymetric discontinuities are often sites of aggregation for fish and their prey (e.g., Cowen et al. 2000), and interactions between the salinity field and these features could be an important feature of habitat. Another important mechanism for the effects of flow on habitat for fish is stimulation of foodweb productivity, for example, through nutrient loading (Nixon 1988) or stratification (Skreslet 1997). Previous analyses have suggested that stimulation of phytoplankton production is an unlikely mechanism for the responses of nekton populations to flow (Kimmerer 2002b).

Despite the complexities, salinity is the most important variable for determining the locations of pelagic estuarine organisms and therefore their physical habitat (Mouny and Dauvin 2002; Jung and Houde 2003; Dege and Brown 2004; Kimmerer 2004). Our findings generally imply that extent of suitable salinity by itself is not a major determinant of the responses of abundance to flow for most of the estuarine species we examined. Dynamic attributes of habitat that vary with flow, such as retention by estuarine circulation or transport to rearing areas, may be more important than quantity of habitat for some fish species.

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Explaining Patterns of Pelagic Fish Abundance in the Sacramento-San Joaquin Delta

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Abstract Investigating the effects of environmental, biological, and anthropogenic covariates on fish populations can aid interpretation of abundance and distribution patterns, contribute to understanding ecosystem functioning, and assist with management. Studies have documented declines in survey catch per unit effort (CPUE) of several fishes in the Sacramento-San Joaquin Delta, a highly altered estuary on the US west coast. This paper extends previous research by applying statistical models to 45 years (1967–2012) of trawl survey data to quantify the effects of covariates measured at different temporal scales on the CPUE of four species (delta smelt, *Hypomesus transpacificus*; longfin smelt, *Spirinchus thaleichthys*; age-0 striped bass, *Morone saxatilis*; and threadfin shad, *Dorosoma petenense*). Model comparisons showed that along with year, the covariates month, region, and Secchi depth measured synoptically with sampling were all statistically important, particularly in explaining patterns in zero observations. Secchi depth and predicted CPUE were inversely related for all species indicating that water clarity mediates CPUE. Model comparisons when the year covariate was replaced with annualized biotic and abiotic covariates indicated total suspended solids (TSS) best explained CPUE trends for all species, which extends the importance of water clarity on CPUE to an annual timescale. Comparatively, there was no empirical support for any other annualized covariates, which included metrics of prey abundance, other water quality parameters, and water flow. Top-down and bottom-up forcing remain important issues for understanding delta ecosystem functioning; however, the results of this study raise new questions about the effects of changing survey catchability in explaining patterns in pelagic fish CPUE.

Keywords Delta and longfin smelt · Sacramento-San Joaquin Delta · Zero-inflated generalized linear models · Water flow · Zooplankton · Water quality

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Introduction

The dynamics of fish populations involve a complex suite of biological processes operating at different temporal and spatial scales. Abiotic and biotic variables modulate the intrinsic biological properties of individual fish species and structure the diversity and abundances of species within ecosystems. Such variables can be ecological, environmental, climatic, and anthropogenic, and they synthetically influence ecosystem dynamics. Ecological variables are often described in the context of bottom-up (Chavez et al. 2003; Frederiksen et al. 2006) or top-down (Cury and Shannon 2004; Hunt and McKinnell 2006) control of food webs, while environmental variables such as temperature, dissolved oxygen, and others have been shown to influence early life history (Norcross and Austin 1988) and the distribution of fishes within ecosystems (Breitburg 2002; Craig 2012; Buchheister et al. 2013). Climate variability can have a multipronged impact, exerting influence on specific life stages, such as the formation of new year classes (Houde 2009), or at the level of individual species (Hare et al. 2010) or whole ecosystems (Winder and Schindler 2004; Drinkwater et al. 2009). Numerous anthropogenic stressors such as pollution, nutrient enrichment and eutrophication, introduction of nonnative species, and perhaps most notably, overexploitation have been documented to influence

ecosystem structure and fish abundance (Islam and Tanaka 2004; Molnar et al. 2008; Diaz and Rosenberg 2008;Worm et al. 2009).

Globally, centuries of anthropogenic change have transformed estuarine and coastal waters into systems with reduced biodiversity and ecological resilience (Jackson et al. 2001; Lotze et al. 2006). Given the importance of these areas to marine life, efforts to remediate the cascading effects of anthropogenic stressors will undoubtedly require deep consideration of principles inherent to ecosystem-based management (EBM; Link 2010). However, before strategic and tactical management policies can be effectively implemented, EBM rooted or otherwise, the relative roles of natural and anthropogenic factors that affect ecosystem structure and associated species abundances must be well understood.

San Francisco Bay is a tectonically created estuary located on the US Pacific coast that has experienced considerable anthropogenic change (Nichols et al. 1986). The bay and its watershed occupies 1.63×10^7 ha and drains 40 % of California's land area (Jassby and Cloern 2000). Freshwater is supplied to the estuary primarily from the Sacramento and San Joaquin rivers, which converge to form a complex mosaic of tidal freshwater areas known collectively as the Sacramento-San Joaquin Delta (referred herein as the delta). Most naturally occurring wetlands in the estuary have been lost due to morphological changes to the system for agriculture, flood control, navigation, and water reclamation activities (Atwater et al. 1979). Other notable changes include modifications to the volume of freshwater entering the delta and thus the natural delivery of land-based sediment (Arthur et al. 1996), massive sediment loading resulting from large-scale hydraulic mining activities (Schoellhamer 2011), introduction and invasion of nonindigenous species (Cohen and Carlton 1998), input of contaminants (Connor et al. 2007), and reported decreases in chlorophyll-*a* (Alpine and Cloern 1992), zooplankton (Orsi and Mecum 1996), and fish catch per unit effort (CPUE; Sommer et al. 2007).

A variety of tools can be used to understand how specific changes to ecosystem components influence fish population dynamics. These include directed field studies, statistical analyses, and multidimensional mechanistic modeling activities, with all often being required to develop a robust understanding of ecosystem dynamics. In the delta, there has been a considerable focus on empirical analyses designed to examine how temporal trends in CPUE statistically relate to various abiotic and biotic variables. Researchers have described freshwater flow within the delta as a key structuring variable of fish CPUE (Turner and Chadwick 1972; Stevens and Miller 1983; Sommer et al. 2007) along with the salinity variable X_2, which is defined as the horizontal distance up the axis of the estuary where the tidally averaged near-bottom salinity is 2 psu (Jassby et al. 1995; Kimmerer 2002; Kimmerer et al. 2009; MacNally et al. 2010). However, the evidence supporting these inferences was based on relationships between annual CPUE indices and metrics of water flow and/or X_2, which can be limiting since collapsing many raw field observations of CPUE into annual indices leads to a sizable loss of potentially valuable information. Feyrer et al. (2007, 2011) applied statistical models to raw survey data collected from the delta to quantify fish occurrences in relation to water quality variables; however, they did not examine CPUE or consider variables at broader temporal scales.

This study builds on previous empirical analyses by examining how measures of CPUE in the delta statistically relate to a broad suite of abiotic and biotic variables across multiple temporal scales and exclusively from the perspective of raw field observations. The analyses presented here follow a two-step procedure that reflects the specific objectives of this study, (1) investigate the role of covariates measured synoptically at the time of fish sampling to elucidate their effects on CPUE and (2) modify the analytical framework used for the first objective to examine the relative role of various abiotic and biotic covariates hypothesized to influence CPUE at an annual timescale. For the second objective, the covariates considered were annualized metrics of zooplankton density, chl-*a* concentration, water quality, and water flow. These analyses contribute to the understanding of ecosystem dynamics within the delta and thus aid the formulation of EBM strategies by providing foundational information of fish population responses to natural and anthropogenically modified system attributes.

Methods

Focal Fish Species

Reported declines of fish CPUE in the delta have revolved primarily around four species: delta smelt, *Hypomesus transpacificus*, longfin smelt, *Spirinchus thaleichthys*, age-0 striped bass, *Morone saxatilis*, and threadfin shad, *Dorosoma petenense*. Accordingly, these species are the focus this study. The delta smelt is a relatively small (60–70 mm standard length (SL)), endemic, annual, spring spawning, planktivorous fish that is distributed primarily in the delta and surrounding areas (Moyle et al. 1992). Delta smelt were listed as threatened under the US Endangered Species Act (ESA) in 1993 and endangered under the California Endangered Species Act (CESA) in 2010. The endemic longfin smelt is also a relatively small (90–100 mm SL), anadromous, semelparous, spring spawning fish with an approximate 2-year life cycle that is broadly distributed throughout the estuary (Rosenfield and Baxter 2007). Longfin smelt were listed as threatened under the CESA in 2010. Striped bass is a larger (>1 m SL), relatively long-lived, anadromous, late-spring spawning species deliberately introduced to the San

Francisco Estuary from the US east coast in 1879 (Stevens et al. 1985). Although subadult and adult fish reside primarily in estuarine and coastal waters, age-0 fish can be found in lower salinity areas where they feed on zooplankton and macroinvertebrates. Threadfin shad was discovered in the delta during the early 1960s (Feyrer et al. 2009) and is a relative small (<100 mm SL), summer spawning planktivorous fish that primarily inhabits freshwater areas of the estuary.

Field Sampling

The California Department of Fish and Wildlife (CDFW) has been conducting the Fall Midwater Trawl (FMWT) survey in the delta nearly continuously since 1967 (Stevens and Miller 1983; see http://www.dfg.ca.gov/delta/projects.asp?ProjectID=FMWT for additional details). The survey was initiated to measure the relative abundance of age-0 striped bass; however, survey data have been used to infer patterns in relative abundance of a variety of species inhabiting the delta (Kimmerer 2002; Sommer et al. 2007). Monthly cruises are conducted from September through December, and the number of tows each month has increased from approximately 75–80 during the early years of the program to >100 in more recent years. The survey follows a stratified fixed station design such that sampling occurs at approximately the same location within predefined regional strata (17 areas excluding areas 2, 6, and 9 per the CDFW's protocol). Sampling intensity is related to water volume in each regional stratum such that samples are taken every 10,000 acre ft for areas 1–11 and every 20,000 acre ft for areas 12–17; Fig. 1). At each sampling location, a 12-min oblique tow is made from near bottom to the surface using a 3.7 m×3.7 m square midwater trawl with variable mesh in the body and a 1.3-cm stretch mesh cod end. Vessel speed over ground during tows can be variable since sampling procedures are designed to maintain a constant cable angle throughout the tow. Each catch is sorted and enumerated by species and station-specific measurements of surface water temperature, electrical conductivity (specific conductance), and Secchi depth are recorded. CPUE is defined as number of fish collected per trawl tow.

Sampling Covariates

Generalized linear models (GLMs; McCullagh and Nelder 1989) were used to evaluate the effects of sampling covariates on CPUE of the four focal fish species. GLMs are defined by the underlying statistical distribution for the response variable and how a set of linearly related explanatory variables correspond to the expected value of the response variable. The relationship between explanatory variables and the expected value of the response variable is defined by a link function, which must be differentiable and monotonic.

Since CPUE was defined as fish count per trawl, the Poisson and negative binomial distributions were considered. Plots of the proportion of FMWT tows where at least one target animal was captured across the time series for each species showed low values for many years, which gave rise to the possibility that these data were zero-inflated (Fig. 2). In general, zero-inflated count data imply that the response variable contains a higher proportion of zero observations than expected based on a Poisson or negative binomial count process. Ignoring zero inflation can lead to overdispersion and biased parameter and standard error estimates (Zuur et al. 2009).

Zero-inflated distributions are a mixture of two distributions, one that can only generate zero counts and another that includes zeros and positive counts. In effect, the data are divided into two groups, where the first group contains only zeros (termed false zeros) and the second group contains the count data which may include zeros (true zeros) along with positive values (Zuur et al. 2009, 2012). To identify the appropriate model structure (zero-inflated versus standard GLM) and distribution of the count data (negative binomial versus Poisson), a variety of preliminary models were fitted to the FMWT data. Diagnostic plots, evaluation of overdispersion, and model comparisons using likelihood ratio tests and Akaike's information criterion (AIC; Akaike 1973; Burnham and Anderson 2002) all strongly supported application of a zero-inflated negative binomial distribution, which can be expressed as (Brodziak and Walsh 2013):

$$\Pr(y_i) = \begin{cases} \pi_i + (1-\pi_i)\cdot\left(\frac{k}{\mu_i + k}\right)^k & y_i = 0 \\ (1-\pi_i)\cdot\frac{\Gamma(y_i + k)}{\Gamma(k)\cdot\Gamma(y_i + 1)}\cdot\left(\frac{k}{\mu_i + k}\right)^k\cdot\left(\frac{\mu_i}{\mu_i + k}\right)^{y_i} & \text{otherwise} \end{cases} \quad (1)$$

where y_i is the i^{th} CPUE observation, π_i is the probability of a false zero, and μ_i and k are the mean and overdispersion parameters of the negative binomial distribution, respectively. The top equation represents the probability of obtaining a zero CPUE value, which is a binomial process that can occur either as a false zero or a true zero adjusted by the probability of not obtaining a false zero. The bottom equation is the familiar negative binomial mass function adjusted by the probability of not obtaining a false zero. GLMs were specified to mode π_i and μ_i as linear combinations of covariates with logit and log link functions, respectively.

The covariates measured synoptically with sampling that were considered included year, month, area (all categorical), and the continuous covariate Secchi depth, which was rescaled by subtracting the mean and dividing by its standard deviation. Inclusion of levels of categorical covariates with very few positive CPUE values caused model convergence and estimation problems, so levels with <5 % of the total

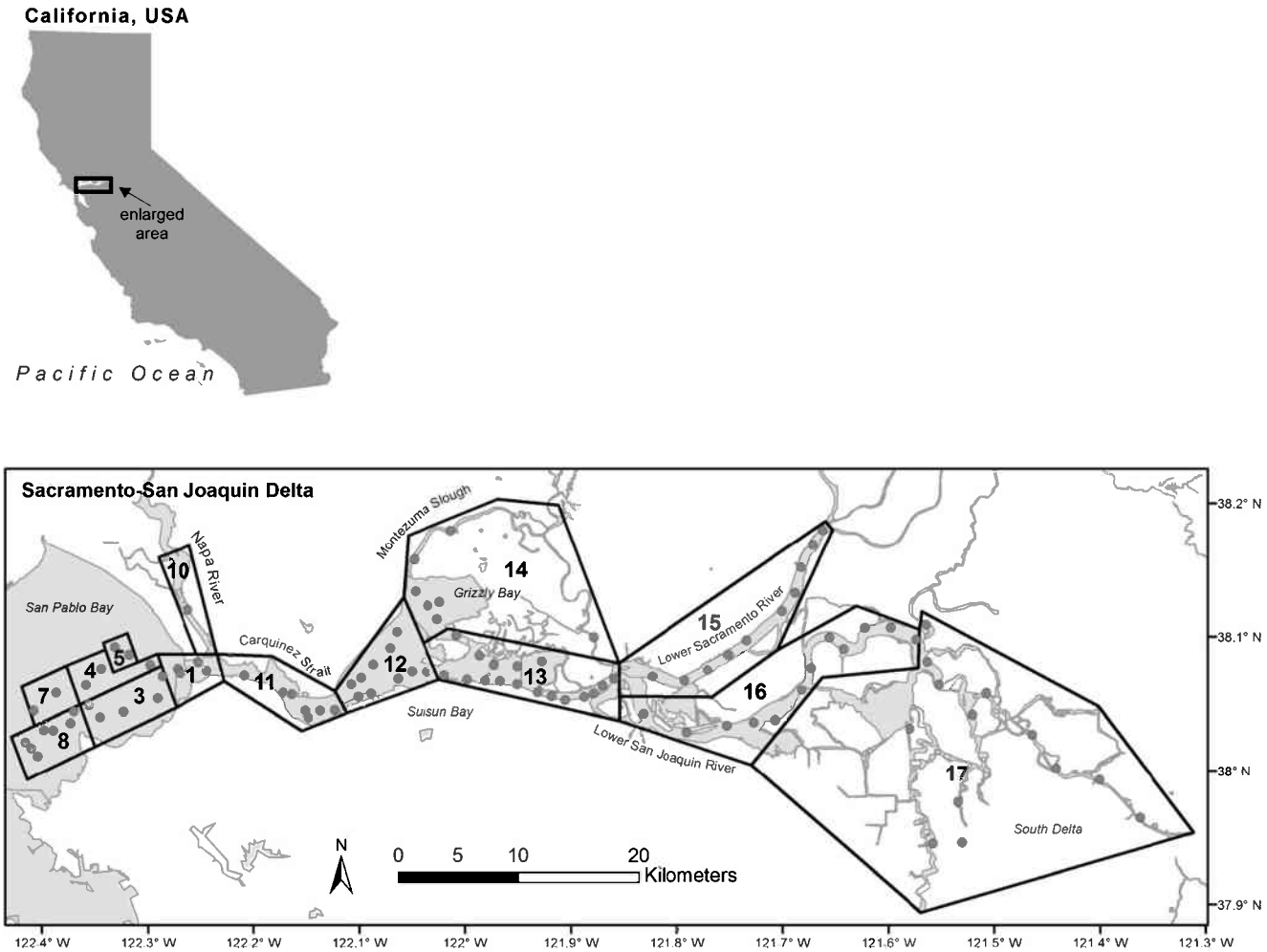


Fig. 1 Aerial stratification (*polygons*) and sampling locations (*circles*) for the Fall Midwater Trawl survey within the Sacramento-San Joaquin Delta, 1967–2012. Areas 2, 6, and 9 are not shown because they have not been consistently sampled and thus are not used by the California Department of Fish and Wildlife for estimation of catch per unit effort indices. No sampling occurred in 1974, September 1976, December 1976, and 1979. Figure adapted from Newman (2008)

survey catch of each species were deemed uninformative and excluded from the analysis. The covariates surface water temperature and surface salinity were also considered; however, variance inflation factors indicated that month/temperature and area/salinity were collinear. Month and area were chosen over temperature and salinity because an appreciable number of catch records did not have associated measures of temperature and/or salinity, and it was desirable to base analyses on the most available information. Also, the variables month and area arguably have the potential to be more useful in a management context. Interaction terms were excluded because the high proportion of zeros in the data lead to many year/area and month/area combinations for which there were no positive CPUE observations. Model parameterizations for each species ranged from inclusion of only a year covariate for the count and probability of false zero models to the saturated model with all four covariates specified for both components, including the possible combinations of unbalanced covariate specifications. AIC was used for model selection, and predictions were generated from the most supported model using estimated marginal means (Searle et al. 1980). Coefficients of variation for yearly predicted CPUE values were estimated from standard deviations of 1000 nonparametric bootstrapped samples (Efron and Tibshirani 1993). Models were fitted to data from 1967 to 2012 with the exception of 1974, September 1976, December 1976, and 1979 when no sampling occurred.

Annual Covariates

The covariate year is included in models when the goal is to develop a time series of estimated CPUE indices. However, the year covariate is simply a proxy for the ecosystem conditions over an annual timescale and thus has no direct relation to the vital rates of fish populations. Therefore, to more directly investigate factors potentially underlying interannual patterns in CPUE for each fish species, the aforementioned zero-inflated GLM structure was modified in two ways: (1) the year covariate was replaced by several hypothesized biotic and abiotic

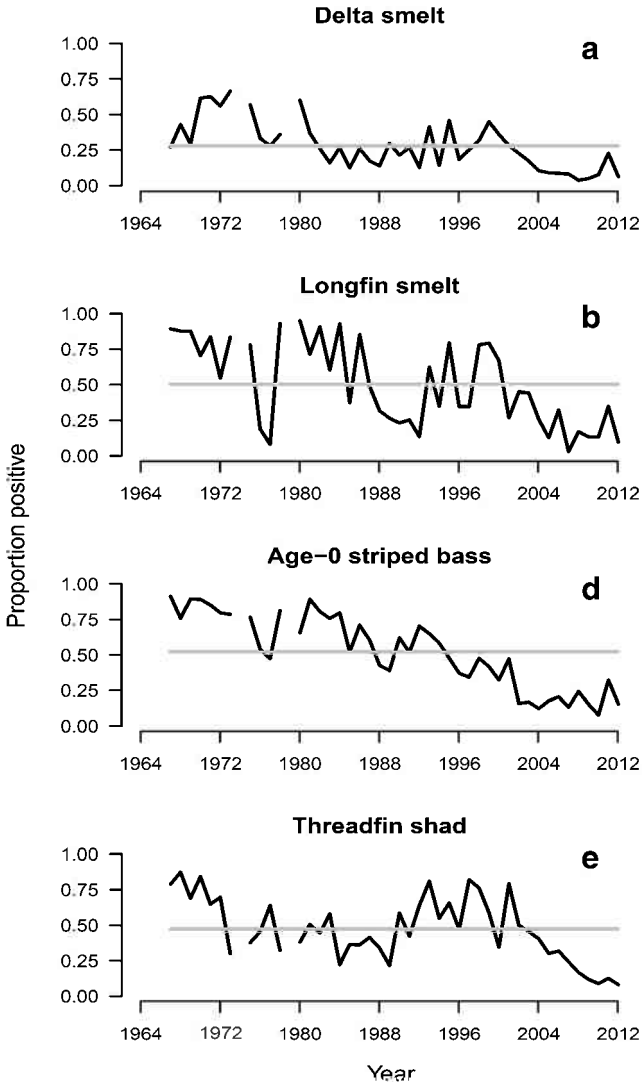


Fig. 2 Yearly proportions of positive tows (at least one target animal captured) based on the Fall Midwater Trawl survey, 1967–2012, for **a** delta smelt, **b** longfin smelt, **c** age-0 striped bass, and **d** threadfin shad. No sampling occurred in 1974, September 1976, December 1976, and 1979. *Horizontal line* is the time series mean

annualized continuous covariates, which operationally implied that the yearly value of each annualized covariate was assigned to each observed CPUE corresponding to the same year and (2) a single parameterization that included the annualized covariate along with month and area was fitted to isolate the effect of each annualized covariate on CPUE. Broad categories of the annualized covariates were zooplankton density (several taxa), chl-*a* concentration as a proxy for phytoplankton biomass, water quality metrics, and water flow (a total of 26). The years analyzed were 1976–2010, which was due to availability of chl-*a* data (began in 1976) and water flow measures (obtained through 2010). AIC was used to compare among competing annualized covariates for each fish species.

In terms of biotic covariates, the California Department of Water Resources (DWR) in collaboration with the CDFW have been compiling data on zooplankton density in the delta since 1968 (see http://www.water.ca.gov/bdma/meta/zooplankton.cfm for additional details, including specific sampling locations). The zooplankton monitoring program was initiated to investigate the population trends of pelagic organisms consumed by young fishes, particularly age-0 striped bass. Although the initial focus was to evaluate seasonal patterns in mysid abundance, the program expanded shortly after its inception to assess population levels of other key zooplankton taxa. Sampling occurs monthly at approximately 20 fixed stations. The zooplankton sampling gear consists of a Clarke-Bumpus net mounted directly above a mysid net, and the unit is deployed in an oblique fashion from near bottom to the surface. Each net is equipped with a flow meter, and all samples are preserved for sorting in the laboratory. For each station, zooplankton taxa are expressed as the total number per cubic meter of water sampled. Starting in 1976, chl-*a* concentration was recorded synoptically with zooplankton sampling.

The zooplankton taxa examined were adult calanoid copepods, adult cyclopoids, a combination of the two, and mysids. Annual estimated mean densities of zooplankton and chl-*a* were based on lognormal GLMs fitted to data from the core sampling locations and first replicate sample. The categorical covariates considered were year, survey (which is approximately equivalent to month), and area along with the continuous variable Secchi depth, which was again rescaled. Levels of categorical variables with <5 % of the total zooplankton density of each group again caused estimation problems and excluded from the analysis. Collinearity was assessed using variance inflation factors, and bias-corrected predicted (Lo et al. 1992) time series were generated from the most supported model using estimated marginal means.

In terms of abiotic covariates, the DWR has been monitoring water quality parameters at discrete sampling locations in the delta since 1970 (see http://www.water.ca.gov/bdma/meta/discrete.cfm for additional details, including sampling locations). The program was established to provide information for compliance with flow-related water quality standards for the delta set forth in the series of regulatory water right decisions and to provide abiotic data that could aid the interpretation of results from concurrent biological monitoring programs. Samples are taken at approximately 1 m depth and roughly within a 1-h window of the expected occurrence of high tide from 19 fixed stations. Sampling frequency is bimonthly during the rainy season (October/November to February/March) and monthly during the dry season (March/April to September/October).

Annual water quality metrics considered were mean summer (Jul–Sep) and winter (Jan–Mar) water temperature, total suspended solids (TSS) or filterable solids, volatile suspended solids (VSS) as a measure of the organic component of TSS, and turbidity. The annual mean water temperatures were

estimated from a multiple linear regression model while annual mean TSS, VSS, and turbidity estimates were obtained from bias-corrected lognormal GLMs. The covariates considered were categorically defined year, month, and area. Variance inflation factors were again used to assess collinearity, and predicted mean values for each year were based on estimated marginal means from the most supported model.

The water flow covariates considered were classified into two groups, "historical", which refers to measured flows taken from monitoring equipment located at various points in the delta, and "unimpaired", which is an estimated reference quantity intended to represent broader watershed-level hydrology in the absence of man-made facilities that affect flow. For each group, monthly inflow and outflow time series were assembled. Historical inflow included combined measurements from the Sacramento River, Yolo Bypass, and Eastern Delta (San Joaquin River and adjacent areas; Fig. 1), while historical outflow is a net quantity of inflow and an estimate of delta precipitation less total delta exports and diversions. All historical flow time series were based on DAYFLOW, which is a computer program designed to estimate daily average delta outflow (see http://www.water.ca.gov/dayflow/ for more details). Unimpaired inflow is an estimate of water entering the delta from the expansive watershed while unimpaired outflow is a net value adjusted for natural losses (e.g., evaporation and vegetation uptake). Flow data were provided courtesy of W. Bourez (MBK Engineers, Sacramento, CA).

For each flow covariate, a single value was calculated by averaging monthly flow values in four different ways: (i) from Jan–Jun within the year of sampling, (ii) from Mar–May within the year of sampling, (iii) from Jan–Jun of the preceding sampling year, and (iv) from Mar–May of the preceding sampling year. This approach gave rise to 16 annual flow covariates. Lagged flow covariates were considered to investigate possible delayed effects of flow on CPUE. For the most supported annualized covariate, 95 % prediction intervals of CPUE and probabilities of false zeros were based on 1000 nonparametric bootstrapped model fits (Efron and Tibshirani 1993). All statistical analyses were performed with the software package R (version 2.15.1, R Development Core Team 2012), and zero-inflated GLMs were fitted by accessing the "pscl" library.

Results

Field Sampling

Complete tow, month, area, and Secchi depth information was available for 15,273 stations sampled during monthly fall cruises from 1967 to 2012 (excluding 1974, Sep 1976, Dec 1976, and 1979 when no sampling occurred). Application of the 5 % cutoff rule for levels of categorical covariates indicated that all levels of month contained adequate nonzero CPUEs for inclusion in analyses. However, spatial data summaries showed that CPUEs were quite low in some areas, and the 5 % rule led to the inclusion of only areas 12–16 for delta smelt, 11–14 for longfin smelt, 12–16 for YOY striped bass, and 15–17 for threadfin shad (Fig. 1). Total numbers of tows analyzed for each species were 8802 for delta smelt (max. CPUE of 156 animals in December 1982), 6582 for longfin smelt (max. CPUE of 3358 animals in September 1969), 8733 for age-0 striped bass (max. CPUE of 1100 animals in September 1967), and 5019 for threadfin shad (max. CPUE of 4012 animals in December 2001). Although high CPUE values did occasionally occur, the data for each species were strongly skewed toward zero and very low CPUE values. The average percent of nonzero catches across all years analyzed was 28.1 % for delta smelt, 50.2 % for longfin smelt, 52.1 % for age-0 striped bass, and 47.1 % for threadfin shad (Fig. 2).

Sampling Covariates

Based on AIC statistics, the full zero-inflated negative binomial GLM (model M_4) received the most empirical support for each species (Table 1). For delta smelt, model M_5 received modest empirical support (ΔAIC=5.9), and for the other three species, no other parameterizations were comparatively supported. The superior performance of model M_4 suggested that all covariates were statistically important for each species and that CPUE and the probabilities of false zeros varied considerably by year, month, area within the delta, and across the domain of observed Secchi depths.

The model predicted yearly CPUE indices showed differing patterns for each species (Fig. 3). For delta smelt, higher predicted CPUE generally occurred in the early 1970s, 1980, and also for various years during the 1990s. The highest value occurred in 1991, and low CPUE was predicted for much of the 1980s and 2000s. Longfin smelt predicted CPUE was variable and high during the late 1960s, early 1970s, and for a few years during the early 1980s. Since 2000, predicted CPUE was consistently low with 2007 marking the lowest index value on record. Age-0 striped bass predicted CPUE consistently declined through time. The first year in the survey (1967) marked the highest age-0 striped bass predicted CPUE value on record while 2002 marked the lowest value. Threadfin shad predicted CPUE declined in the late 1960s, rebounded to higher but variable levels from the mid-1980s to early 2000s, and declined to the lowest value on record in 2012. Average species-specific CPUE across the time series was as follows: 1.24 fish/tow for delta smelt, 13.4 fish/tow for longfin smelt, 5.34 fish/tow for age-0 striped bass, and 22.9 fish/tow for threadfin shad. The precision of the estimated indices for all species was fairly low as bootstraped estimated

Table 1 Model selection statistics associated with the zero-inflated generalized linear models used to analyze catch-per-unit-effort data from the Fall Midwater Trawl survey for delta smelt, longfin smelt, age-0 striped bass, and threadfin shad, 1967–2012. Covariate abbreviations: *Y* year, *M* month, *A* area, *S* Secchi depth; and *nc* indicates model failed to converge successfully. No sampling occurred in 1974, September 1976, December 1976, and 1979

Model	Count covariates	False zero covariates	No. par.	Delta smelt		Longfin smelt		Age-0 striped bass		Threadfin shad	
				AIC	ΔAIC	AIC	ΔAIC	AIC	ΔAIC	AIC	ΔAIC
M_1	Y	Y	89	*nc*	*nc*	30,253.0	944.1	36,708.6	1299.4	24,364.7	1334.3
M_2	Y+M	Y+M	95	20,844.2	1348.6	29,751.4	442.5	36,630.4	1221.2	24,319.7	1289.4
M_3	Y+M+A	Y+M+A	103	19,872.9	377.3	29,602.4	293.6	36,038.7	629.5	23,336.2	305.8
M_4	Y+M+A+S	Y+M+A+S	105	19,495.6	0.0	29,308.9	0.0	35,409.2	0.0	23,030.3	0.0
M_5	Y+M+A+S	Y+M+A	104	19,501.5	5.9	29,323.0	14.1	35,423.5	14.3	23,246.9	216.7
M_6	Y+M+A+S	Y+M	100	19,795.0	299.4	29,356.0	47.1	35,537.2	128.0	*nc*	*nc*
M_7	Y+M+A+S	Y	97	19,801.9	306.3	29,690.6	381.7	*nc*	*nc*	23,332.8	302.3
M_8	Y+M+A	Y+M+A+S	104	19,635.3	139.7	29,497.7	188.8	35,677.2	268.0	23,045.0	14.6
M_9	Y+M	Y+M+A+S	100	19,795.2	299.6	29,588.6	279.7	35,988.1	578.9	23,956.3	926.0
M_{10}	Y	Y+M+A+S	97	19,834.8	339.2	29,601.4	292.5	36,137.9	728.7	23,993.2	962.8

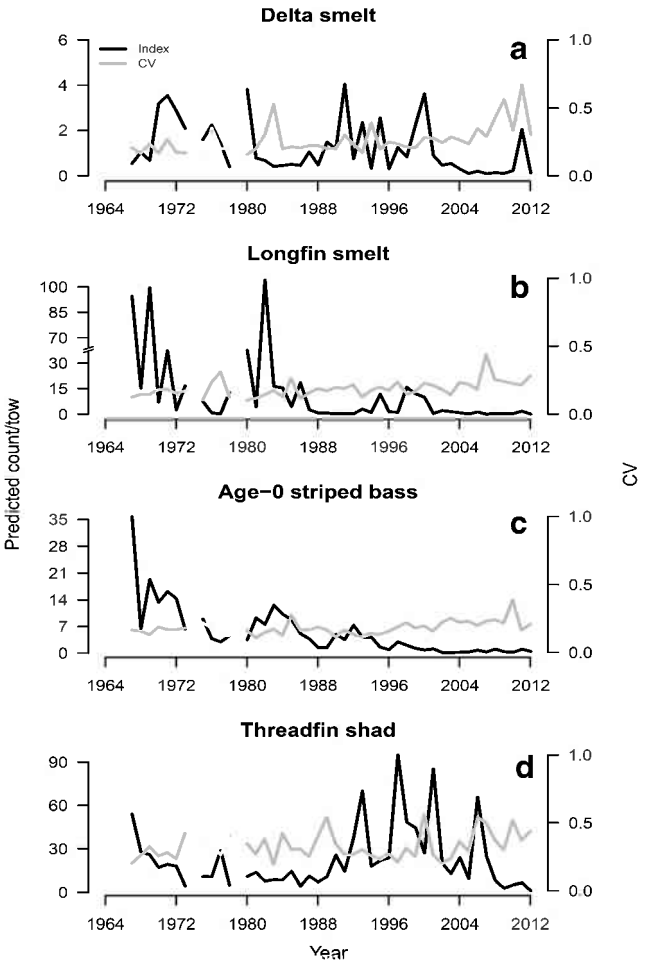


Fig. 3 Predicted yearly catch per unit effort (mean count per tow) and associated coefficients of variation (CV) based on zero-inflated generalized linear models applied to Fall Midwater Trawl survey data, 1967–2012, for **a** delta smelt, **b** longfin smelt, **c** age-0 striped bass, and **d** threadfin shad. No sampling occurred in 1974, September 1976, December 1976, and 1979. Note break in left *y*-axis for longfin smelt

yearly CVs predominately ranged between 0.15 and 0.45 with occasional values greater than 0.5.

Peak predicted monthly CPUE occurred in October for delta smelt, December for longfin smelt, September for age-0 striped bass, and November for threadfin shad (Fig. 4). Delta smelt predicted CPUE indices for November and December did not differ considerably from its peak month nor did the threadfin shad predicted December CPUE when compared to its peak. Spatially, highest predicted CPUE occurred in area 15 for delta smelt, area 12 for longfin smelt, area 15 for age-0 striped bass, and area 17 for threadfin shad. Age-0 striped bass predicted CPUE for areas 12 and 14 were comparably similar in magnitude to its peak.

The response in predicted CPUE across the range of observed standardized Secchi depths was strong and consistent across each species, as higher predicted CPUE values corresponded to low observed Secchi depths. This result emerged because the estimated Secchi depth coefficients associated with the count component of model M_4 were consistently negative across species. Related were the consistently positive estimated coefficients for the false zero model component of each species. Therefore, predicted CPUE declined with increased water clarity (higher Secchi depth) and the probabilities of false zeros increased with water clarity. In terms of actual water clarity conditions in the delta, the minimum observed Secchi depths for delta smelt, longfin smelt, age-0 striped bass, and threadfin shad were 0, 0, 0, and 0.12 m, respectively, while the maximum were 2, 1.6, 2, and 2.09 m. Relative to the maximum predicted CPUE for each species, the observed Secchi depth at which estimated CPUE decreased by 25, 50, and 75 %, respectively, was approximately 0.07, 0.17, and 0.35 m for delta smelt, 0.10, 0.25, and 0.50 m for longfin smelt, 0.11, 0.23, and 0.53 m for age-0 striped bass, and 0.4,

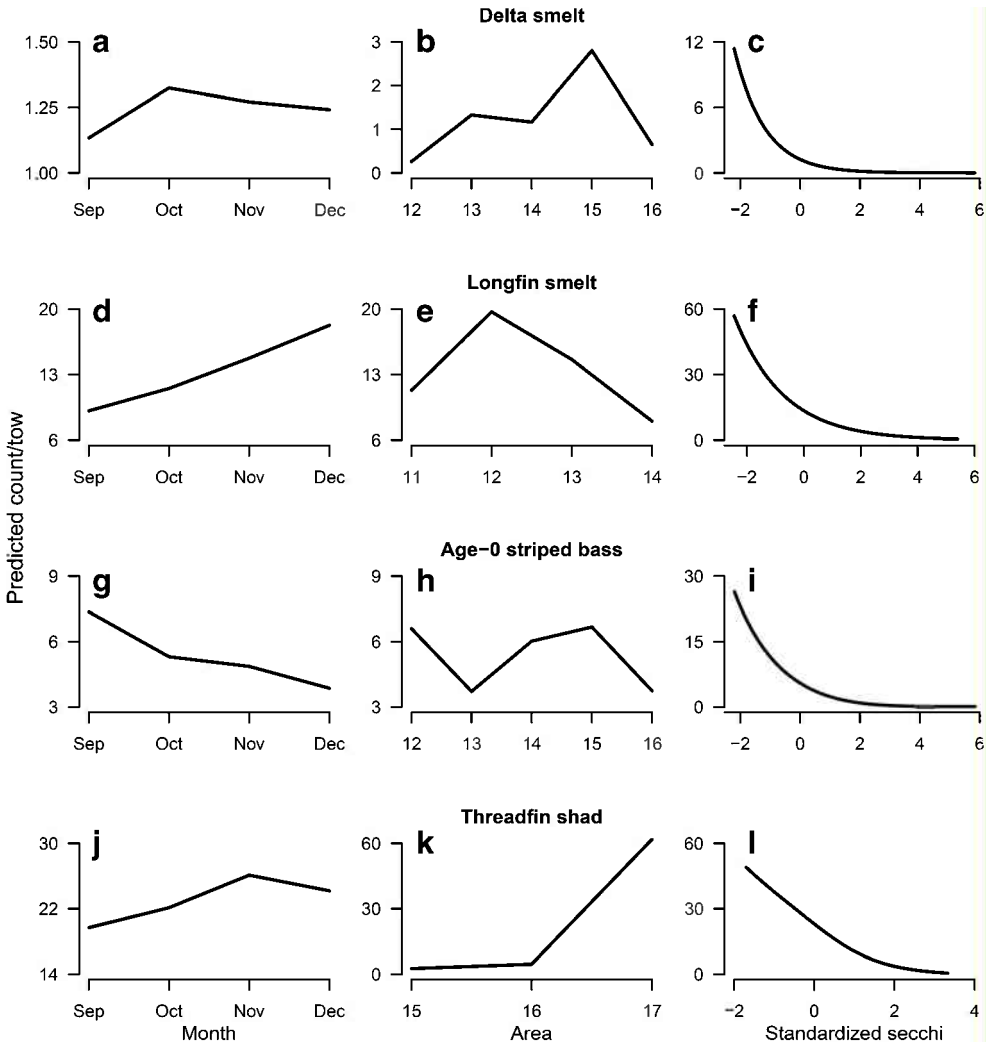


Fig. 4 Predicted catch per unit effort (mean count per tow) by sampling month, area, and across the range of observed standardized Secchi depths, respectively, based on zero-inflated generalized linear models applied to Fall Midwater Trawl survey data, 1967–2012, for (**a**–**c**) delta smelt, (**d**–**f**) longfin smelt, (**g**–**i**) age-0 striped bass, and (j–l) threadfin shad. No sampling occurred in 1974, September 1976, December 1976, and 1979

0.74, and 1.12 m for threadfin shad. Collectively, these results suggest that an increase from virtually no water clarity to roughly 0.5 to 1 m of water clarity corresponded to a 75 % or greater reduction in predicted CPUE for all species.

Annual Covariates

Predicted trends of the annualized biotic and abiotic variables showed differing patterns through time. Adult copepod density (calanoid, cyclopoid combined) has been variable but generally decreasing in the delta, with this trend being largely driven by taxa within the calanoid group (Fig. 5a–e). In contrast, the predicted trend in cyclopoid copepod density has been increasing since the mid-1990s; however, the comparably low density of cyclopoid copepods marginalized the impact of this group on the combined copepod trend. Estimated mysid density has been fairly stable since 1990 but much reduced from peak and moderate levels in the mid-1980s and late 1970s, respectively. The predicted trend of chl-*a* was relatively high and variable in the early part of the time series but considerably lower and more stable since 1987, which is when the lower trophic level food web of the delta changed in response to impacts by the introduced clam *Cobubula amurensis* (Kimmerer 2002).

Trends in predicted mean summer and winter water temperatures were generally stable over time, with estimated mean winter temperatures being slightly more variable than mean summer temperatures (Fig. 5f–j). Predicted trends of TSS, VSS, and turbidity in the delta were similar in that they showed considerable declines since the mid-1970s. Patterns in the various water flow variables showed distinct periods of "wet" and "dry" delta hydrology over time. Peak flow events occurred in 1983, the mid-1990s, and more recently in 2006, while low flows were observed in mid-1970s, early 1990s and late 2000s (Fig. 6). As expected, comparisons of type-specific (historical, unimpaired) patterns of inflows and outflows were generally the same qualitatively, with the latter simply reflecting reductions in water volume due to utilization. For the historical inflows and outflows, the two chosen averaging periods yielded virtually the same yearly volumes; however,

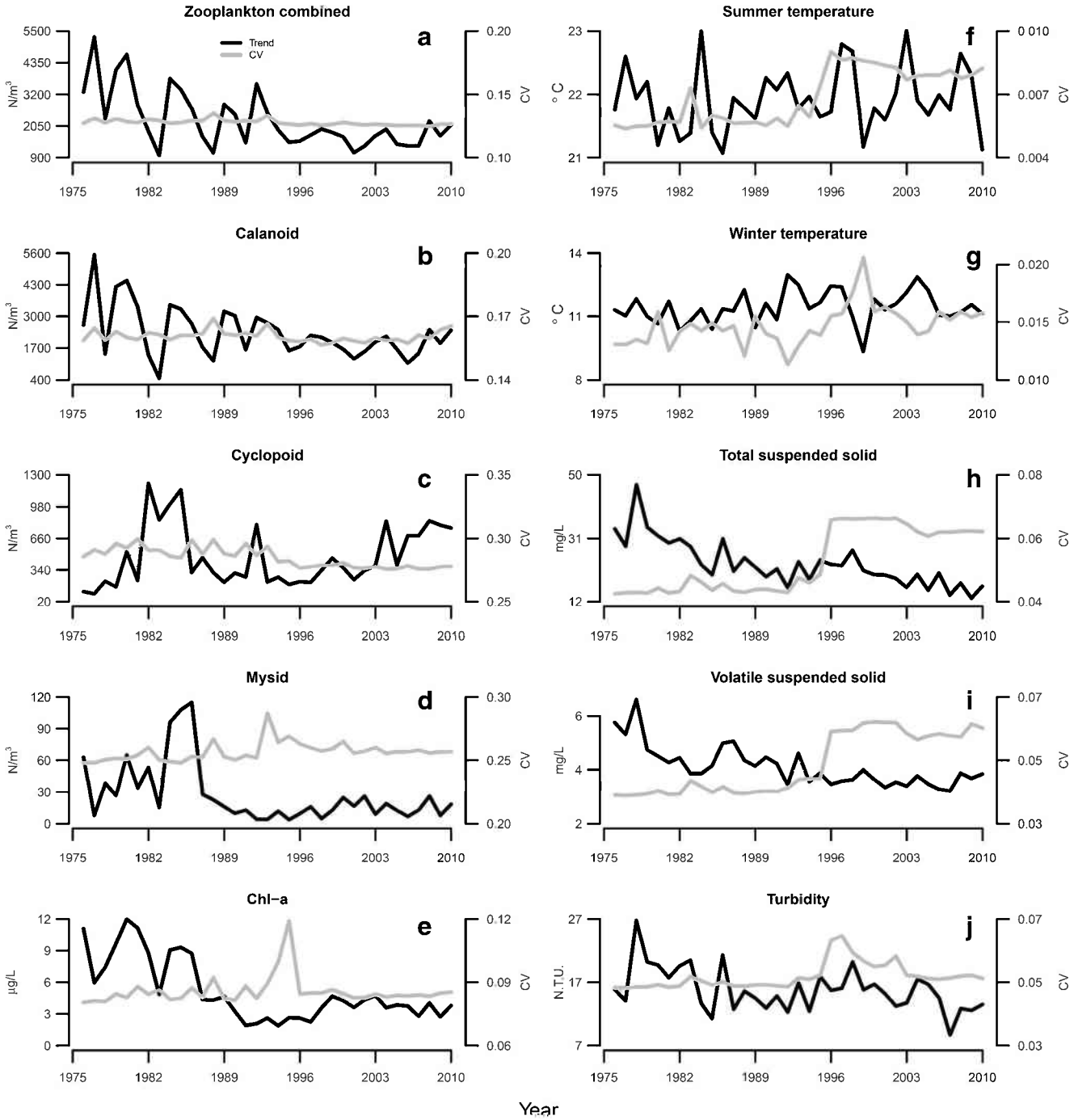


Fig. 5 Annualized mean trends and associated coefficients of variation (CV) based on various linear and generalized linear models fitted to zooplankton and discrete water quality data, 1976–2010, for **a** zooplankton combined (adult calanoid copepod and adult cyclopoid), **b** adult calanoid, **c** adult cyclopoid, **d** mysid, **e** chl-*a*, **f** summer water temperature (Jul–Sep), **g** winter water temperature (Jan–Mar), **h** total suspended solid, **i** volatile suspended solid, and **j** turbidity

there were notable differences in yearly volumes of unimpaired inflow and outflow depending on the monthly averaging period. The precision of all estimated biotic and abiotic covariates was very good as evidenced by consistently low CVs.

Based on AIC statistics, the annualized variable TSS received the most empirical support for all species (Table 2). Comparatively, there was no empirical support for any other annualized prey, water quality, or flow covariates. Predicted CPUE and probabilities of false zeros across the range of TSS were similar for three of the four species, with the exception being the predicted CPUE for threadfin shad (Fig. 7). Over the range of TSS, predicted delta smelt, longfin smelt, and age-0 striped bass CPUE increased, while the CPUE trend for

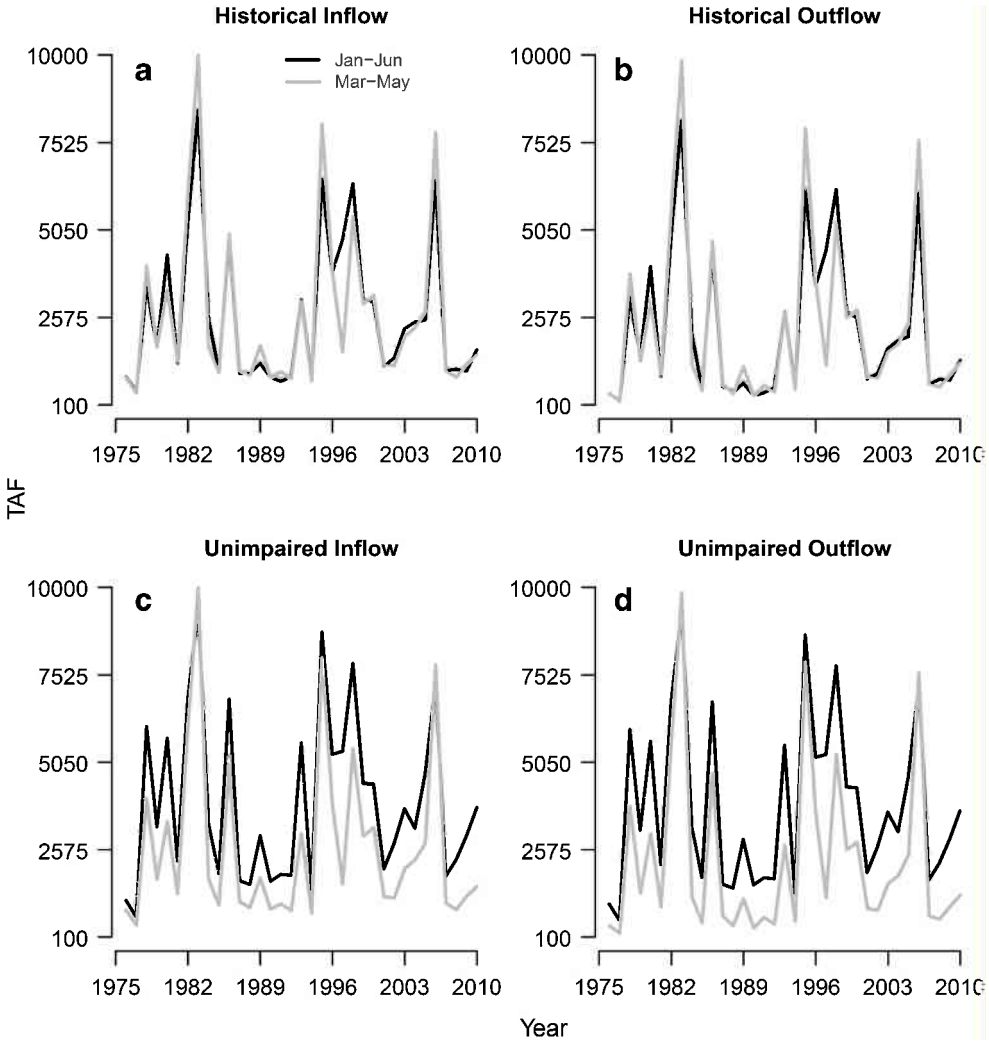


Fig. 6 Annualized trends in flow averaged monthly from January–June and March–May for **a** historical inflow, **b** historical outflow, **c** unimpaired inflow, and **d** unimpaired outflow. Flow variables lagged by 1-year are not shown

threadfin shad showed an inverse relationship. For all species, the predicted trends in probabilities of false zeros were fairly pronounced and decreasing with TSS. In terms of precision, the bootstrapped prediction intervals for both model components were generally narrow for all species.

Discussion

Sampling Covariates

Use of statistical models to quantify the importance of spatio-temporal and environmental covariates on survey CPUE can aid in understanding the dynamics of fish populations. For all species, the covariates year, month, region, and Secchi depth were important in explaining patterns in the observed CPUE data, particularly the zeros. However, relability of the results presented herein directly depends on satisfying the underlying modeling assumptions. For each species, plots of residuals for the count and false zero model components across the observed domains of the covariates showed no distinct patterns, and overdispersion was adequately handled by the zero-inflated model structure. Therefore, from a model diagnostics perspective, the means of the negative binomial and binomial distributions appear to be well estimated. In terms of precision, bootstrapped CVs of the predicted yearly CPUEs were fairly lowfor all species and likely due to the relatively high sampling intensity of the FMWT survey and the high proportion of consistently low observed CPUE values. However, the CV estimates do depend on the assumption that gear catchability (defined as q in the equation $CPUE_y=qN_y$) has remained constant over time and space, so it is possible that they are optimistic. Since the inception of the FMWT survey, the number of monthly sampling locations has grown considerably (~25 %), yet accompanying studies of potential gains/losses in bias and precision of predicted CPUE are absent from the literature. In general, model-based approaches can be useful in the design of fishery-independent surveys (Peel et al. 2013), and the methods in this study could support optimization studies to evaluate design elements, appropriate

Table 2 Model selection statistics associated with the zero-inflated generalized linear models used to evaluate the biotic and abiotic annualized covariates for delta smelt, longfin smelt, age-0 striped bass, and threadfin shad, 1976–2010

Model	Annual covariate	Delta smelt		Longfin smelt		Age-0 striped bass		Threadfin shad	
		AIC	ΔAIC	AIC	ΔAIC	AIC	ΔAIC	AIC	ΔAIC
A_1	Adult calanoid copepods	15,122.3	304.1	24,968.2	1642.2	27,545.5	691.4	19,325.6	263.8
A_2	Adult cyclopoid copepods	15,080.4	262.2	24,419.8	1093.8	27,420.7	566.6	19,247.5	185.7
A_3	Adult calanoid, adult cyclopoid combined	15,105.3	287.1	24,896.4	1570.3	27,433.2	579.1	19,310.9	249.1
A_4	Mysids	15,164.8	346.6	24,145.5	819.4	27,125.5	271.4	19,322.2	260.4
A_5	Chl-*a*	15,070.8	252.5	23,758.9	432.9	26,932.9	78.7	19,326.7	264.9
A_6	Summer temperature	15,113.2	295.0	24,633.0	1306.9	27,536.3	682.2	19,311.5	249.7
A_7	Winter temperature	15,095.2	277.0	24,282.6	956.5	27,472.6	618.5	19,325.3	263.5
A_8	Total suspended solids	14,818.2	0.0	23,326.1	0.0	26,854.1	0.0	19,061.8	0.0
A_9	Volatile suspended solids	15,074.5	256.3	24,612.9	1286.8	27,106.2	252.1	19,213.2	151.3
A_{10}	Turbidity	14,853.1	34.8	23,449.7	123.6	27,493.2	639.0	19,196.7	134.9
A_{11}	Historical outflow Jan–Jun	14,974.3	156.0	23,509.0	183.0	27,390.9	536.8	19,288.4	226.6
A_{12}	Historical outflow Mar–May	15,067.4	249.1	23,766.1	440.0	27,396.4	542.3	19,318.2	256.4
A_{13}	Historical outflow Jan–Jun, 1-year lag	15,164.2	346.0	24,872.2	1546.1	27,521.8	667.7	19,316.3	254.5
A_{14}	Historical outflow Mar–May, 1-year lag	15,158.5	340.3	24,925.1	1599.0	27,536.0	681.8	19,330.4	268.6
A_{15}	Historical inflow Jan–Jun	14,975.6	157.3	23,497.8	171.8	27,394.6	540.5	19,290.8	229.0
A_{16}	Historical inflow Mar–May	15,065.6	247.4	23,707.9	381.9	27,387.8	533.6	19,317.2	255.3
A_{17}	Historical inflow Jan–Jun, 1-year lag	15,162.8	344.6	24,879.9	1553.8	27,524.4	670.2	19,315.9	254.1
A_{18}	Historical inflow Mar–May, 1-year lag	15,158.4	340.1	24,929.6	1603.5	27,531.7	677.6	19,329.0	267.2
A_{19}	Unimpaired outflow Jan–Jun	14,989.8	171.6	23,615.2	289.1	27,436.2	582.1	19,315.2	253.3
A_{20}	Unimpaired outflow Mar–May	15,025.4	207.2	23,968.6	642.5	27,451.5	597.4	19,331.6	269.8
A_{21}	Unimpaired outflow Jan–Jun, 1-year lag	15,167.2	349.0	24,899.4	1573.3	27,549.8	695.7	19,317.4	255.5
A_{22}	Unimpaired outflow Mar–May, 1-year lag	15,152.6	334.4	24,944.6	1618.5	27,557.8	703.7	19,329.1	267.3
A_{23}	Unimpaired inflow Jan–Jun	14,989.9	171.7	23,613.4	287.3	27,436.7	582.6	19,315.4	253.5
A_{24}	Unimpaired inflow Mar–May	15,025.5	207.2	23,969.1	643.0	27,452.3	598.1	19,331.6	269.8
A_{25}	Unimpaired inflow Jan–Jun, 1-year lag	15,167.1	348.9	24,899.4	1573.3	27,550.0	695.9	19,317.4	255.6
A_{26}	Unimpaired inflow Mar–May, 1-year lag	15,152.7	334.5	24,944.3	1618.2	27,558.3	704.2	19,329.0	267.2

sample sizes, and allocation of resources for future FMWT surveys. The estimated monthly, regional, and Secchi depth effects generated relatively unique predicted CPUE patterns for each species, which can, in turn, be used as important foundational information for future hypothesis-driven field studies and mechanistic modeling activities.

The annual frequency of zero CPUE observations over the course of the entire FMWT survey was appreciably high for all species (Fig. 2). As a means of coarsely evaluating the temporal pattern of zero inflation in the FMWT data, model M_4 and its nonzero-inflated counterpart (intercept only parameterization for the false zero component) were sequentially fitted to subsets of the FMWT data set truncated by decade for each species. That is, the two models were applied to only 1960s data, then to 1960s–1970s data, then to 1960s–1980s data, and so on through the full time series. With the exception of the 1960s data for longfin smelt, AIC statistics strongly supported the zero-inflated parameterization for all species and time periods. Therefore, it appears that the FMWT survey data have almost always contained more zero CPUE observations than would otherwise be expected given a negative binomial count process, which raises the question, why?

Failing to successfully encounter target populations can arise because they are rare, samples are taken in suboptimal habitats (true zeros), or because samples are taken in optimal habitats but reduced survey catchability across time, space, and/or ecosystem conditions prevent successful collections (false zeros). For delta smelt, rarity may be a plausible explanation, especially given that the highest predicted yearly CPUE was only 4.04 fish per tow and the 45-year average was just 1.24 fish per tow. However, species rarity does not seem likely for the other three fishes given that predicted yearly longfin smelt CPUE values early in the time series were very high (>70 fish per tow), estimated adult striped bass abundance exceeded 1 million fish in the early 1970s (Stevens et al. 1985) thus requiring considerable age-0 production, and threadfin shad have been viewed as highly abundant since appearing in the delta (Feyrer et al. 2009).

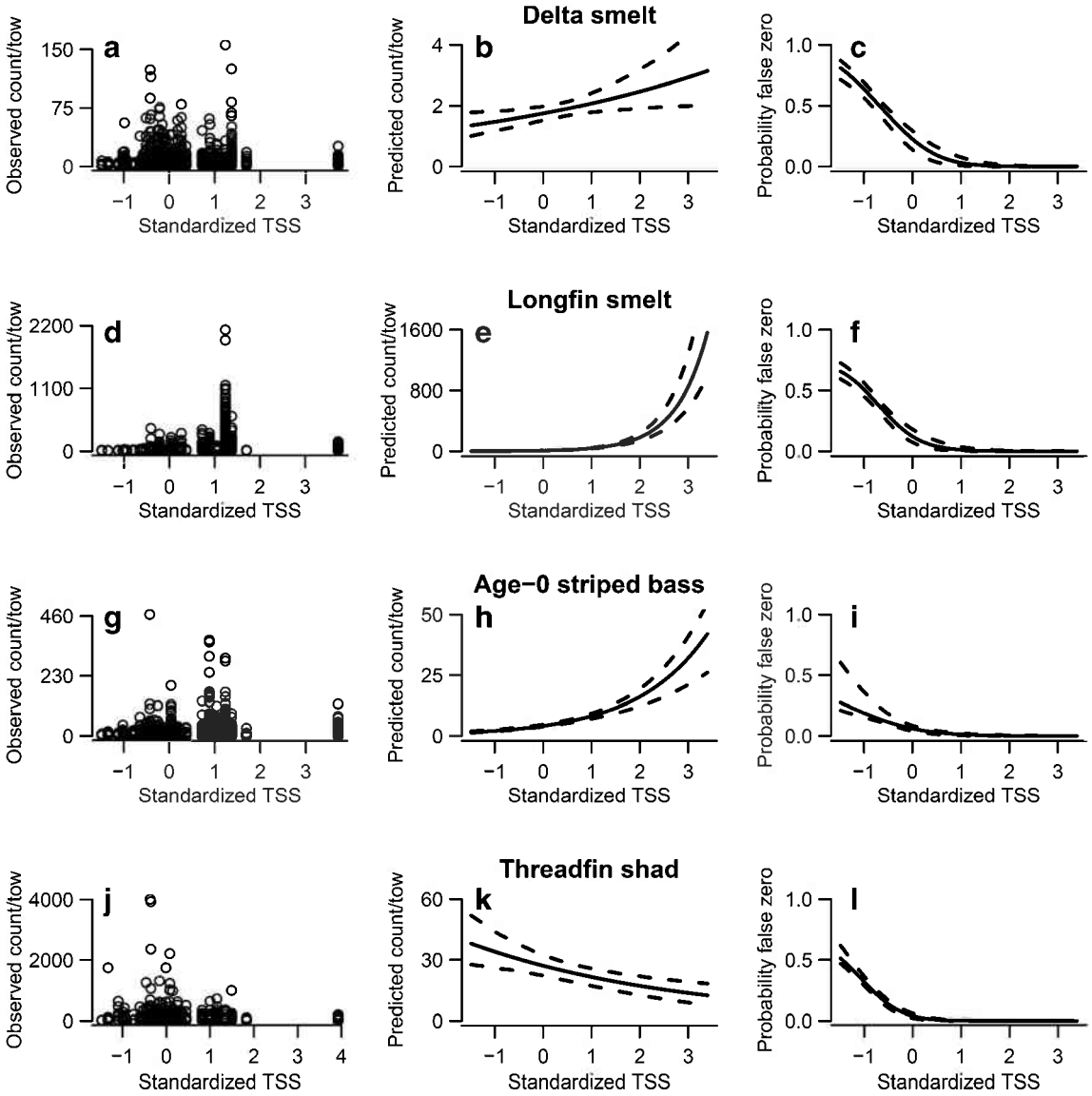


Fig. 7 Observed catch per unit effort (CPUE, mean count per tow, *left panels*), predicted CPUE (*middle panels*), and predicted probabilities of false zeros (*right panels*) with 95 % prediction intervals across observed standardized TSS for (**a**–**c**) delta smelt, (**d**–**f**) longfin smelt, (**g**–**i**) age-0 striped bass, and (**j**–**l**) threadfin shad

The FMWT survey does follow a fixed station sampling design, which raises the possibility that samples are consistently taken at locations that do not support high localized fish abundance. Additionally, if habitat utilization of fishes in the delta has systematically changed over time in response to morphological alterations of the estuary and/or sustained regimes of ecosystem conditions, differences in CPUE and distribution become confounded. The relatively high spatiotemporal sampling intensity of the FMWT survey may somewhat mitigate these concerns, but the four focal species are schooling pelagic fishes, and thus, variable distributions through time and space should be expected.

The consistency of the model prediction to Secchi depth for all species warrants deeper consideration, especially in the context of false zeros. Feyrer et al. (2007) analyzed raw FMWT survey data to evaluate fish occurrences (presence/absence of delta smelt, age-0 striped bass, and threadfin shad) in relation to various environmental variables and documented an inverse response with Secchi depth. Feyrer et al. (2011) updated that analysis and extended it to derive habitat index values for delta smelt (but see comments provided Manly et al. (2015)). The results of this study generalize the importance of Secchi depth to include CPUE. Feyrer et al. (2007) noted that higher presence/absence of delta smelt at lower Secchi depths could be due to required turbidity for feeding and/or turbidity mediated top-down predation impacts. A third potential explanation is that catchability of the FMWT survey sampling gear changes with Secchi depth. In general, Secchi depth is a coarse measurement of water clarity, and it is not possible to

distinguish among constituent groups causing low measurements. If those constituent groups are largely organic material, then a positive fish CPUE response to food availability is possible. Conversely, if those constituent groups are not largely organic, then higher CPUE at lower Secchi depths could be due to compromised foraging impacts of visually oriented piscivores such as larger striped bass (Horodysky et al. 2010). However, all of the fishes in this study are pelagic, planktivorous feeders, and thus, it is reasonable to assume that vision plays a central role in their sensory ecology. Animals could be more effective at gear avoidance under higher Secchi depths than at lower Secchi depths simply because of a larger field of visibility for gear detection.

Although experimentally testing the variable catchability hypothesis is challenging, flume trials to assess gear behavior under various hydrographic conditions, video equipment attached to sampling gear, and coordinated field studies using multiple survey gears designed to quantify relative catchabilities could be informative. Additional modeling efforts may also assist in identifying and quantifying covariate effects on relative catchability. In terms of the bottom-up hypothesis, characterization of water column constituents synoptic with fish stomach content analysis could assist in understanding trophic interactions and prey selectivity, which could aid in determining if the inverse relationship of CPUE and Secchi depth is a response to food availability. Regarding top-down impacts, results of striped bass and other fish predator diet composition studies in the delta have shown very little consumption of delta smelt and longfin smelt, and modest consumption of age-0 striped bass and threadfin shad (Nobriga and Feyrer 2007; Nobriga and Feyrer 2008). However, these studies were temporally abbreviated, and each acknowledged potential biases due to spatial limitation of predator stomach collections. Therefore, systematic temporal and spatial diet composition studies of piscivorous fishes could be helpful in more fully understanding predation impacts of larger fishes.

Annual Covariates

The annualized covariates considered were chosen in an effort to evaluate the effects of hypothesized covariates on fish CPUE that were potentially operating at an annual timescale. The choice to focus on the annual timescale was motivated from the notion that yearly environmental conditions have the potential to impact early life history and thus new year class formation. However, the analytical approach taken here to evaluate annual covariates can be used for variables aggregated across other potentially meaningful scales. For example, biotic or abiotic variables summarized monthly or seasonally could be used to more directly explore drivers of within-year CPUE patterns, and variables could be aggregated spatially to investigated rivers of fish distribution within the delta. Studies of this type represent fruitful areas of future research.

The strong empirical evidence supporting TSS as the best annualized covariate for all species is consistent with the importance of Secchi depth documented in the analysis of sampling covariates. Trends in the model predicted CPUEs and probabilities of false zeros across TSS were analogous to those associated with Secchi depth, with the exception of predicted threadfin shad CPUE which showed a modest decline with TSS. Inspection of the raw threadfin shad CPUE data in relation to TSS showed relatively high frequencies of both zero (>50 % of the tows analyzed) and large CPUE values (>100 fish per tow, 3.9 % of the tows analyzed) at low TSS values when compared to high TSS values. The collective presence of these relatively infrequent large observed CPUEs and numerous observed zero CPUE values likely created the declining predicted CPUE and probability of false zero relationships with TSS (Fig. 7k). The results for the other three species strongly confirm the effect that more turbid water yields higher predicted CPUE and demonstrates that it is also detectable at an annual timescale. As a stand-alone result, the concept that water clarity mediates CPUE keeps the bottom-up, top-down, and variable gear catchability hypotheses in play; however, the strong support for the annualized TSS covariate combined with the lack of empirical support for any of the annualized prey covariates and the aforementioned relative absence of the focal fish species in predator diets may favor the variable catchability hypothesis.

Much of the contemporary understanding regarding covariate effects on fish CPUE in the delta has revolved around flow, particularly outflow and the location of X_2. In this study, X_2 was not considered largely because it is highly variable, often moving significant distances within a single tidal cycle (pers. com., W. Bourez, MBK Engineers, Sacramento, CA) and because it is a proxy covariate directly influenced by flow. Thus, inclusion of the various flow covariates constitutes a more direct evaluation of delta hydrology. CPUE indices of pelagic fishes in the delta have been showed to be positively related to delta outflow (Kimmerer 2002; Sommer et al. 2007), but it is important to note that higher flow regimes lead to higher TSS concentrations. For the data in this study, the historical outflow January–June and March–May time series are each positively correlated with TSS and signficant at the $\alpha=0.07$ level (Pearson's product moment correlations, $\rho_{JJ}=0.32$ [$p=0.058$], $\rho_{MM}=0.31$ [$p=0.067$]). Therefore, higher delta outflow leads to poorer water clarity, which, in turn, could increase survey gear catchability and lead to higher estimated yearly CPUE indices.

If the annualized covariates analysis is restricted to only include the flow covariates, the results indicated that historical outflow averaged January–June received the most support for delta smelt and threadfin shad, and historical inflow averaged January–June and averaged March–May were best supported

for longfin smelt and age-0 striped bass, respectively (Table 2). However, there was competing empirical support for historical inflow averaged January–June for delta smelt (ΔAIC=1.3) and for historical outflow averaged January–June (ΔAIC=3.1) for age-0 striped bass. Collectively, these results fail to confirm the effect of a single dominant flow covariate on fish CPUE in the delta, which is arguably not surprising since the underlying dynamics of the focal fish species are likely shaped by intersections of a complex suite of biological, ecological, and environmental processes.

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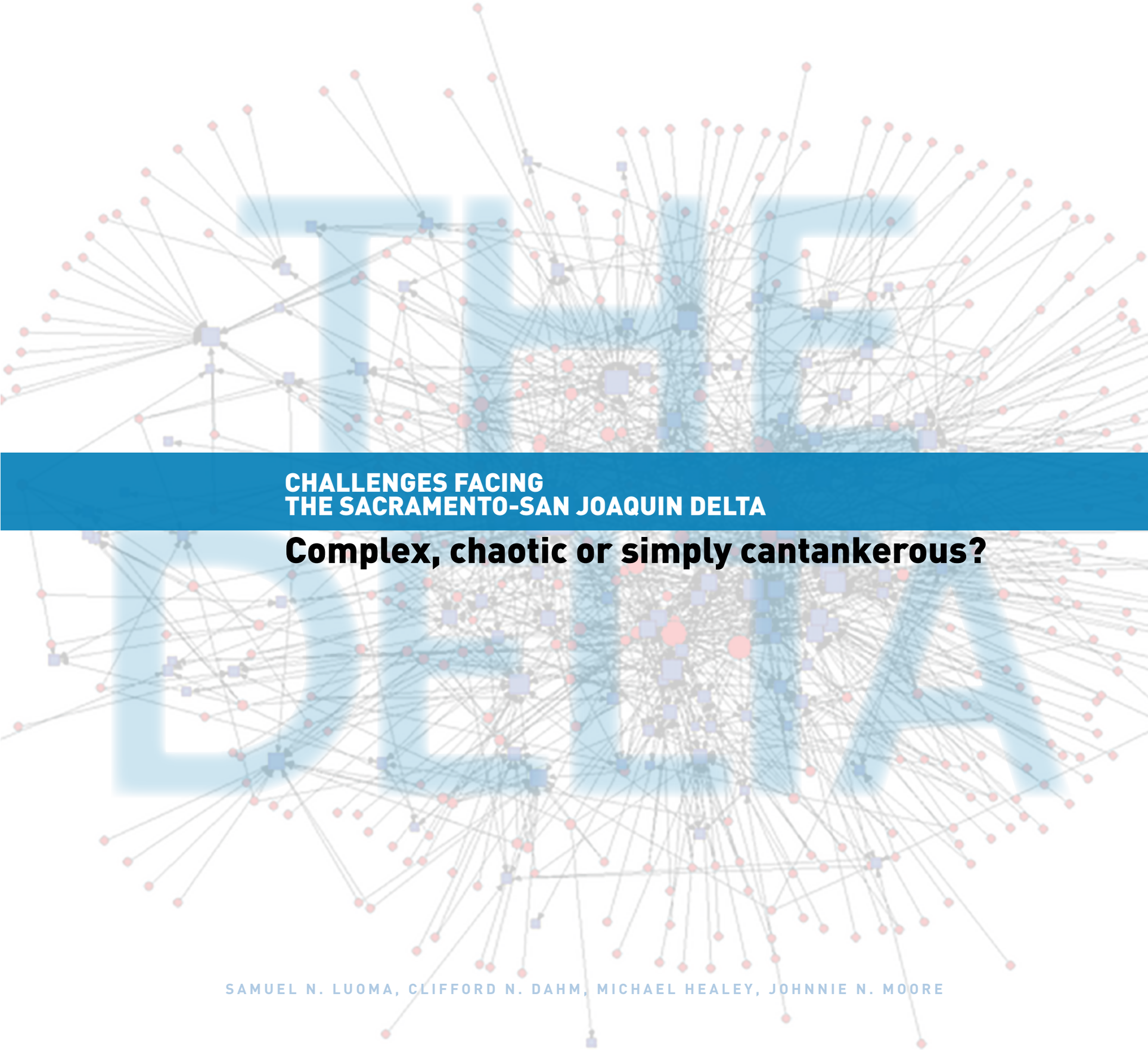
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CHALLENGES FACING THE SACRAMENTO-SAN JOAQUIN DELTA

Complex, chaotic or simply cantankerous?

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Challenges Facing The Sacramento-San Joaquin Delta: Complex, Chaotic, or Simply Cantankerous?

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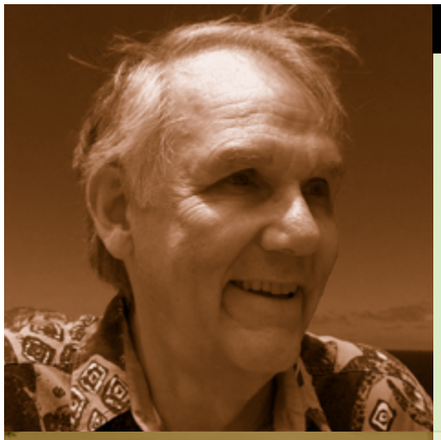
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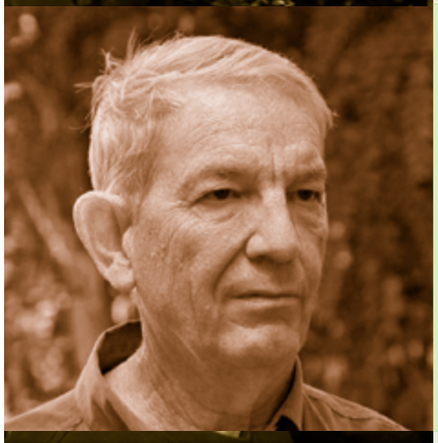
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Sam Luoma is the lead author of this paper. He was the founding father of the CALFED Science program and served as the first Lead Scientist from 2000-2003. Luoma developed the structure for the program and worked for years to assure its independence as the provider of science for CALFED.



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Cliff Dahm, as the fourth Lead Scientist, took the reins in July 2008 during a time of fiscal crises, staff furloughs, and stop-research orders. He led the program through the passage of the Delta Reform Act of 2009 that created the DSC, established the Delta Science Program (DSP), and enabled the Delta Independent Science Board. He also guided the DSP during the initial development of the Delta Plan. Dahm left in early 2012 and returned as interim lead scientist in fall 2015.



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Mike Healey, the third Lead Scientist, was science advisor to the Delta Vision Blue Ribbon Task Force, which laid the foundation for the legislation that created the Delta Stewardship Council. Healey served in 2007 and 2008, until Dahm took over. Healey was the editor in chief of the first issue of *State of Bay Delta Science, 2008.*



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Johnnie Moore served as the second Lead Scientist from 2004 to 2006, at the time when the California Bay-Delta Authority was challenged as a governing agency. Planning that eventually led to the transition to the Delta Stewardship Council was initiated on his watch.

EXECUTIVE SUMMARY



"In these times of uncertainty it is important to be nimble, be timely and be prepared in our decisions and our implementation. We cannot afford to shy away from bold actions but we must broaden the definition of "bold" to include more than engineering: conservation alternatives, the environment and governance must be a part of every decision."

— SAMUEL N. LUOMA

RECIRC2590.

Executive Summary

In 2014, the California Natural Resources Agency and the U.S. Department of the Interior asked the authors of this paper, as four former leaders of The Delta Science Program, to summarize the challenges faced by water supply and ecological resource managers in this critically important region of Northern California. They concluded that the challenges are so complex as to meet the definition of a "wicked" problem. Such problems can't be ignored, defy straightforward characterization, and have no simple solutions. Yet they must be actively managed to maximize beneficial and minimize adverse outcomes.



Several runs of Chinook salmon in the Sacramento River are endangered or listed (juveniles pictured here). Photo: Roger Tabor, USFWS.

In California, water supply and demand are increasingly out of balance. At the same time, the very cornerstones of the water supply system are changing. Snowpack is declining with warming temperatures, groundwater is being pumped at an unsustainable rate, water infrastructure is aging, and human demand for water continues to grow. Meanwhile, many native species and ecological systems in the Delta are on the point of collapse. Add the uncertainties of drought and flood and a 60% chance of a significant earthquake by 2050 resulting in cascading levee failures, and the need for a new approach is urgent. Repeated management crises suggest that the status quo is unsustainable. Water managers no longer have the flexibility they once had in dealing with the multi-year droughts that are inherent to the California climate. Furthermore, management initiatives are often delayed by the multiplicity of agencies and actors involved and by litigation. Managing the water supply system alone is complicated. But add in the imperative to sustain the ecological and social values of the Delta and every decision becomes unimaginably complex.

In this context, the following paper calls for Delta management to become more nimble and better coordinated. The situation requires bold, timely, and well-considered actions, taken incrementally (in stages) where possible, with the understanding that any management action typically leads to new complexities that must also be managed. With water scarcity has come the awareness that problems are less amenable to traditional engineering solutions, and that attempts at dramatic, simple solutions may intensify the risk of unexpected, if not catastrophic, consequences. Simultaneous attention to a portfolio that includes actions like addressing overuse and mis-use of water, and improving ground water management and storage, should accompany any necessary water infrastructure adjustments. Renewed emphasis on reducing known stressors, restoring native ecosystems, learning from our actions, and managing collaboratively and adaptively is essential if native species are to be retained. Comprehensive modeling that takes account of the many dimensions of the Delta problem should provide a foundation for determining the best approaches to implementing restoration and water management initiatives and forecasting the degree to which they will be effective.

Thanks to the public's long-term investment in good science, the Delta is one of the most intensively studied systems in the world. Managers have information to work with, although important questions remain unsettled. Throughout decades of conflict over water issues, all parties have agreed that advancing the state of scientific knowledge is fundamental to making constructive progress. As we enter an era of increasing uncertainty about climate and water supply, science conducted in collaboration among multiple institutions must be brought to bear and decisions must transcend individual agency directives or the needs of special interests.

Forecasting the future of complex problems like the Delta will require scientific models that can simulate the consequences of different management approaches. Such models have been developed for water operations; are in their early stages for the ecosystem (DiGennaro et al. 2012) and climate change (Cloern et al. 2011); and have been used to envision alternative futures for the Bay-Delta (e.g., Lund et al. 2010).

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WHAT IS THE DELTA?

The Delta is where the Sacramento and San Joaquin rivers flow out of the mountains and onto valley floodplains, spreading out onto a 3,000-square-kilometer landscape of islands and shallow waterways before flowing into the San Francisco Bay. Before it was diked, drained, and developed, the Delta was a vast wetland complex of low islands, shifting channels, woody debris piles, and tule marshes. Today, the Delta is a patchwork of largely agricultural islands separated by deep channels and protected by 1,100 miles of aging levees. It hosts farms, fisheries, water projects, recreational areas, and the state capitol in Sacramento. Geographically, it is the largest delta on the Pacific coast and encompasses an area almost the size of Rhode Island.

The Delta is...

- **One of the largest waterworks in the world.** This critical hub of a regional water redistribution system is a complex network of dams, pumps, canals, drains and reservoirs, all of which are managed jointly by local, state and federal institutions to meet goals of flood control, water supply, and environmental conservation.
- **A real place where people live and play,** with a rich cultural history. More than 570,000 people live in the greater Delta, mostly in the urbanizing regions around the margin of the Delta. Many of them derive their livelihoods directly from the Delta. Most of the rest use the Delta for transportation, recreation, and as a source of water.



- **The heart of California's agricultural economy,** which produces more food than any other state with $45 billion in sales per year. Because California produces most of the fruits and nuts and a high percentage of vegetables consumed in the US, restrictions on water for agriculture in the greater Delta affect the availability and price of these agricultural products throughout the US and elsewhere. If production relocates because of water shortages in California, some of the conflicts over water will also relocate.



- **Home to more than 750 species of plants and animals.** The California Floristic Province, of which the Delta is a part, is one of 25 hotspots of biodiversity across the world cited as highest priority areas for conservation of species (Myers et al. 2000). Some species are present year round, like Delta smelt, Sacramento splittail, salt marsh harvest mouse, and soft bird's beak. Other species are important culturally or economically, including salmon, sturgeon, and migratory waterfowl and shorebirds. The presence of migratory species connects the Delta to ecosystems far to the north, south, and west just as the existence of the water distribution system connects the Delta to regions far to the south and east. The Delta is truly an internationally connected ecosystem with contributions to local and state enterprise, to regionally valuable fisheries, and to global biodiversity.

Photos, this page: Birds Eye View

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Challenges remain in merging models of various types and in ensuring the models are reliable and address issues at the geographic and temporal scales appropriate for management. If carefully implemented and interpreted, such models would provide valuable guidance and a foundation for both coordination and evaluation of management initiatives.

Water scarcity has defined and will continue to define the future of the Delta and all that is linked to it. California has risen to the challenge of water scarcity in the past to build an economy and a society that is, in many ways, the envy of the world. Accepting water scarcity raises economic, ecological, water infrastructure and organizational complexities in the Delta to a new level, well beyond traditional approaches that consider water supply solutions in isolation. Nevertheless, California has the tools and the intellectual resources to manage the multiple dimensions of the problem and thereby achieve the state's twin goals of a reliable water supply and an ecologically diverse Delta ecosystem.

DELTA CHALLENGES

- **California's water supply is over-allocated.** State water rights allocate more than 500% of average annual river flows (Grantham and Viers 2014). The current drought, climate change, and normal year-to-year variability in precipitation are increasing uncertainty in water supply.
- **California's vast water management infrastructure is decaying** and overtaxed. This increases the risk of catastrophe.



Photo: Chris Austin

- **Delta water availability uncertainties will have consequences throughout seven western states and into Mexico,** due to California's participation in the Colorado River Basin Compact. Although the California economy has proved resilient to year-to-year water shortages in the past (Hanak et al. 2012), negative consequences of a more permanent water scarcity will be increasingly difficult to avoid (Howitt et al. 2014) and will carry over to the economies of the region, the nation, and the world.
- **Native ecosystems and species are declining.** Multiple interacting factors affect their well-being, only some of which are well understood. Predicting the outcome of changes to water operations, landscapes, or levees is uncertain, at best.



Photo: NOAA

- **Upgrading levees to address growing risks will be costly** (risks include earthquakes, storms, rising sea level). Not all levees are fixable, sustainable, or defensible in perpetuity. Failure of levees in one part of the Delta, however, increases the risk of failure elsewhere. Multiple, simultaneous levee breaks would allow a massive salinity intrusion into the Delta. Turning the Delta brackish would threaten agricultural crops and urban water supplies that rely on high-quality water exported from the area.



Photo: Birds Eye View

- **Water quality is threatened by the complex spectrum of chemicals entering the Delta.** Sources include agricultural runoff, industries, wastewater treatment plants, urban stormwater discharges, and atmospheric fallout. Chemicals interact with physical conditions in the Delta, and with other stressors in the system, in a dizzying number of ways, making risks to water supply and native organisms difficult to assess.
- **Delta management is unusually complex.** More than 230 agencies, institutions and stakeholders are involved. Each plays a useful role. However, a number of these entities have very different core interests, conflicting visions, and competing priorities. The result: institutional fragmentation that slows decision-making and confounds collaborative management.

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INTRODUCTION



Thermalito Afterbay, part of the State Water Project system downstream of Oroville Dam.
Photo: Matt Elyash, CDFW

If the problem were just about allocating freshwater flows, it might be solvable. Add in the complexity of moving water through a hydrologically and hydrodynamically complex Delta and it becomes complicated. Add the uncertainty of ecological responses and the institutional complexity of many actors with many visions and the problem becomes wicked. Then add the ever-changing water supply and ecological and economic contexts within which decisions must be made, and the problem becomes devilishly wicked.

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Introduction

California, the most prosperous state in the nation, has an economy and a lifestyle built on water — and an illusion that freshwater is always abundant. However, the current drought, now entering its fourth year, has brought sharply into focus the fact that water is a scarce resource. With snowpack in the Sierras at a record low, Governor Jerry Brown has decreed serious water rationing, stating: "This is the new normal and we'll have to learn to cope with it." (KTLA 5 News 2015).

Shortages of water and conflicts over water use are nothing new in California. The Delta of the Sacramento and San Joaquin rivers (the Delta; Fig. 1) is at the center of these conflicts. Major state and federal water projects began delivering water from the Delta in 1949 to agricultural and urban users in the San Joaquin Valley and southern California. This redistribution of water stimulated economic growth, but the projects were soon plagued by conflict over whether, when, and how to transfer water from the Delta (Hanneman and Dyckman 2009). Conflict intensified with the listing under the federal and state endangered species acts of more than 50 native species found in the Delta (DSP 2013). As public concern grew, new policies were put in place to address environmental effects. These initiatives also led to improved understanding of the Delta, the listed species, and the complexities of managing the Delta to achieve a reliable water supply and a healthy ecosystem. Nevertheless, listed species continue to decline and dissatisfaction with water deliveries continues to grow. There is concern that the present approach to water operations is unsustainable in the face of widening demands[1] and shrinking supplies. Frustration with management's inability to satisfy all the demands for water has led to litigation, distrust among parties, and the threat of policy paralysis, with cascading consequences for California, the semi-arid west and the nation (see *Delta Conflicts* at left).



Shasta Dam. Photo: USBR

In this paper we look at multifaceted questions about water and environmental management in the Delta. Our goal is not to evaluate specific recent initiatives, but to provide a larger framework to guide implementation of these and future initiatives. We illustrate how the complexity of the Delta problem complicates management and leads to inefficiency and conflict. We give examples of trade-offs, disagree-

DELTA CONFLICTS: CASCADING CONSEQUENCES

- Federal and State regulations curtail water exports from the Delta when legally protected species, like salmon and Delta smelt, are drawn into the pumps.
- Local restrictions on exporting water from the Delta impact the intricately balanced supply and demand of interdependent water transport networks throughout California and the Colorado River Basin.
- The Colorado River Basin Compact is a complicated deal that defines water rights of users in the seven states that share the river. For example, Southern California obtains water from both the Delta and the Colorado River Basin. California's supply of Colorado River water was reduced with implementation of the Compact. Nevertheless, reducing supplies to Southern California from the Delta increases their reliance (within the bounds of the agreement) on water from places like Lake Mead in the Colorado River system. (Fleck 2012) Integration of interstate water infrastructure via these complicated agreements means that decisions about water exports from the Delta have cascading consequences for flows in the Colorado River, as well as endangered species conservation and water supply disputes throughout the Colorado River Basin.
- With so much at stake, it is not surprising that water managers argue that water disputes throughout the arid and semi-arid western US cannot be resolved in the absence of decisions about managing the Delta. (Austin 2015; Fleck 2012)

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ments and the consequences of failure in managing these issues. We discuss why bold new approaches to managing Delta issues are urgently needed to address inefficiencies in water use, aging infrastructure, and the deteriorating condition of native species. We also show that it is important to ensure that those actions take full advantage of existing knowledge, are implemented incrementally where possible, and are accompanied by ongoing evaluations of outcomes and subsequent adjustments, as necessary. Our hope is that this paper will help managers and policy-makers better appreciate the complexity of water and environmental management in the Delta, and understand that there are ways to move forward.

The Problem

At its simplest, the problem of the Delta is similar to water challenges throughout the arid and semi-arid western U.S.: growing demands and over-allocated resources. For example, California has water rights that allocate over 500% of average annual river flows (Grantham and Viers 2014). Media reports often focus on the conflict over whether water should be exported from the Delta or left flowing through the Delta to San Francisco Bay to sustain listed native fish species. All this attention to flows and fish creates the impression that if only water managers in the major river basins would "get their act together," the problem could be solved. But the problem of the Delta is more complex than a simple decision about allocating flows. It is a problem with many different dimensions (Table 1) and interactions that confound simple answers.

Historically, the problem of water management was about supply: not enough

TABLE 1. *The Delta Problem: A nationally important but "wicked" problem with many dimensions and potentially contradicting solutions.*

Dimension	Problem	Some Characteristics
Physical	Natural system seasonal and episodic	Strong seasonality of water supply; highly variable year-to-year; drought and floods the norm; changing climate; high earthquake damage potential.
Socio-Economic	Unsupportable demand from population, economy	Growth nearing limits of water supply; inadequate awareness that water is scarce; directly linked to the rest of the semi-arid West.
Water Supply	Increasingly vulnerable water infrastructure	Aging conveyance and levee systems stretched to limits; snowpack declining; groundwater exploited at an unsustainable rate; water used is out of balance and inadequately tracked.
Environment	Multiple stresses on ecosystem	Many native species at risk; scale of change massive, difficult or impossible to reverse; stresses difficult to manage, may act in combination, can change over space and time.
Ecosystem Restoration	Difficulty ensuring project success	Some projects help native species while others attract invasive species; benefits of water diversion mitigations questionable; successes, failures, and challenges inadequately tracked.
Institutional	Insufficiently unified vision for the Delta	Plethora of institutions with their own visions and contradicting missions; monitoring programs plentiful yet uncoordinated; management programs inconsistently coordinated and evaluated.
Science	Key uncertainties remain	Multi-institutional, collaborative approach requires new support; equal need for broadly applied science and research focused on immediate policy issues; data sharing must be improved.
Management	Contradictions among solutions	Problems can be characterized in many possible ways; single-focus problem solving can create unanticipated outcomes; management must be continual and adaptable.

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THE DELTA: A WICKED PROBLEM

- If the problem were just about allocating flows, it might be solvable.
- Add in the complexity of moving water through a hydrologically and hydrodynamically complex Delta and it becomes complicated.
- Add the uncertainty of ecological responses and the institutional complexity of many actors with many visions and the problem becomes *wicked* (Dryzek et al. 2013).
- Then add the ever-changing water supply and ecological and economic contexts within which decisions must be made, and the problem becomes *devilishly wicked*.

water in the south and more abundant water in the north. California's impressive water system was designed to address this supply problem. But California's water problems can no longer be solved through supply management and traditional engineering solutions alone. Water supply and demand are increasingly out of balance, and the cornerstones of the water supply system are changing. Snowpack is declining with warming temperatures, groundwater is being mined at an unsustainable rate, the infrastructure is aging, human demand for water continues to grow and the Delta ecosystem continues to deteriorate. The accelerating pace of these changes introduces a new urgency into the need to find novel ways to manage the host of variables that affect water and the Delta ecosystem.

Human use of the Delta and surrounding lands has changed the landscape and water quality in ways that create serious environmental challenges (Fig. 2). We know that multiple factors (e.g., water flows, water quality, invasive species, predation pressure, and habitat loss) interact to increase risks to native species. Despite measures to address individual stresses, the situation for many native species is increasingly dire (Sommer et al. 2007). Largely because of massive landscape transformations, the Delta cannot be restored to what it once was (NRC 2012). But the situation for native species can be improved, and there is a new urgency in taking advantage of whatever opportunities exist to do that. Exactly how to reduce the cumulative impacts of the stresses on the ecosystem is not clear (Baxter et al. 2010), but the need to address this multiplicity of problems and their interactions is as urgent as the need to address water-supply issues.

Another aspect of the problem is that more than 230 agencies, institutions and stakeholders claim a role in water and environmental management but come with different core interests — and often conflicting visions of how the Delta should be managed. The resulting institutional fragmentation creates conflict and slows decisions. Addressing the water supply and ecosystem problems of the Delta will require management institutions that are both nimble and sufficiently coordinated to take bold, timely and well considered actions.

Formally, the problem of water and environmental management in the Delta fits the definition of a "wicked" problem in the sense of Rittel and Webber (1973; see *The Delta: A Wicked Problem* above). Recognition of the Delta as a wicked problem presents a new way to think about management. Wicked problems have no single correct



Fresh water from the Delta system supplies both irrigation water for farms and drinking water to cities as far away as Los Angeles. Delta waters also sustain fish and wildlife and recreational activities. Photos: NeilArmstrong2 (left); Bird's Eye View (center and right).

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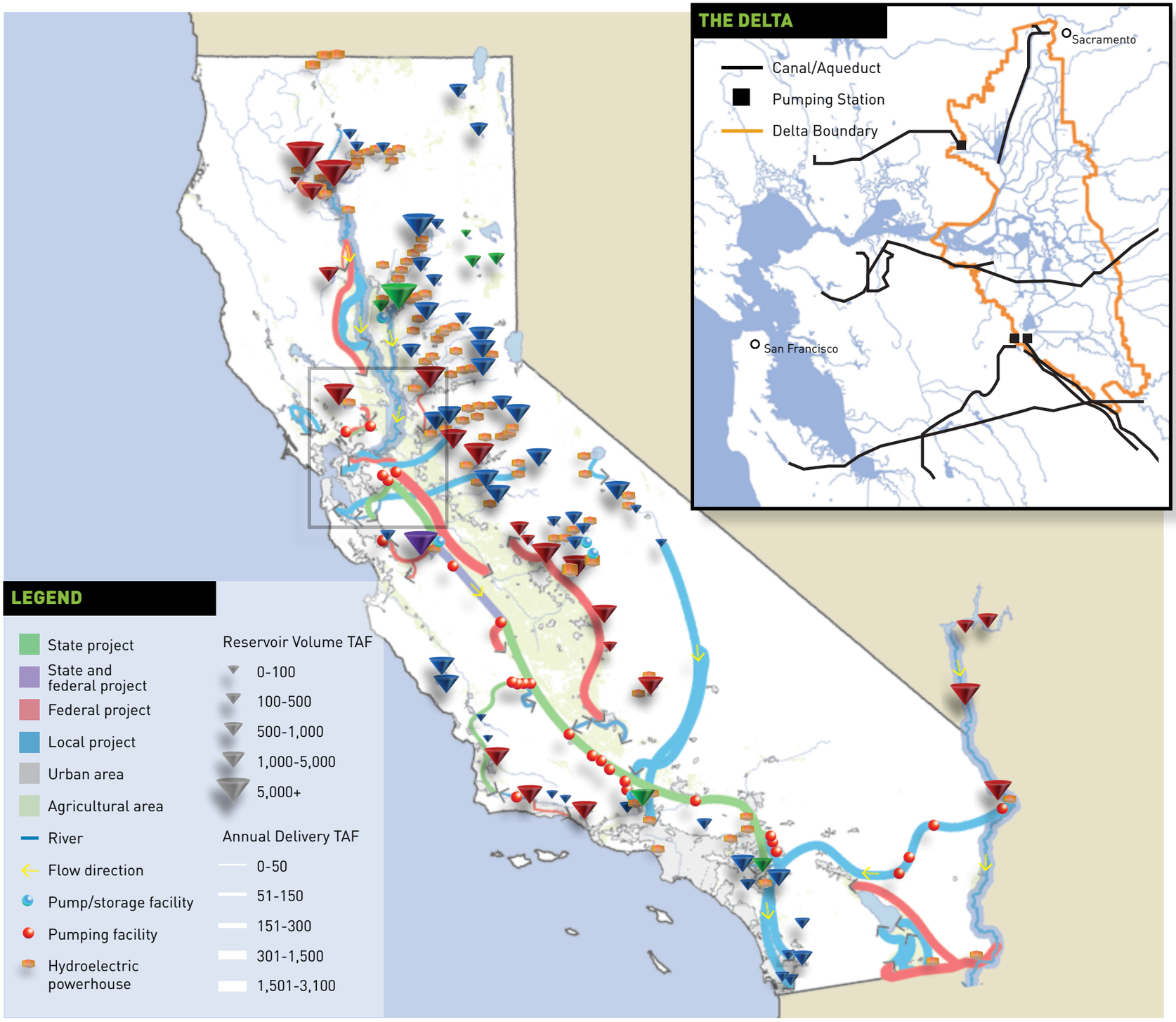


FIGURE 1. *Water supply system in California (large map) showing reservoirs and canals storing and transporting water from the wetter northern areas of the state to the drier southern and coastal areas. The Delta (inset) is at the heart of the system, pumping water to the south from two large pumping plants in the southern Delta. Reservoir volume and annual delivery is in millions of acre feet. Within the Delta, different zones are dominated by different uses and economic productivity. Agriculture is the most important economic activity in the Delta's economy producing $800 million annually in crops (e.g., corn, alfalfa, tomatoes, wheat, and wine grapes). Adding all value-added activities (wineries, dairies, canneries, etc.), the Delta produces $2.6 billion in total economic output and 13,000 jobs for the counties encompassing the Delta and $5.3 billion and 25,000 jobs statewide. Recreation is the second most important economic activity in the Delta, generating $312 million and over 3000 jobs annually within delta counties, and over 5300 jobs and $353 million statewide. Natural gas from the Delta also produces more than 20% of California's gas-powered electricity (DPC 2012).*

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characterization and no single correct solution, only better or worse approaches to management of the situation. This means the Delta's problems cannot be solved in the traditional sense, but they can be actively managed to minimize adverse outcomes and maximize beneficial outcomes (Healey 2008). Difficult political decisions and bold actions will be necessary, and this will require thinking outside the box, thinking holistically, making learning integral with doing, and finally and honestly embracing the equivalent value of water supply and ecological health. Addressing demand will be as important as addressing supply; restoring ecological function (as Moyle et al. [2012] suggest) will receive as much attention as re-engineering water-distribution infrastructure; and broadly coordinated actions will take precedence over individual institutional missions. The Delta Stewardship Council, the Delta Reform Act, and the Delta Plan provide an institutional and policy framework for this kind of operational innovation.

Why is the Delta Problem Important?

As the hub of a regional water-redistribution system, the Delta is a critical node in a complex network of dams, pumps, canals, drains and reservoirs, all of which are managed jointly by local, state and federal institutions to meet goals for flood control, water supply, and environmental conservation (Fig. 1). This engineering marvel is one of the largest waterworks in the world. Through California's participation in the Colorado River Basin Compact, uncertainties about water availability from the Delta have consequences throughout seven western states and into Mexico.

Water is a fundamental driver of the economy of the western US. California's economy is the most productive in the country (Fig. 2; see *Economy Underpinned* below). The water system is the lifeblood of this economic powerhouse and fuels the nation's most productive agricultural sector. The Delta contributes to the California economy in myriad other ways. Commercial shipping moves through the Delta to and from the ports of Stock-

THE INTERNATIONAL, NATIONAL AND STATE-WIDE IMPORTANCE OF AN ECONOMY UNDERPINNED BY AVAILABILITY OF WATER FROM THE CALIFORNIA DELTA

- A gross domestic product of $2.2 trillion.
- The 8th largest economy in the world, equal to Brazil's.
- Contributes 13% to the total economic output of the United States.
- Ranks 1st in the nation for patents.
- Outpaces all other states in venture capital investment with 41% of all companies in the U.S. receiving venture capital from California.
- Has the highest rate of employment by U.S. subsidiaries of foreign companies.
- Exports $174 billion of products annually ($48 billion from computer and electronics goods) for 11% of total U.S. exports.
- Imports more than $230 billion in goods from other states and countries.
- Entertainment industry in California accrues over $47 billion per year.
- California produces more food than any of the 50 states with $45 billion in sales per year, including:
  - 40% of annual national agricultural production; 45% of all the fruits and vegetables, including:
    - 98-99% of U.S. almonds, walnuts and pistachios.
    - 90-95% of broccoli, strawberries, grapes, and tomatoes.
    - 74% of all lettuce.
    - Produces many crops year round supplying the nation with fresh produce throughout the winter.
- Because California produces most of the fruits and nuts and a high percentage of vegetables consumed in the US, restrictions on water for agriculture in the greater Delta affect the availability and price of these agricultural products throughout the US and elsewhere.
- If production relocates because of water shortages in California, some of the conflicts over water will also relocate.

References in footnote 3, p. 30.

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CONSTRUCTION OF DAMS

Blocked fish migration; altered hydrology and temperature; reduced sediment transport.

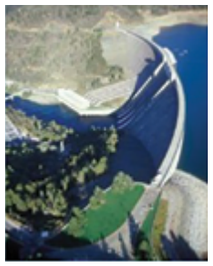


Photo: USBR

WATER DIVERSIONS

Changed hydrology and hydrodynamics; fish entrainment; migratory fish signal impairment; altered water quality.



Photo: CDFW/Matt Elyash

COASTAL UPWELLING

Affect coastal marine ecology; changes abundance and types of migratory species in the Estuary from year-to-year.

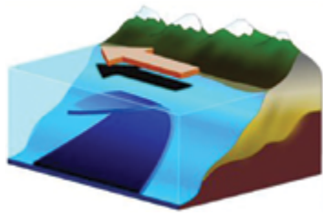


Image: NOAA/OER

ATMOSPHERIC RIVERS

Major source of precipitation and dominant cause of flooding.

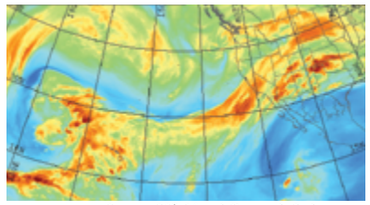


Image: US Naval Research Laboratory

CLIMATE CHANGE

Warmer temperatures; altered timing and intensity of precipitation; more rain and less snow; earlier snowmelt; reduced runoff, sea level rise.

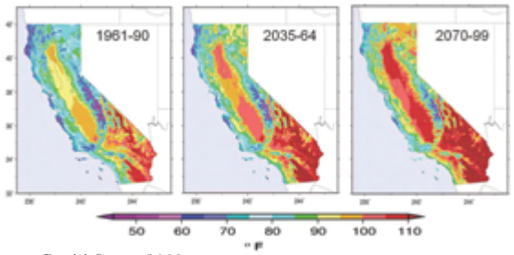


Image: Daniel Cayan, 2009

EL NIÑO/LA NIÑA

Affect precipitation patterns and amounts throughtout the US: major contributor to wet and dry years in California.

INVASIONS BY NON-NATIVE SPECIES

Non-native species competition with native species; predation pressure; habitat alteration.



Photo: DBW



Photo: Cindy Brown

SALINITY INTRUSION

Driven by drought, sea level rise, tidal surges, or catastrophic levee failure.



Photo: Bird's Eye View

TRANSFORMATION OF THE LANDSCAPE

Habitat reduction and alteration; altered hydro–dynamics; native species declines and non-native species increases.



Photo: Aerial Archives/Alamy

LEVEES

Disconnected rivers and channels from floodplain and wetlands; earthquake vulnerability; storm and tidal surge vulnerability.



Photo: DWR

DISCHARGE OF NUTRIENTS AND TOXIC SUBSTANCES

Nutrient inputs drive algal blooms and enhance growth of invasive plants; toxins affect species survival and bioaccumulate, making fish unsafe to eat.

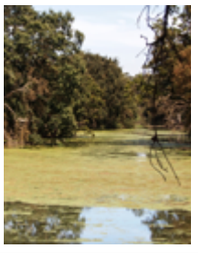


Photo: Bird's Eye View

FIGURE 2. *The Delta ecosystem responds to factors both within the physical Delta and from regional stressors and drivers of change, including the ocean. Eleven major factors affecting the current Delta are highlighted in this regional view of the Delta and surrounding landscapes. Aerial photo research: Amber Manfree.*

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ton and Sacramento, and several major rail lines cross the Delta. Natural gas is generated and stored in the Delta. Silicon Valley, the heart of America's electronics industry, gets half its water directly from the Delta. California's entertainment industry — America's largest export — is also centered in cities dependent upon Delta water (Farhi and Rosenfeld 1998). Although the California economy has proved resilient to year-to-year water shortages in the past (Hanak et al. 2012), negative consequences of a more permanent water scarcity will be increasingly difficult to avoid (Howitt et al. 2014) and will carry over to the economies of the region, the nation, and the world.

The Delta is also of considerable ecological importance. With San Francisco Bay, it is home to more than 750 species of plants and animals. The California Floristic Province, of which the Delta and Bay are a part, is one of 25 hot spots of biodiversity across the world cited as highest-priority areas for conservation of species (Myers et al. 2000). Some species are present year-round, like Delta smelt, Sacramento splittail, salt marsh harvest mouse, and soft bird's beak. Other species that are important culturally or economically, including salmon and sturgeon, utilize the Bay and Delta seasonally. Migratory waterfowl and shorebirds use the Bay and Delta as a feeding and nursery habitat during only a brief part of their lives, but these species could not exist without these systems. The presence of migratory species connects the Delta to ecosystems as distant as Alaska, the Pacific Ocean and South America, just as the water distribution system connects the Delta to regions far to the south and east. The Delta is truly an internationally connected ecosystem with contributions to local and state enterprise, to regionally valuable fisheries, and to global biodiversity.

Finally, the concept of the Delta as a place, enshrined in the 2009 Delta Reform Act, makes tangible the human dimension of issues such as water export and management, environmental management, and habitat restoration. All these activities go on in a real place, a place where people live and play, a place with a rich cultural history. More than 570,000 people live in the greater Delta itself, mostly in the urbanizing regions around the margin of the Delta (Secondary Zone, Fig. 1). Many derive their livelihoods directly from the Delta. Most of the rest use the Delta for transportation, recreation, and as a source of water. The importance of this social dimension of the Delta is a critical consideration in every decision that affects the fate of the region.



Sandhill cranes, listed species in California. Photo: Rick Lewis

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The Delta, a Study in Complexity

Physical System Complexity

The Delta began forming about 10,000 years ago when rising sea level slowed the outflow of the Sacramento and San Joaquin rivers through Carquinez Strait. Sediments accumulated east of the strait and created a complex of low islands, shifting channels, large woody debris, and tule marshes (Whipple et al. 2012) that bedeviled early settlers but were the natural habitat of many species now in trouble.

Human activity has transformed the original complex wetlands and river floodplains into a 3,000 square km patchwork of approximately 57 islands separated by 1,100 km of sloughs and winding waterways (CDWR 2015). It is the largest delta on the Pacific coast of North America (almost the size of the state of Rhode Island). The islands of the central Delta are used primarily for agriculture, although there is a small amount of residential property. Only remnants of the original marsh remain, and many of these are highly managed (Ferner 2012).

The physical character of the Delta is at the center of some of the most complex and contentious aspects of the Delta problem. The islands of the Delta are protected by 1,800 km of levees (Fig. 3). The levees are aging and at risk of failures from numerous causes. In the 1990s, 160 levee breaches occurred, and breaches continue at a high rate (Bates and Lund 2013). Delta islands have subsided, particularly in the center and western portion of the Delta where the surfaces of many islands are now five meters or more below sea level (Moore and Shlemon 2008), increasing the risk of levee failure. Droughts and floods also increase the risk of levee failure, and this risk will likely increase as these events become more frequent and more severe with climate change. Rising sea level, another consequence of climate change, further increases the risk of levee failure. Finally, the levee system is highly vulnerable to earthquakes. There is an estimated 60% probability that an earthquake of magnitude 6.5 or greater will occur in or near the Delta sometime in the next 35 years (Moore and Shlemon 2008). Levee maintenance is costly and upgrading levees to address the growing risks is costlier still. Ultimately, prioritization of maintenance and land uses will be necessary, and incremental approaches to this have been proposed (DSC 2015). But the levee system is also interconnected, making solutions more complex. Breaks or intentional breaches in one levee could increase the risk of levee failure elsewhere in the Delta. If any of these risks results in multiple, simultaneous levee breaks, there would be cascading consequences for water transit, water exports, local economics, and use of islands to benefit the ecosystem.



Remote sensing photography of Delta levee vulnerability from a joint NASA, DWR & CalTech project.

A most important consideration in the discussion of levee maintenance is that the levees are an essential part of the California water-distribution system. Delta channels are designed, in part, to channel Sacramento River water from the north Delta to the south Delta, where it is exported via massive pumps to the Central Valley and southern California (Fig. 1). This makes the levees critical to all the human uses of Delta water. One of the greatest concerns of Delta water managers is that multiple levee failures would allow a massive salinity intrusion that would threaten the many agricultural crops and urban water supplies that rely on high-quality water exported from the Delta. Desalini-

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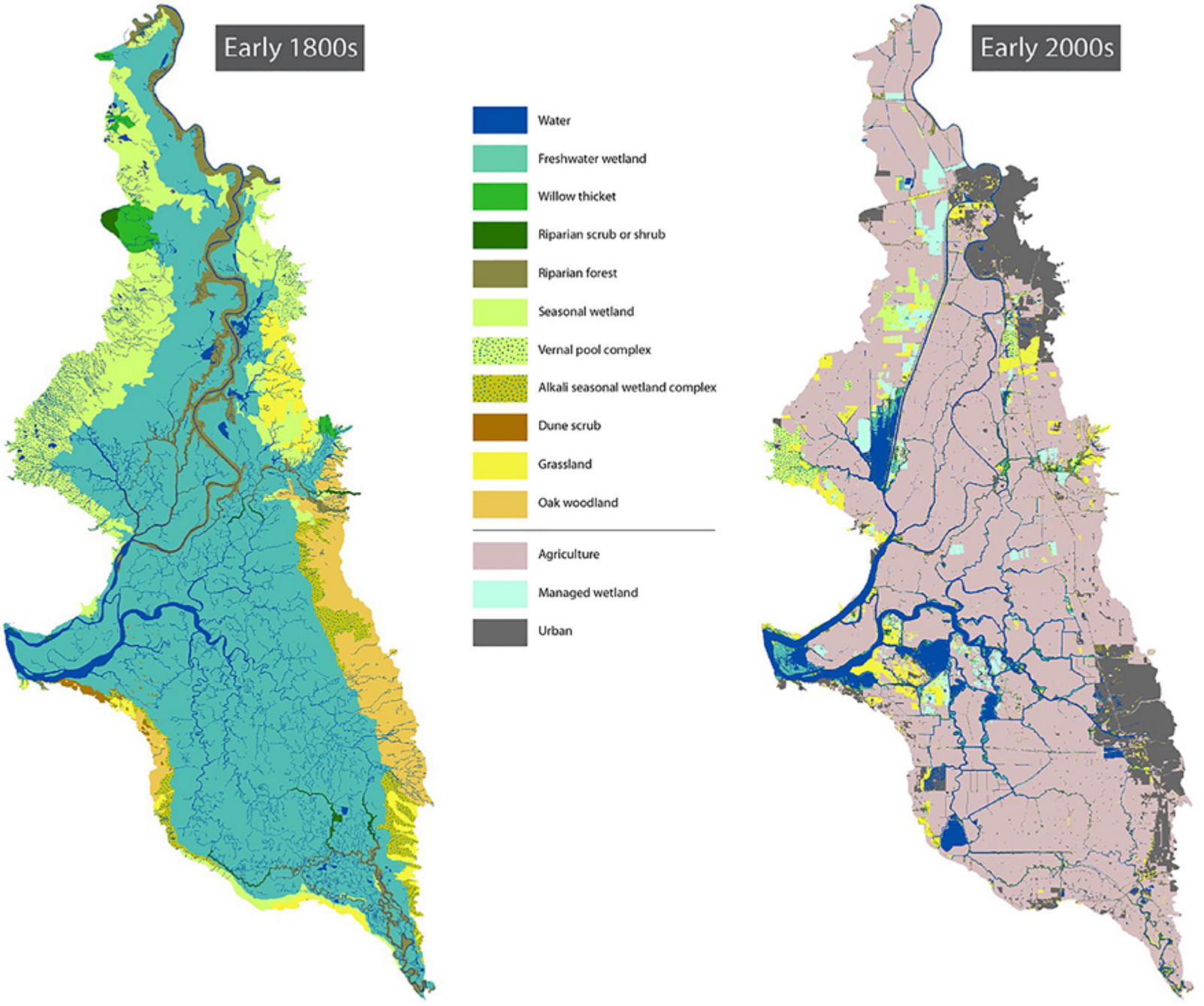


FIGURE 3. *Maps of the Delta showing the transformation from a complex system of river and distributary channels of multiple sizes and shapes to the present water transport system dominated by straightened and simplified channels. Transformation also included a major simplification of native landscape types to an agriculturally dominated landscape. From the Sacramento-San Joaquin Delta Historical Ecology Study, available at: www.sfei.org/DeltaHEStudy (Whipple et al. 2012)*

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zation is not economically feasible to remove salt from irrigation water because of the volumes (and thus cost) involved. Water treatment facilities can remove salt from drinking water, but at a considerable increase to the cost of drinking water. In addition, there is a potential risk to human health from carcinogens that form during water treatment when the source water contains higher levels of organic matter and bromide (Richardson and Postigo 2012).

Under the current levee configuration, river flows out of the Delta provide a flow barrier that prevents intrusion of seawater from San Francisco Bay. If river flows drop too low, circulation driven by the tides (the strongest hydrodynamic force in the Delta) can carry salt, dissolved organic materials, bromide, and other chemicals to the water supply diversion points in the Delta. Reservoir releases are crucial in maintaining river flows in summer and fall when rainfall is limited. Thus, exports of high-quality water from the Delta depend upon a complex interaction among climate, reservoir operations, and levee configurations. For example, during prolonged droughts, there is increased risk that reservoir supplies will not be sufficient to maintain the flows that keep salinity away from the interior Delta. At the present time, after four years of drought, reservoir supplies are shrinking, the flow barrier is weakening, and water managers are adjusting levee configurations, each with their own problems, to ensure the quality of freshwater delivered from the Delta (Rubissow-Okamoto 2014).

Water Supply Complexity

The complexity of Delta water issues partly revolves around widening demand for water from a supply that is not only limited but also highly variable and growing increasingly uncertain. California's water supply is based upon four pillars: surface water, snowpack, groundwater, and the massive human-built infrastructure that stores and redistributes water from these sources. The human-built system is effective in managing seasonal variability and regional redistribution of water. Large storms that occur in late fall, winter, and early spring are a major source of California's water supply, contributing 30% to 45% of all precipitation in central and northern California (Dettinger et al. 2011). These storms are associated with atmospheric rivers, bands of warm, moist air from the subtropics that sweep across the Pacific and make landfall as a series of high-intensity rainstorms (with snow in the high mountains). These intense storms are a mixed blessing, sometimes providing much-needed water and at other times causing significant flooding and property damage.

California precipitation comes both as rainfall and snowfall in the high mountains. Rainfall runs off immediately, and water managers must decide whether to store this water in reservoirs for water supply or to release water to reduce future flood risk (Knowles et al. 2006). Snowpack provides a critical second source of water. California reservoirs begin to release their stored water as precipitation declines in late spring. These reservoirs are then refilled by snowmelt from carefully metered mountain snowpacks. Typically, snowpack provides just under half of California's water supply (Dettinger 2015), allowing seasonal redistribution to proceed into the late fall when the rains normally begin again.

Year-to-year variability in precipitation is a predominant feature of the California climate and is by far the greatest in the U.S. (Dettinger et al. 2011). If one or two large winter storms do not materialize, the year will be dry; if there is an additional large storm or two, the year will be wet. Complex cycles of ocean climate[2] contribute to a tendency for wet or dry periods to occur over multiple years, adding another layer of complexity to the water supply picture (Cayan et al. 1998). The reservoirs were originally designed to buffer the effect of precipitation variation, but as demand has grown the system has become increasingly less flexible. The capacity of reservoirs in the Sacramento and San Joaquin basins is about 1.1 times average annual runoff (Lund et al. 2007). Thus, reservoirs allow water managers flexibility for within-year water management but no longer provide much flexibility for dealing with multi-year droughts. Finally, long-term trends in California's water supply associated with climate change portend growing uncertainty in water supply and uncertainty about strategies for coping with increasing variability (see *Uncertainties* at right).

For decades, groundwater has provided the backup to lessen the effect of surface water variability. Of the total California water supply, about 40% comes

UNCERTAINTIES ABOUT CALIFORNIA'S FUTURE WATER SUPPLY ARISING FROM CLIMATE CHANGE

- More precipitation falls as rain in late winter and less as snow in mid-winter.
- Spring snowmelt occurs earlier because of higher temperatures.
- Less snow and earlier melting means less water stored as snowpack and more uncertainty about water availability from reservoirs in the late summer and fall.
- Higher temperatures yield less runoff from the same rainfall amount.
- Average precipitation increases in northern California but decreases in southern California.
- More frequent extremes: prolonged drought, floods from atmospheric rivers.
- Greater dependence on groundwater as a buffer from extremes.
- Increasing costs and decreasing availability of that buffer as groundwater is over-exploited.

Sources: Cloern et al. 2011, Dettinger and Cayan 2014

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from groundwater wells (CDWR 2014). But in some regions groundwater is being used faster than it is being replenished. For example, groundwater supplies in the Central Valley have decreased by about 79 million acre feet since the early 1960s (CDWR 2014; Famiglietti et al. 2011). The current drought has greatly exacerbated the issue. From spring 2013 to spring 2014, before the worst of the present drought hit, groundwater levels dropped in 88% of the wells in California, with 22% of those wells dropping by more than 10 feet in that one year. As groundwater levels drop, costs increase, availability declines, and land subsidence occurs (Faunt and Sneed 2015). These signs of groundwater depletion add considerable uncertainty to the supply picture for the future. Exact measurements of groundwater reserves and the cost to access and use groundwater under different future climatic scenarios are crucial to understand the implications of current rates of groundwater depletion. In 2014, California passed legislation requiring that groundwater reserves be measured and groundwater use regulated. Implementation of this new law will require increased study and monitoring of the groundwater system at local, regional, and statewide scales.

Water Quality Complexity

A broad array of nutrients and potentially toxic chemicals enters the Delta from agricultural runoff, and there exists a long legacy of mining and industrialization in the watershed (van Geen and Luoma 1999; see *Contaminants* at right). Today, more than one hundred industries, wastewater treatment plants, and urban stormwater discharges release waste streams to the Bay and Delta (van Geen and Luoma 1999). The waste streams are mostly treated, but the Bay and Delta are, nevertheless, listed under the federal Clean Water Act as impaired because of the presence of a variety of toxic contaminants. People are advised not to eat striped bass, white sturgeon, and some diving ducks caught in the Bay and Delta because they may contain high concentrations of mercury, selenium, PCBs, or DDT breakdown products.

The complex spectrum of chemicals entering the Delta is continually changing over time as regulations, industry processes, and consumer preferences change. Federal and state regulations (e.g., the Clean Water Act, passed in the 1970s) have made substantial progress in reducing inputs of some toxic chemicals (metals, some organic compounds) into the Bay and Delta (van Geen and Luoma 1999) and reversed adverse ecological effects around what were once contamination hot spots (Hornberger et al. 1999). Nutrient input remains a source of concern, although management has improved in some areas (see *Nutrients* p. 20). Newly emerging contaminants pose another concern, and include pharmaceuticals, flame retardants and personal care products that are shown to cause endocrine disruption in fish and other organisms. There is evidence of toxicity to invertebrates at the base of the food web, at least near the sources of inputs for some pesticides (Weston and Lydy 2010) and PCBs (Jannsen et al. 2011). In addition, selenium causes reproductive effects in some native fish (Stewart et al. 2013). Finally, the fate of chemical wastes is interwoven with the physical characteristics of the modern Delta. Many aspects of water quality are affected by river inflows, Delta hydrodynamics, connections to the Bay, and changing temperature and turbidity. All of these interact with each toxic chemical to create variable exposures over time and space. In short, there is cause for concern about the potential for adverse effects from toxic contaminants, even though exact risks are difficult to assess and are confounded with the effects of other stressors.

Ecological Complexity

Before European colonization, the Delta was a vast, 3000 square km complex of low, forested islands, tule marsh, and meandering channels (Fig. 3). Parts of the Delta flooded and drained with each tidal cycle, and most of the Delta flooded during the spring, after which parts dried out during the long period of low river flow in the summer and autumn. The tidal and seasonal cycles of flooding, draining, drying, erosion and deposition created and sustained the Delta. This was the environment in which native species evolved and in which they thrived. The life cycles of many native species were cued to these natural rhythms. As tides rose and inundated island marshes, fish would invade the marsh along tidal

CONTAMINANTS IN THE DELTA AND SAN FRANCISCO BAY

- Mercury from historic mining sources contaminates food webs.
- Selenium from Central Valley irrigation drainage and Bay refineries affects reproduction of native predator species in the Bay.
- Organic chemicals remaining in sediments from historic use accumulate in food webs including DDT and its breakdown products, and polychlorinated biphenyls (PCBs).
- Pharmaceuticals, flame retardants, and personal care products from waste treatment facilities disrupt endocrine systems of aquatic organisms and birds.
- Multiple, changing pesticides from agriculture and urban uses cause toxicity at least near their points of release.
- Nutrient inputs from waste water treatment facilities and other sources affect Delta food webs.
- Nitrogen, phosphorous and other nutrients stimulate nuisance or toxic algal blooms and water weeds as turbidity of water declines.

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Emergency barrier erected on the False River in 2015 to prevent salinity intrusion into areas tapped for drinking and irrigation water. Photo: Bird's Eye View

"Times of severe drought provide a stark reminder of the complexities of current and future Delta challenges. Drought also underscores the importance of planning for a rapidly changing world. Quick fixes to solve one problem may be necessary, but holistic integrated solutions are ultimately required."

— CLIFFORD DAHM

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NUTRIENT INPUTS: A CHANGING ISSUE WITH REGIONAL IMPLICATIONS

- The waterways of the Delta are enriched with nitrogen, phosphorus, and other nutrients that come from natural sources, agricultural inputs and wastewater treatment facilities.
- Nutrients typically fuel the growth of phytoplankton (open water algae) and aquatic plants that form the base of the food web in the Delta. Plant productivity determines the availability of food resources to zooplankton, aquatic invertebrates, and fish.
- Annual primary production of the phytoplankton in the Delta has typically been low compared with other estuaries because of limited light penetration into turbid waters and the low residence time of water in the Delta (Jassby et al. 2002). Feeding by bottom-dwelling animals that filter the water column also reduces phytoplankton availability to the pelagic food web.
- Summer blooms of a harmful algae (*Microcystis aeruginosa*), that began in 1999, are a new concern (Lehman et al. 2005), for the first time raising the specter of ecological problems from nutrient inputs.
- The problem has been accentuated by an increase in the clarity of the water that allows more light penetration. This occurred as the residual sediments from hydraulic mining passed through the ecosystem and dams captured sediments that originated upstream.
- Nutrient availability, especially ammonium from wastewater treatment plants, facilitated the invasion of two non-native aquatic plants (Brazilian waterweed, and water hyacinth) which are now well established in the Delta (Santos et al. 2009). Both grow well in high nitrogen environments if light is available, and are effective at using ammonium as a source of nitrogen.
- Programs are being initiated to reduce nitrogen discharges. A sustained commitment to experimental nitrogen-removing technologies illustrates that creative new ways to address stressor problems exist. Although it is uncertain to what degree nitrogen reductions alone will shift trajectories for native species, it is an example of bold, prudent action with a low probability of cascading negative outcomes.



Photo: Bird's Eye View

channels, feeding on the abundant food resources of the marshes before retreating into the main Delta channels as the tide ebbed. Shorebirds would also populate the emerging mud flats to probe for food. Fish species such as splittail were adapted to the seasonal flooding, moving onto the floodplains to spawn during the spring floods and retreating to the main river channels with their young as the flood receded.

Very little of this historic ecosystem remains (Fig. 3). The modern Delta is a patchwork of leveed islands separated by channels. These islands do not flood on tidal or even seasonal cycles, unless levees fail. Little wetland habitat remains, and what does is not subject to the extent of flooding and drying that characterized the historic wetlands.

Beyond transformation of Delta habitats, human development imposes a wide array of additional drivers of environmental change (Fig. 2) with effects that vary among species, locations, and with time. The severity of the cumulative effects of these stresses is manifested in the estimate that 80% of native fish species are in decline (Hanak et al. 2011). Many of the risks from individual stressors are understood, but the relative importance of each stressor to the cumulative consequences is difficult to pinpoint. Moreover, natural cycles and climate change constantly shift the baseline conditions in the ecosystem (Cloern and Jassby 2012), adding to the complexity of determining why changes are occurring. As a result, predicting the outcome when water operations, land forms, or the levees are changed is uncertain, at best.

Since passage of the Central Valley Project Improvement Act of 1992, federal and state agencies have focused attention on how to sustain viable populations of native species in the Delta while still maintaining water exports from the Delta. Early attention focused on prevention of mortality at the export pumps (see *Preventing Mortality* p.21) and management of flows through the Delta for the benefit of native species. More than a decade of litigation has been driven by uncertainties about the effectiveness of the regulations that curtail exports, and how these curtailments and other water management operations, in real time, negatively affect the populations of legally

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PREVENTING MORTALITY OF LEGALLY PROTECTED FISH SPECIES IN THE DELTA

- One focus of Delta management is regulations that curtail water exports when legally protected species, such as salmon and Delta smelt, are drawn into the pumps.
- At a larger scale, water project operations also affect water movement and water quality throughout the greater Delta changing, for example, cues that fish such as salmon use to direct their seasonal migration from spawning rivers to the sea and back.
- Today only 5% of the young salmon that enter the Delta in their seaward migration survive to enter the ocean (del Rosario et al. 2013). That proportion dropped from 40% in the 1990s.
- It is difficult to determine unambiguously how much of this mortality is caused by water operations, how much by habitat change or how much by interactions with other causes of mortality such as predation by non-native species (Fig. 2).
- Survival of migrating chinook salmon has been improved to 86 – 94% by scientifically supported actions in the Columbia River system (northwest US; Muir et al. 2001). This means improving migratory survival is feasible and is an example of an opportunity to improve the situation for native species.



Steve Martarano/USFWS

HOW MUCH WATER FOR THE ENVIRONMENT?

- It is common to hear that only 50% of California's water supply is diverted for human use and that the other 50% goes to the environment. (Different sources give slightly different figures for the water balance.)
- In general, one-third of all California water (60% of the environmental water) is in wild and scenic rivers far north of the Delta watershed. These rivers are protected by laws that were established in the 1960s and have been repeatedly declared off limits to the Delta because of poor accessibility, environmental protection and economic reasons.
- The most controversial segment of all water is the approximately 10% (20% of environmental water) that flows through the Delta.
- Most of this water is used for increasing flow that prevents salinity intrusion into the Delta pumping stations. This water may be beneficial to the environment, but it is just as important to human water uses.
- 1-2% of the water is used for wetlands maintenance, which is not highly controversial.
- Most of the controversy is over the 1% or so of the water used to protect endangered species of fish.
- California's recent water wars are about this last remnant of the original inflows to the Delta, a sign of the tightening supply versus demand equation.

Sources: Fox 2015; Mount 2011

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THE PELAGIC ORGANISM DECLINE

- Four pelagic species, two native species (Delta smelt and longfin smelt) and two introduced species (juvenile striped bass and threadfin shad), declined to record low numbers in only a few years beginning in 2002 - 2004.
- The collapse of these populations occurred despite management actions intended to improve conditions in the Delta and relatively moderate hydrological conditions at the time.
- Before this event, most attention had focused on water exports as the principal cause of the declining abundance of native species. Careful re-examination and re-analysis of data was catalyzed by the dramatic change in fish populations.
- Although different stresses (Fig. 2) figured most prominently in different studies, all showed that direct effects of water exports was only one factor - and perhaps no the most important factor - in this most recent species decline in abundance.
- Conceptual models, rooted in ecological theory, are developing ideas about how a number of drivers of change interact to cause precipitous declines in species. These models are qualitative and generalized, but do provide a useful framework for organizing and synthesizing both data and ideas related to the conservation of pelagic fish species.



Delta smelt. Photo: Dave Giordano, Ecositemedia

protected fish species. Even defining water allocations for the environment versus human use has been a source of controversy (see *How Much...* p. 21).

As more has been learned about the Delta ecosystem, it is clear that recovery of native species will require cumulative effects from all stressors to be addressed. A good example of the dire circumstances that characterize the Delta ecosystem is the recent sharp decline of several native fish species, termed the pelagic organism decline or POD (see *Pelagic Organism* above). Statistical studies, improved conceptual models, and improvements in quantitative modeling of the environment all point to multiple causes for the POD, and perhaps a broad change in the overall ecological regime of the Delta. Initial studies of the POD were focused on declines in abundance of a few species such as Delta smelt or longfin smelt and their link to water diversions. But broader conceptual models (e.g., IEP MAST 2015) led to the recognition that more species and other events were involved with this change. The idea that focusing action on one problem will allow relaxation of the regulation of others has underlain much of the contentious dialogue about Delta restoration. The POD studies and others show that concerted action on multiple fronts offers the best opportunity for progress.

It is difficult to pin down the causes of events such as the POD, in large measure because today's Delta is essentially an alien habitat to the hundreds of native species that try to live there. Under these circumstances, it is no surprise that many native species are struggling to survive and that many factors are implicated in their low population numbers. The Delta cannot be returned to the way it was 200 years ago. The great challenge is to figure out how to provide enough suitable living space in the modern Delta for these species to persist (Moyle et al. 2012). The challenge is increased by the continually evolving nature of the ecosystem as new species arrive, and as land use and climate change (see *Non-Native Species* p. 23).

Institutional Complexity

Because managing water and environment is inherently complex, the tendency is to break the perceived problem down into what seem like manageable pieces and address each piece more or less independently. The result has been a plethora of agencies, departments, and commissions at federal, state, regional and local levels of government, each dedicated to addressing one or more components of water and environmental management (Fig 4). Private interests, like the State Water Contractors, and non-governmental organizations, like the San Francisco Estuary Institute and the Nature Conservancy, are also involved. The repeated crises in management of the Delta have only served to increase this institutional complexity (DSC 2013).

When so many institutions with different mandates are involved in management of a critical resource such as the Delta, integration and coordination are critical.

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Small irrigation pump draws from Delta waterway infested with invasive aquatic plants (left); Overbite clam (below). Photos: Bird's Eye View and Andrew Cohen (respectively).

Although there are notable examples of long-standing cooperation and integration among state and federal agencies (the Interagency Ecological Program, for example), there are also notable examples of decision-making that is fragmented and uncoordinated, leading to inefficiency and poor outcomes (NRC 2012). One consequence of the fragmentation of responsibility and authority over the Delta is the increased difficulty of addressing Delta problems. The complexity provides a multiplicity of ways for individuals and organizations that are dissatisfied with water or environmental management to seek redress for their dissatisfaction through litigation. The Delta Reform Act of 2009 attempted to address this complexity by establishing the Delta Stewardship Council with responsibility for achieving the coequal goals of a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. Time will tell whether the Council can achieve sufficient cooperation or has sufficient authority to address institutional complexity.

NON-NATIVE SPECIES AND THE RESTORATION CONUNDRUM

- Aquatic and terrestrial habitats are heavily invaded by non-native species delivered by international shipping, recreational boating, the horticulture and pet industries, agriculture, or deliberate introduction.
- San Francisco Bay and the Delta have been described as the most heavily invaded estuary in the world (Cohen and Carlton 1998). Cohen and Carlton (1998) showed that 40-100% of species found in various aquatic habitats was non-native.
- The consequences of invasions by exotic species can be dramatic.
- A 1986 invasion of the overbite clam changed phytoplankton dynamics in Suisun Bay, and eliminated what was once a large spring bloom of plants essential to native food webs.
- Introduced predators, like striped bass and largemouth bass, have grown to large populations in the Delta, and their predation on native fishes is thought to contribute to the decline of such species.
- Restoration of shallow water habitats is often plagued by invasive plants and invasive predators instead of fostering more habitat for native species. Currently, it is unclear how best to reduce populations of invasive species or how to increase the certainty that new habitat will be best suited for native species.



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The Role of Science

As we noted earlier, the Delta is one of the most studied ecosystems in the world. A growing understanding underpins ongoing adaptations in managing the Delta. Throughout the decades of conflict over water issues, all parties have recognized that advancing the state of scientific knowledge is fundamental to making constructive progress. As we enter an era of increasing uncertainty about climate and water supply, commitments to multi-institutional science that informs policy beyond agency decisions are critical. Continuing advancement of scientific understanding and effective integration of science into management will require science that embraces differences of scientific opinion, structures science in a way that is useful for management decisions, and quantifies uncertainty. Looking into the future of complex problems like the Delta will require scientific models that can simulate the consequences of different management approaches. Such models have been developed for water operations; are in their early stages for the ecosystem (DiGennaro et al. 2012) and climate change (Cloern et al. 2011); and have been used to envision alternative futures for the Bay-Delta (e.g., Lund et al. 2010). The understanding necessary to integrate and strengthen these models is growing rapidly, but is scattered among agencies and research institutes and needs to be brought together. Challenges remain in merging models of various types, and in ensuring the model output is sufficiently reliable for management. But if carefully implemented and interpreted, such models can provide valuable guidance to policy, management, and science (Healey et al. 2008).

Continuously improving models and scientific understanding of the Delta problem is necessary but not sufficient to manage successfully the complex technical, political and resource challenges facing the Delta. There will always be uncertainties that surround any action. Difficult political choices will be necessary. Adaptive management is the preferred approach to implementing management actions in the face of uncertainty. Regular monitoring and evaluation of the Delta's response to management is the best way to detect unexpected outcomes and adjust management actions to deal with uncertainties. Although a number of monitoring and assessment programs exist to aid in such evaluations, there is not as yet a unified set of performance criteria for the key dimensions of the Delta problem. As adaptive management becomes more fully implemented, such criteria must be developed, implemented, and reported on regularly. Effective adaptive management also requires collaboration, communication, and transparency among all interest groups as well as a willingness to overcome the institutional barriers to collaborative decision-making. Recent commitments to collaborative decision-making are encouraging (e.g., the Collaborative Adaptive Management and Policy Team) but sustaining those initiatives has always been a challenge.

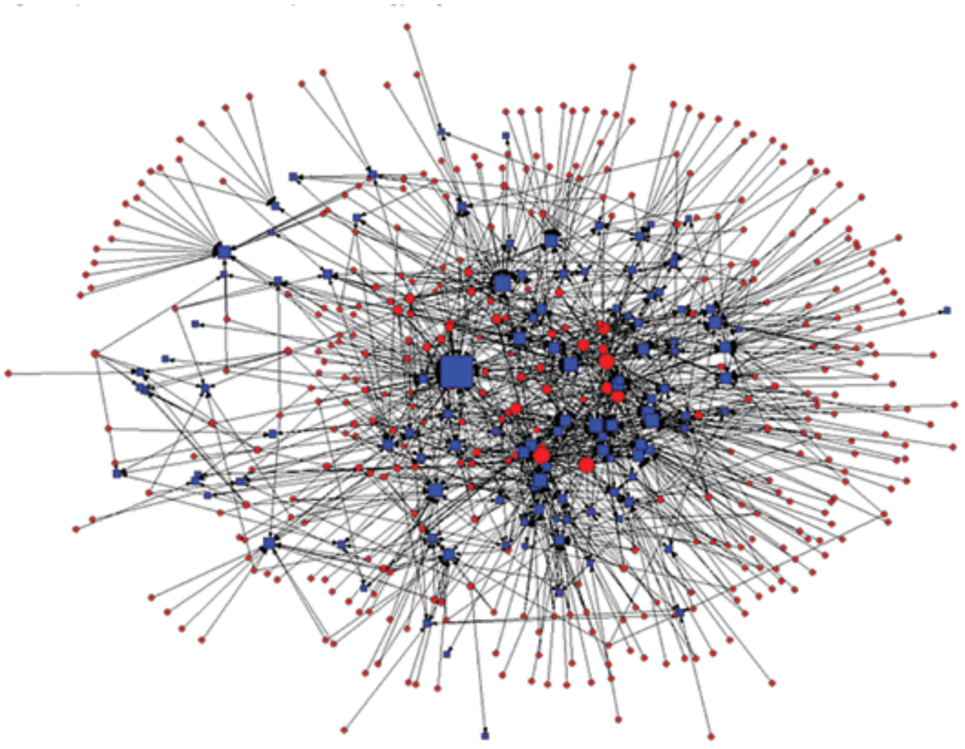


FIGURE 4. *Complexity diagram of actors (red circles) and institutions (blue squares) involved in water governance of San Francisco Bay (With permission from Lubell et al. 2014).*

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CONCLUSION



Fishing family along the Sacramento River. Photo: Bird's Eye View

Continuously

improving models and scientific understanding is necessary but not sufficient to manage successfully the complex technical, political and resource challenges facing the Delta. Difficult political choices will be necessary in the face of uncertainty. Risks can be reduced by tracking the response of the Delta, in all dimensions, and adjusting actions accordingly

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Conclusions: Coping with Complexity

The Sacramento-San Joaquin Delta is at the hub of an interconnected water-delivery system that feeds the impressive economy of California and also influences the economies of most of the western U.S. At the same time, the Delta is an ecological resource of international significance with a rich social and cultural history. The challenge in managing the Delta is to preserve all these important functions in the face of a widening demand for water that frequently exceeds available supply, including demand from a growing population, a growing economy, valuable agriculture, and a unique environment. The challenge is enhanced by climate change, which is raising temperatures, changing storm patterns, and reducing snowpack, leading to an increasingly uncertain supply of water and changing environmental conditions. Unsustainable mining of groundwater (Bredehoeft and Alley 2014) is increasing costs and decreasing the availability of a source of water that has long provided a buffer against drought. Water managers no longer have the flexibility they once had in dealing with the multi-year droughts that are inherent to the California climate. Managing the water supply system alone is complicated. But add in the imperative to sustain the ecological and social values of the Delta and every decision becomes considerably more complex. The current arrangement for addressing this combination of complexity, uncertainty, and change is unsustainable as evidenced by both declines in native species and dissatisfaction with water deliveries.

From an environmental perspective, the ecosystem of the Delta is vastly transformed from its original state, making life difficult for a host of native species. Multiple interacting factors affect the well-being of native species. Some of these factors are well understood, but their interactions and cumulative consequences are not, making it impossible to make definitive statements about what is causing native species to decline. As a result, predicting the outcome when water operations, land forms, or the levees are changed is uncertain, at best. Nevertheless, opportunities exist to conserve and restore aspects of the native system and to structure the rest of the Delta to make it more hospitable to native species. Realizing those opportunities without jeopardizing water supply is the ultimate challenge in managing the Delta.

Many of the approaches used in water-scarce environments elsewhere are under-utilized in the Delta. While adjustments to the infrastructure as it ages are essential, opportunities exist to simultaneously redefine bold action as we pursue proven (although not always initially popular) ways to work more effectively with what we have (www.energy.ca.gov/wet/). Examples include the following:

- Groundwater recharge and conjunctive use offer storage potential beyond that available for surface waters (CIWR 2015).
- Initiatives to promote water reuse, water recycling, and desalination in selected circumstances are under-utilized and can help address the imbalance between demand and supply (ACWA 2015).
- Priorities for maintenance and upgrades of the levees can be built from growing understanding of physical vulnerabilities, climate change, economics, and water transit needs (DSC 2015).
- Making water conservation a continual, long-term, statewide investment is a necessary part of accepting water scarcity (USEPA 2015; NatGeo 2014).
- Greater attention to both the tributaries and the Bay in Delta planning, including wetlands restoration, offer opportunities for both protection from sea level rise and ecosystem restoration (Save the Bay 2015).
- Continuing the precedent of improving water quality from tributary inputs and within Delta sources can help counter the expansion of exotic species (Brown and Caldwell 2015).

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- Risk reduction for catastrophic Delta infrastructure failure can include investing in targeted levee improvements, addressing additional stresses from sea-level rise and planning for climatic extremes such as atmospheric rivers and long-term droughts.
- Making the "One Delta, One Science" concept a reality will improve the underpinning for political actions in the face of uncertainty (DSP 2013).

Complex, wicked problems like the Delta rarely yield to the simplistic solutions directed at only one dimension of the problem. The lack of flexibility resulting from the already complete allocation of a shrinking water supply, combined with the serious deterioration of the native ecosystem, will reduce the effectiveness of many traditional engineering solutions in the Delta. History shows that large-scale, irreversible, physical changes in the water system are particularly risky (see *San Luis Drain* opposite) unless they promote flexibility and are implemented incrementally (see *South Florida Example* p. 28). Incremental, as used here, does not imply "small," but "implementation in stages" such that lessons learned from early increments can be used to improve design of later increments. While economics alone may not always support such an approach, it is time to recognize that other dimensions of the issue also must carry weight.

New approaches to scenario-building and modeling can help managers explore the potential outcome of major management initiatives and anticipate problems before they arise. Modeling and scenario-building needs to be a collaborative, multi-institutional activity. As we enter an era of increasing uncertainty about climate, water supply, the fate of the Delta's native ecosystem, and institutional complexity, multi-institutional collaborative approaches will become increasingly important.

IMPLEMENTING INADEQUATELY UNDERSTOOD ENGINEERING SOLUTIONS: THE SAN LUIS DRAIN EXAMPLE

An example of implementing a simple solution to a complex problem is the issue of irrigation drainage in the Central Valley.

- As a part of the Central Valley Water project in the 1950s, governments were obligated to deal with the return drainage that resulted from the export of water from the Delta.
- The simplest solution was to build drainage infrastructure under the agricultural fields and a canal (the San Luis Drain) to take the drainage to San Francisco Bay.
- The first increment of that system was completed in the 1980s with the drainage canal temporarily terminating near Kesterson Wildlife Refuge.
- Soon after the drainage disposal began, severe deformities were observed in birds, including birds that were part of the international Pacific Flyway. Later studies showed a massive ecological disaster, which was eventually attributed to heretofore unknown selenium contamination in the drainage (Presser 1994).
- Later studies showed that a similar, if not worse outcome was likely if the drain was extended to the Bay (Presser and Luoma 2000).
- Dealing with this problem has been much more expensive than the San Luis Drain itself. Adverse effects of irrigation drainage products such as selenium will always be an important consideration in any plans that change water redistribution systems. The selenium problem cannot be solved, but it is being incrementally managed by land retirement and multiple, local in-valley treatment systems. The San Luis Drain was a multi-million dollar "stranded investment" that resulted from a poorly understood, simplistic engineering "solution" to a complex problem with many dimensions.

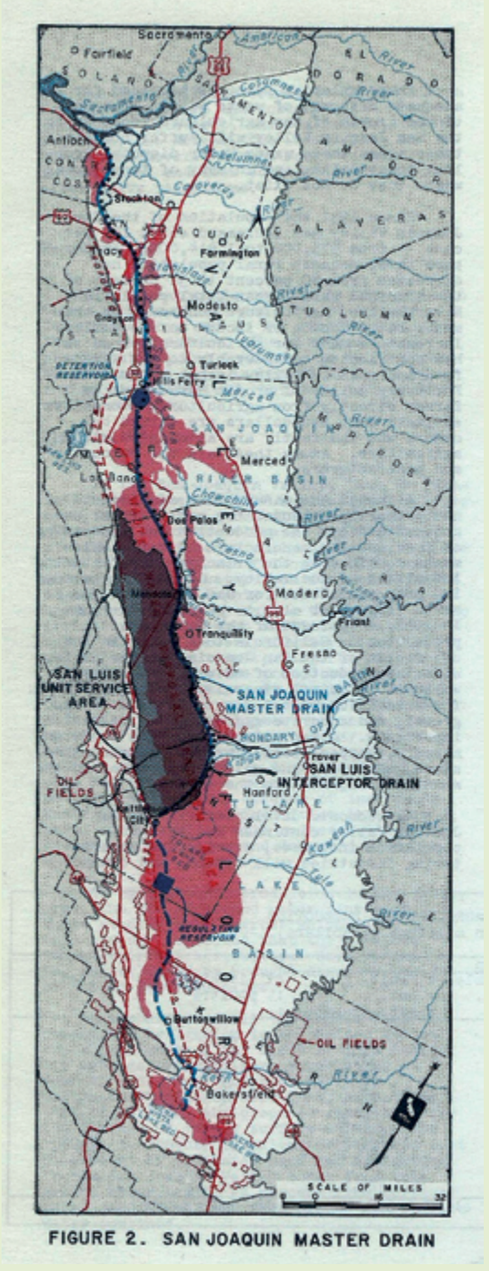


FIGURE 2. SAN JOAQUIN MASTER DRAIN

San Joaquin Valley master drain plan circa 1965. Map: DWR

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INCREMENTALLY APPROACHING A COMPLEX PROBLEM: A SOUTH FLORIDA EXAMPLE

Most Delta restoration projects have not been in place long enough to draw conclusions about the approaches being used. But the Kissimmee River in south Florida provides an example of how an incremental approach to restoration can work. Key elements of this widely proclaimed restoration success are listed here (see Dahm et al. 1995):

- River channelized for flood control from 1962-1971 at a cost of $38 million
- Collapse of key bird and fish communities
- Mounting interest and public pressure for restoration
- Pilot project to reroute some canal water back onto floodplain from 1984-1988 with positive responses from birds and fish
- Design phase for a large-scale restoration in the early 1990s with a rigorous evaluation program
- Testing sediment plug from old spoils piles to see if the channelized river could be rerouted onto the old floodplain in 1996; plug functioned as designed
- Construction of Phase One restoration 2000-2001 for about 30 kilometers of river and 3,200 hectares of wetland
- Initial restoration largely successful
- Currently carrying out Phase Two of restoration
- Restoration costs to date approaching one billion dollars



Kissimmee River restoration, showing flood control channel filled in so river meanders could be restored. Photo: South Florida Water Management District

Water scarcity has defined and will continue to define the future of the Delta and all that is linked to it. California has risen to the challenge of water scarcity in the past to build an economy and a society that is, in many ways, the envy of the world. The present problem of water scarcity seems more complex and less amenable to traditional engineering solutions than in the past. But California has the tools and the intellectual resources to manage the problem and to achieve the twin goals of a reliable water supply and an ecologically diverse Delta ecosystem.

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Yolo Bypass floodplain during drought.
Photo: Bird's Eye View

As we enter an era of increasing uncertainty about climate, water supply, the fate of the Delta's native ecosystem, and institutional complexity, multi-institutional collaborative approaches will become increasingly important. California has the tools and the intellectual resources to manage these problems and, as difficult as they are, achieve the twin goals of reliable water supply and an ecologically diverse Delta ecosystem.

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Footnotes

1 Widening demands for water are expected from projected population growth, economic growth, and demands to use water for the environment. The Delta Reform Act of 2009 states its "coequal" goals as "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place" (CA Water Code 85054). "Widening" means overall demand, not necessarily increasing demand per capita.

2 The El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) phenomena are two examples of ocean climate influences (http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html).

3 http://www.bloomberg.com/news/articles/2015-01-16/brown-s-california-overtakes-brazil-with-companies-leading-world http://ajed.assembly.ca.gov/keyinsightsintoinnovation and https://www.census.gov/foreign-trade/statistics/state/data/ca.html http://www.ppic.org/content/pubs/report/R_512EHR.pdf https://watershed.ucdavis.edu/files/biblio/R_314EHR_Paying_for_Water.pdf http://en.wikipedia.org/wiki/Economy_of_California http://www.delta.ca.gov/res/docs/ESP/ESP_ES_FINAL.pdf Howitt et al. 2014 https://watershed.ucdavis.edu/files/biblio/DroughtReport_23July2014_0.pdf http://www.delta.ca.gov/res/docs/ESP/ESP_ES_FINAL.pdf http://www.washingtonpost.com/wp-srv/inatl/longterm/mia/part1.htm

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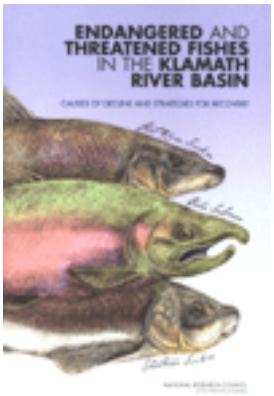








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Committee on Endangered and Threatened Fishes in the Klamath River Basin, National Research Council

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This report has been reviewed in draft form by persons chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the National Research Council Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The committee and the NRC thank the following for their review of this report:

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or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Paul Risser, Oregon State University, and Stephen Berry, University of Chicago. Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the committee and the National Research Council.

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Preface

The federal Endangered Species Act (ESA) of the United States has the admirable goal of minimizing extinction rates through regulations and actions that are intended to produce recovery of species that are in critical decline. For any given species listed under the act, agencies implementing the ESA must choose from an immense array of possibilities the ones most likely to lead to recovery, and in doing so they must forego the luxury of an extended interval of monitoring or experimentation.

Remedies for the recovery of species often have harmful or at least frustrating effects on people and institutions. In such instances, the affected parties often are especially dissatisfied with the implementation of remedies that are not absolutely secure scientifically. But the ESA does not allow delay, which would defeat its purpose. Thus, some of the remedies prescribed by agencies ultimately will prove ineffective and may cause economic or social disruption without any tangible benefit to listed species.

The National Research Council's Committee on Endangered and Threatened Fishes in the Klamath River Basin deals in its final report with three Klamath basin fish species listed under the federal ESA. The committee's work is broad in that it encompasses the entire actual or potential range of those species in the Klamath basin, regardless of the boundaries set by ownership or management, and with all the potential environmental changes that could suppress or promote the welfare of the species. The committee, in response to its charge, has given particular attention to evaluation of the certainty underlying specific kinds of remedies that might lead to the recovery of species. The issues that the committee has dealt with are specific

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to the basin, but the Klamath basin presents in microcosm most of the problems that are generally identified with implementation of the ESA. Especially prominent in the Klamath basin is controversy over the extent to which remedies that have uncertain outcomes should be pursued even though they are economically or socially painful.

One issue especially well highlighted by the Klamath basin is the relative weight that should be given to professional judgment as opposed to direct empirical evidence that appears to be contradictory to that judgment. Whereas professional judgment is essential for successful ESA implementations where site-specific information is absent, its use is more problematic when initial judgments fail empirical tests. Reversal of an initial judgment may seem to be an abandonment of duty or principle, but it is unrealistic to expect that all initial judgments will be proved scientifically sound. By raising this issue in specific terms in its interim report, the committee has generated considerable controversy in the Klamath basin. The committee believes, however, that a rational and consistent resolution of the issue works toward the long-term stability and effectiveness of the ESA. The committee's final report gives a more detailed view of the committee's approach.

The committee owes a great debt of gratitude to the National Research Council staff members who have guided it through the production of the final report. Suzanne van Drunick, project director, has been especially critical to the success of the committee; David Policansky, James Reisa, and Bryan Shipley also helped the committee in numerous ways; Norman Grossblatt, Mirsada Karalic-Loncarevic, and Kelly Clark helped with the many details that made the report ready for publication. The committee is also appreciative of James MacMahon and other board members for their oversight of this study. The committee is grateful to Leslie Northcott of the University of Colorado for helping to produce the manuscript of the report and to Marylee Murphy and Rebecca Anthony of the University of Colorado for their work on figures and tables.

The committee benefited immensely from the help and advice of scientists and administrators who have dealt with environmental issues in the Klamath basin and to contributions from the citizens, organizations, and tribes working and living in the basin. The committee's highest hope is that its work will be a contribution to the long-term general welfare of everyone who resides in, visits, or cares about the Klamath basin.

The National Research Council process for producing the report involves extensive reliance on external reviewers. The committee thanks the reviewers of its final report for their thoughtful contributions.

William M. Lewis, Jr., *Chair*
Committee on Endangered and Threatened
Fishes in the Klamath River Basin

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Summary

Two endemic fishes of the upper Klamath basin (Figure S-1), the shortnose sucker (*Chasmistes brevirostris*) and the Lost River sucker (*Deltistes luxatus*), were listed as endangered under the federal Endangered Species Act (ESA) in 1988 by the U.S. Fish and Wildlife Service (USFWS). USFWS cited overfishing, water management, habitat alteration, nonnative species, poor water quality, and several other factors as likely contributors to the decline of the fishes, which once were very abundant. In 1997, the Southern Oregon Northern California Coast "evolutionarily significant unit" of coho salmon (*Oncorhynchus kisutch*), which is native to the Klamath basin and several adjacent drainages, was listed by the National Marine Fisheries Service (NMFS) as threatened under the ESA. NMFS cited water management, water quality, loss of habitat, overfishing, and several other potential causes of decline for the coho salmon.

In 2001, in response to biological assessments prepared by the U.S. Bureau of Reclamation (USBR), the two listing agencies issued biological opinions that required USBR to take numerous actions, including maintenance of higher water levels in Upper Klamath Lake and two reservoirs on the Lost River and higher flow of the Klamath River below Iron Gate Dam. Release of the two biological opinions coincided with a severe drought. Because of the new biological opinions and the drought, USBR was prohibited from releasing large amounts of water to farmers served by its Klamath Project, which diverts waters from Upper Klamath Lake and the upper Lost River for use in irrigation through USBR's Klamath Project. The unexpected restrictions on water supply, which severely impaired or eliminated

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FIGURE S-1 Map of the Klamath River basin showing surface waters and landmarks. Source: Modified from USFWS.

agricultural production on the 220,000 acres irrigated by the Klamath Project, caused agricultural water users and others to question the basis for water restrictions, while other parties, fearing adverse effects of the Klamath Project on the endangered and threatened fishes, supported the restrictions.

In late 2001, the Department of the Interior and the Department of Commerce asked the National Academies to form a committee (the Committee on Endangered and Threatened Fishes in the Klamath River Basin)

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to evaluate the strength of scientific support for the biological assessments and biological opinions on the three listed species, and to identify requirements for recovery of the species. The committee was charged to complete an interim report in early 2002, focusing on effects of the Klamath Project, and to complete a final report in 2003 that would take a broad view of the scientific aspects of the continued survival of the listed species (Box S-1). This is the committee's final report.

In its interim report of February 2002, the committee found substantial scientific support for all recommendations made by the two listing agencies for the benefit of the endangered and threatened species, except for recommendations requiring more stringent controls over water levels in Upper Klamath Lake and flows at Iron Gate Dam. The committee also noted, however, that USBR had not provided any substantial scientific support for its own proposal of revised operating procedures, which might have led to lower mean water levels or lower minimum flows.

In 2002, USBR issued a new biological assessment that dealt with the two endangered sucker species and the threatened coho salmon. In response, USFWS prepared another biological opinion on the suckers, and NMFS prepared another biological opinion on the coho salmon. These documents reflect a closer interaction between the agencies than in previous years. USBR moved toward more restrictive operational practices than it had previously proposed and toward development of reserve water supplies; USFWS and NMFS were more cautious in requiring actions whose basis would be contradicted by site-specific studies, and they acknowledged the need to consult with parties in addition to USBR. The biological assessment and the two biological opinions for 2002 cover a 10-yr interval (2002–2012), during which time the listing agencies may require additional consultation and may revise their biological opinions.

PRINCIPAL FINDINGS OF THE COMMITTEE

Lost River and Shortnose Suckers

Upper Klamath Lake

Although suckers of all age classes are present in Upper Klamath Lake, population densities of suckers are low, and there are no signs that the populations are returning to their previously high abundance.

Suckers spawn in tributaries to Upper Klamath Lake, but they are blocked from much potentially suitable spawning habitat by Chiloquin Dam on the Sprague River (Figure S-1). Numerous smaller blockages and diversions also are present but are poorly documented. Expansion of spawning on the Sprague River could increase the abundance of fry descending to

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Box S-1. Statement of Task

The committee will review the government's biological opinions regarding the effects of Klamath Project operations on species in the Klamath River Basin listed under the Endangered Species Act, including coho salmon and shortnose and Lost River suckers. The committee will assess whether the biological opinions are consistent with the available scientific information. It will consider hydrologic and other environmental parameters (including water quality and habitat availability) affecting those species at critical times in their life cycles, the probable consequences to them of not realizing those environmental parameters, and the interrelationship of these environmental conditions necessary to recover and sustain the listed species.

To complete its charge, the committee will:

1. Review and evaluate the science underlying the Biological Assessments (USBR 2001a,b) and Biological Opinions (USFWS 2001; NMFS 2001).
2. Review and evaluate environmental parameters critical to the survival and recovery of listed species.
3. Identify scientific information relevant to evaluating the effects of project operations that has become available since USFWS and NMFS prepared the biological opinions.
4. Identify gaps in the knowledge and scientific information that are needed to develop comprehensive strategies for recovering listed species and provide an estimate of the time and funding it would require.

A brief interim report will be provided by January 31, 2002. The interim report will focus on the February 2001 biological assessments of the Bureau of Reclamation and the April 2001 biological opinions of the U.S. Fish and Wildlife Service and National Marine Fisheries Service regarding the effects of operations of the Bureau of Reclamation's Klamath Project on listed species. The committee will provide a preliminary assessment of the scientific information used by the Bureau of Reclamation, the Fish and Wildlife Service, and the National Marine Fisheries Service, as cited in those documents, and will consider to what degree the analysis of effects in the biological opinions of the Fish and Wildlife Service and National Marine Fisheries Service is consistent with that scientific information. The committee will identify any relevant scientific information it is aware of that has become available since the Fish and Wildlife Service and National Marine Fisheries Service prepared the biological opinions. The committee will also consider any other relevant scientific information of which it is aware.

The final report will thoroughly address the scientific aspects related to the continued survival of coho salmon and shortnose and Lost River suckers in the Klamath River Basin. The committee will identify gaps in the knowledge and scientific information that are needed and provide approximate estimates of the time and funding needed to fill those gaps, if such estimates are possible. The committee will also provide an assessment of scientific considerations relevant to strategies for promoting the recovery of listed species in the Klamath Basin.

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Upper Klamath Lake and would beneficially extend the interval over which they arrive at the lake.

The water quality of the tributaries to Upper Klamath Lake is poor for some native fishes but is probably adequate for the listed suckers. The tributaries do, however, show loss of riparian vegetation and wetland (largely due to agricultural practices), which could adversely influence the survival of fry. The physical condition of channels in general and spawning areas in particular is degraded, but the nature and extent of degradation is poorly documented for the tributaries.

Endangered suckers also spawn near springs that emerge at the margin of Upper Klamath Lake. Some apparently suitable spawning sites are no longer used, probably because entire groups of fish that used the sites were eliminated during the era of fishing, which ended in 1987. Lakeside spawning behaviors are associated with a specific range of depth. During dry years, the amount of appropriate spawning substrate with appropriate water depth is reduced by drawdown of the lake. Data on year-class strength show no indication of a relationship between year-class strength and water level, which might be expected if drawdown were strongly suppressing production of fry.

Fry are strongly dispersed from their points of origin by currents and ultimately are found in shallow water in or near emergent vegetation at the margins of the lake. Loss of such vegetation, especially near the tributary mouths, could be disadvantageous to the fry. The area around the lake associated with preferred depths and presence of emergent vegetation varies with water level; drawdown, especially in dry years, reduces this area. Standardized sampling of fry and studies of year-class strength for large fish do not, however, indicate associations between water level and abundance of larvae.

Juveniles seek somewhat deeper water than larvae. There is substantial juvenile mortality, but current information is insufficient to show whether it is extraordinary in comparison with mortality in other lakes that have more favorable living conditions.

Subadult and adult fish seek deeper water than younger fish and congregate in specific areas of Upper Klamath Lake. In contrast to the tributaries, poor water quality in the lake itself appears to be their greatest vulnerability. Direct evidence of harm to large fish by poor water quality includes physical indications of stress and mass mortality of large fish ("fish kills") at times of exceptionally poor water quality.

Mass mortality of large fish occurs during the second half of the growing season, but not in all years. Upper Klamath Lake is hypertrophic (extremely productive) because its rich supplies of phosphorus lead to extreme abundance of phytoplankton dominated by *Aphanizomenon flos-aquae*, a nitrogen-fixing bluegreen (cyanobacterial) alga. High abundances of

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Aphanizomenon induce high pH through high rates of photosynthesis. Although strong algal blooms of this type occur each year, conditions for mass mortality are associated with a specific sequence of weather events involving calm weather succeeded by windy weather.

Low concentrations of dissolved oxygen probably are the immediate cause of death of endangered suckers during episodes of mass mortality, but other water-quality factors may contribute to stress. Mass mortality of large fish in Upper Klamath Lake has occurred for many decades, but anthropogenic factors, especially those leading to strong dominance of *Aphanizomenon*, probably have increased its severity and frequency. Poor water quality may also challenge the sucker populations in other ways. High pH, for example, could be harmful to young fish even if they are not subject to the mass mortality of larger fish.

Because hypertrophic conditions indicate very high supplies of phosphorus, much attention has been given to the possibility of reducing the phosphorus load passing from the watershed to Upper Klamath Lake. The prospects for suppressing algal blooms by this means in Upper Klamath Lake seem poor, however, because about 60% of the external phosphorus load is derived from natural sources. In addition, the anthropogenic component of load is accounted for by dispersed sources, which are difficult to control, and the internal load (phosphorus released from lake sediments) is about double the external load.

The key change over the last 50 yr in Upper Klamath Lake probably was the rise of *Aphanizomenon*, which replaced diatoms as the dominant type of algae. Diatoms probably were limited by nitrogen depletion and thus were unable to use fully the rich phosphorus supplies of the lake, whereas *Aphanizomenon* is able to fix nitrogen and thus can fully exploit the high availability of phosphorus, which causes it to reach very high abundances. Various anthropogenic factors could have contributed to the rise of *Aphanizomenon*; one example is increased transparency of the lake caused by disconnection of its associated wetlands, which were sources of dark humic compounds. Reestablishment of these sources would seem advisable but may be impractical because the organic deposits in the wetlands oxidized extensively after the wetlands were drained.

There is no evidence of a causal connection between water level and water quality or fish mortality over the broad operating range in the 1990s, the period for which the most complete data are available for Upper Klamath Lake. Neither mass mortality of fish nor extremes of poor water quality shows any detectable relationship to water level. Thus, despite theoretical speculations, there is no basis in evidence for optimism that manipulation of water levels has the potential to moderate mass mortality of suckers in Upper Klamath Lake. Planning must anticipate that poor water quality will continue to affect the sucker populations of Upper Klamath Lake.

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Suckers in Upper Klamath Lake also are affected by entrainment from the Link River near the outflow of the lake. Screens installed at the main irrigation-water withdrawal point probably will be beneficial, but loss of small fish still can be expected. The Link River Dam intakes still are not screened.

Nonnative fishes, which are diverse and abundant in Upper Klamath Lake, may be suppressing the populations of endangered suckers there, but no practical mechanisms for reducing their abundance are known.

Other Locations in the Klamath Basin

Below Upper Klamath Lake, waters of the upper basin collect through the Lost River system, which is regulated by the Klamath Project (Figure S-1). The headwaters include tributaries to Clear Lake and Gerber Reservoir. These tributaries support recurrently successful spawning of endangered suckers, as shown by the apparently stable populations of suckers in the two reservoirs. Unprecedented drawdown of both reservoirs in the drought year of 1992 coincided with deteriorating body condition and increased incidence of parasitism in the suckers. Thus, the conditions of 1992 have been used by USFWS in setting thresholds of water level for these lakes.

On the Lost River below Gerber Reservoir and Clear Lake (Figure S-1), all waters are strongly affected by the Klamath Project and are unsuitable for suckers, although they still offer some opportunities for restoration, especially through increases in water depth for Tule Lake Sumps and Lower Klamath Lake.

Reservoirs of the main stem Klamath have created new habitat capable of holding endangered suckers, but recruitment of young fish has not been observed. Reservoirs have low potential to support self-sustaining populations.

Coho Salmon

The peak migration of adult coho salmon in the Klamath basin occurs between late October and mid-November; the fish spawn primarily in tributaries. Fry reach peak abundance in March and April, and can disperse as far as the tributary mouths, but most appear to stay close to the areas where they originate. Coho develop through the juvenile stage in the tributaries over about 1 yr. They may occupy the main stem at times but are nearly absent from it by late summer, when the water is warmest. Winter habitat in the tributaries is critical for the juvenile coho but has not been well studied.

Juveniles smoltify and migrate downstream in spring, with a peak in April. Short transit times facilitated by high flow could be favorable to the

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migrating smolts, although this has not been demonstrated for the Klamath River. Smolts spend approximately 1 mo in the estuary and then enter the ocean, where they spend about 1.5 yr before returning to the Klamath River. Ocean conditions such as productivity affect the strength of year classes.

The most important cause of impairment of coho salmon probably is excessively high summer temperatures in tributary waters. Coho salmon, unlike Chinook salmon, remain in freshwater for an entire year, during which they mainly occupy tributaries, where summer water temperatures can be dangerously high. Causes of extreme temperatures include diversion of cold flows for use in agriculture, flow depletion that leads to warming of cool water, and destruction of riparian vegetation that leads to loss of shading. Temperatures also are excessively high in the main stem, but at present high temperatures there probably are more relevant to other species that are more likely than coho to use the main stem for rearing. Decrease in main-stem temperatures by augmentation of main-stem flows is problematic because augmentation water must be derived from the surface layer of Iron Gate Reservoir, which is very warm in summer. Projections of benefit to be expected from possible thermal manipulations may not have taken into account the exceptional importance of nocturnal thermal minimums in determining the energetic balance of coho exposed to high temperatures; nocturnal minimums can be as important as daily maximums in determining the survival of juvenile coho salmon.

Barriers to passage caused by dams and diversion structures are important to coho salmon. The main-stem dams on the Klamath River block spawning movements, as do Dwinnell Dam on the upper Shasta River and the Trinity River Diversion project on the Trinity River. Numerous small dams used by individual irrigators or ditch companies also block movement of coho in tributaries. Dams also have contributed to habitat degradation.

Coho habitat has been seriously degraded in the tributaries. Lack of cover and impairment of substrate through deposition of sediments are common. Woody debris, which is critical as cover for young fish, has largely been lost as a result of human activity. Excessive depletion of flow may separate fish from adequate habitat in the last half of summer.

Competition between hatchery coho and the smaller wild coho during migration to the estuary may be severe. Probably even more important are competition and predation from large numbers of Chinook salmon and steelhead that are released from hatcheries to the main stem when smoltification of the coho is in progress.

The Klamath River Fish Kill of 2002

During the second half of September 2002, numerous fish died in the lowermost 40 mi of the Klamath River main stem, 150 mi below Iron Gate

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Dam (Figure S-1). Most of the dead fish were adult Chinook salmon that had just entered the lower Klamath River. At least 33,000 Chinook, of a total estimated spawning run of about 130,000, died. The immediate cause of death was massive infection by two types of pathogens that are widely distributed and generally become harmful to fish under stress, particularly if crowding occurs. The fish kill, although important for Chinook salmon, did not involve many coho salmon (about 1% of the total dead fish) because coho enter the river later than Chinook, and thus were mostly absent when conditions leading to mass mortality occurred.

The California Department of Fish and Game (CDFG), through an analysis of environmental conditions over 5 yr of low flow within the last 15 yr, showed that neither the flows nor the temperatures that occurred in the second half of September 2002 were unprecedented. A study by the U.S. Geological Survey (USGS) supports this conclusion. Thus, no obvious explanation of the fish kill based on unique flow or temperature conditions is possible.

CDFG has proposed that the shape of the channel in the lowermost reaches of the Klamath main stem changed in 1997–1998 under the influence of high flows, which caused fish entering the river to be unable to proceed upstream under low-flow conditions. An alternate hypothesis is that an unusual combination of temperature, flow, and migration conditions occurred in 2002, possibly in association with weather that prevented the river from showing nocturnal cooling to an extent that would usually be expected.

The two hypotheses—or others that may be proposed—are difficult to test because the conditions coinciding with the fish kill were unexpected and therefore largely unmonitored. If a lasting change in channel configuration was responsible, recurrence of the episode can be expected with similar low flows in the future. If other factors were responsible, recurrence may be much less likely. It is unclear what the effect of specific amounts of additional flow drawn from controllable upstream sources (waters from reservoirs on the Trinity River or Iron Gate Reservoir) would have been. Flows from the Trinity River could be most effective in lowering temperature.

Legal, Regulatory, and Administrative Context of Recovery Actions

Adaptive management is accepted in principle by the listing agencies but has not been implemented in the Klamath basin for the benefit of the listed species, except as part of the Trinity River Restoration Project. Information collected through monitoring and research has been valuable, but the absence of an integrated, evolving management plan connected to monitoring, research, review, and periodic readjustment of management actions will hamper progress in the future. Although agencies must meet the re-

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quirements of the ESA, many actions that could benefit the listed species can also be justified from the viewpoint of ecosystem management favorable to numerous other species, some of which are perilously close to listing, and to ecosystem functions that have great practical value.

Specifically with reference to ESA Section 4(f), USFWS and NMFS recovery planning for the three listed species has stalled and needs to be revived. Jeopardy consultations, which have focused on operation of the Klamath Project, must be broadened geographically because critical environmental resources of the listed species are found not only in but also beyond the Klamath Project. Furthermore, USFWS and NMFS appear to have overlooked take (mortality and impairment) of the listed species that is incidental to agricultural practice, private water management, and other activities beyond the control of USBR, and thus have not taken full advantage of their authorities under ESA Section 9.

The listing agencies have been criticized for using pseudoscientific reasoning ("junk science") in justifying their requirements for the protection of species in the upper Klamath basin. The committee disagrees with this criticism. The ESA allows the agencies to use a wide array of information sources in protecting listed species. The agencies can be expected, when information is scarce, to extend their recommendations beyond rigorously tested hypotheses and into professional judgment as a means of minimizing risk to the species. In allowing professional judgment to override site-specific evidence in some cases during 2001, however, the agencies accepted a high risk of error in proposing actions that the available evidence indicated to be of doubtful utility. The committee, as explained in its interim report, found some proposed actions as given in the 2001 biological opinions to lack substantial scientific support. In their biological opinions of 2002, the listing agencies appear to have resolved this issue either by obtaining concessions from USBR through mechanisms that are generally consistent with USBR's goal of delivering irrigation water (for example, through establishment of a water bank) or by redesigning their requirements to bring them into greater conformity with the existing evidence.

RECOMMENDATIONS

Recovery of endangered suckers and threatened coho salmon in the Klamath basin cannot be achieved by actions that are exclusively or primarily focused on operation of USBR's Klamath Project. While continuing consultation between the listing agencies and USBR is important, distribution of the listed species well beyond the boundaries of the Klamath Project and the impairment of these species through land- and water-management practices that are not under control of USBR require that the agencies use their authority under the ESA much more broadly than they have in the past.

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Recommendation 1. The scope of ESA actions by NMFS and USFWS should be expanded in several ways, as follows (Chapters 6, 8, 9).

- NMFS and USFWS should inventory all governmental, tribal, and private actions that are causing unauthorized take of endangered suckers and threatened coho salmon in the Klamath basin and seek either to authorize this take with appropriate mitigative measures or to eliminate it.
- NMFS and USFWS should consult not only with USBR, but also with other federal agencies (e.g., U.S. Forest Service) under Section 7(a)(1); the federal agencies collectively should show a will to fulfill the interagency agreements that were made in 1994.
- NMFS and USFWS should use their full authority to control the actions of federal agencies that impair habitat on federally managed lands, not only within but also beyond the Klamath Project.
- Within 2 yr, NMFS should prepare and promulgate a recovery plan for coho salmon, and USFWS should do the same for shortnose and Lost River suckers. The new recovery plans should facilitate consultations under ESA Sections 7(a)(1), 7(a)(2), and 10(a)(1) across the entire geographic ranges of the listed species.
- NMFS and USFWS should more aggressively pursue opportunities for non-regulatory stimulation of recovery actions through the creation of demonstration projects, technical guidance, and extension activities that are intended to encourage and maximize the effectiveness of non-governmental recovery efforts.

Recommendation 2. Planning and organization of research and monitoring for listed species should be implemented as follows (Chapters 6, 8, 10).

- Research and monitoring programs for endangered suckers should be guided by a master plan for collection of information in direct support of the recovery plan; the same should be true of coho salmon.
- A recovery team for suckers and a second recovery team for coho salmon should administer research and monitoring on the listed species. The recovery team should use an adaptive management framework that serves as a direct link between research and remediation by testing the effectiveness and feasibility of specific remediation strategies.
- Research and monitoring should be reviewed comprehensively by an external panel of experts every 3 yr.
- Scientists participating in research should be required to publish key findings in peer-reviewed journals or in synthesis volumes subjected to external review; administrators should allow researchers sufficient time to do this important aspect of their work.
- Separately or jointly for the upper and lower basins, a broadly based, diverse committee of cooperators should be established for the purpose of pursuing ecosystem-based environmental improvements throughout the

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basin for the benefit of all fish species as a means of preventing future listings while also preserving economically beneficial uses of water that are compatible with high environmental quality. Where possible, existing federal and state legislation should be used as a framework for organization of this effort.

Recommendation 3. Research and monitoring on the endangered suckers should be continued. Topics for research should be adjusted annually to reflect recent findings and to address questions for which lack of knowledge is a handicap to the development or implementation of the recovery plan. Gaps in knowledge that require research in the near future are as follows (Chapters 5, 6).

- Efforts should be expanded to estimate annually the abundance or relative abundance of all life stages of the two endangered sucker species in Upper Klamath Lake.
- At intervals of 3 yr, biotic as well as physical and chemical surveys should be conducted throughout the geographic range of the endangered suckers. Suckers should be sampled for indications of age distribution, qualitative measures of abundance, and condition factors. Sampling should include fish other than suckers on grounds that the presence of other fish is an indicator of the spread of nonnative species, of changing environmental conditions, or of changes in abundance of other endemic species that may be approaching the status at which listing is needed. Habitat conditions and water-quality information potentially relevant to the welfare of the suckers should be recorded in a manner that allows comparison across years. The resulting survey information, along with the more detailed information available from annual monitoring of populations in Upper Klamath Lake, should be synthesized as an overview of status.
- Detailed comparisons of the Upper Klamath Lake populations (which are suppressed) and the Clear Lake and Gerber Reservoir populations (which are apparently stable), in combination with studies of the environmental factors that may affect welfare of the fish, should be conducted as a means of diagnosing specific life-history bottlenecks that are affecting the Upper Klamath Lake populations.
- Multifactorial studies under conditions as realistic as practicable should be made of tolerance and stress for the listed suckers relevant to poor water-quality conditions in Upper Klamath Lake and elsewhere.
- Factors affecting spawning success and larval survival in the Williamson River system should be studied more intensively in support of recovery efforts that are focused on improvements in physical habitat protection for spawners and larvae in rivers.
- An analysis should be conducted of the hydraulic transport of larvae in Upper Klamath Lake.

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- Relevant to the water quality of Upper Klamath Lake, more intensive studies should be made of water-column stability and mixing, especially in relation to physiological status of *Aphanizomenon* and the occurrence of mass mortality; of mechanisms for internal loading of phosphorus; of winter oxygen concentrations; and of the effects of limnohumic acids on *Aphanizomenon*.
- A demographic model of the populations in Upper Klamath Lake should be prepared and used in integrating information on factors that affect individual life-history stages.
- Studies should be done on the degree and importance of predation on young fish by nonnative species.
- Additional studies should be done on the genetic identities of subpopulations.

Recommendation 4. Recovery actions of highest priority based on current knowledge of endangered suckers are as follows (Chapter 6).

- Removal of Chiloquin Dam to increase the extent of spawning habitat in the upper Sprague River and expand the duration over which larvae enter Upper Klamath Lake.
- Removal or facilitation of passage at all small blockages, dams, diversions, and tributaries where suckers are or could be present.
- Screening of water intakes at Link River Dam.
- Modification of screening and intake procedures at the A Canal as recommended by USFWS (2002).
- Protection of known spawning areas within Upper Klamath Lake from disturbance (including hydrologic manipulation, in the case of springs), except for restoration activities.
- For river spawning suckers of Upper Klamath Lake, protection and restoration of riparian conditions, channel geomorphology, and sediment transport; elimination of disturbance at locations where suckers do spawn or could spawn. These actions will require changes in grazing and agricultural practices, land management, riparian corridors, and public education.
- Seeding of abandoned spawning areas in Upper Klamath Lake with new spawners and physical improvement of selected spawning areas.
- Restoration of wetland vegetation in the Williamson River estuary and northern portions of Upper Klamath Lake.
- Use of oxygenation on a trial basis to provide refugia for large suckers in Upper Klamath Lake.
- Rigorous protection of tributary spawning areas on Clear Lake and Gerber Reservoir, where populations are apparently stable.
- Reintroduction of endangered suckers to Lake of the Woods after elimination of its nonnative fish populations.

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- Reestablishment of spawning and recruitment capability for endangered suckers in Tule Lake and Lower Klamath Lake, even if the attempts require alterations in water management, provided that preliminary studies indicate feasibility; increased control of sedimentation in Tule Lake.
- Review of all proposed changes in Klamath Project operations for potential adverse effects on suckers; maintenance of water level limits for the near future as proposed by USBR in 2002 but with modifications as required by USFWS in its most recent biological opinion (2002).

Recommendation 5. Needs for new information on coho salmon are as follows (Chapters 7, 8).

- Annual monitoring of adults and juveniles should be conducted at the mouths of major tributaries and the main stem as a means of establishing a record of year-class strength for coho. Every 3 yr, synoptic studies of the presence and status of coho should be made of coho in the Klamath basin. Physical and chemical conditions should be documented in a manner that allows interannual comparisons. Not only coho but other fish species present in coho habitats should be sampled simultaneously on grounds that changes in the relative abundance of species are relevant to the welfare of coho and may serve as an early warning of declines in the abundance of other species. Results of synoptic studies, along with the annual monitoring at tributary mouths, should be synthesized as an overview of population status at 3-yr intervals.
- Detailed comparisons should be made of the success of coho in specific small tributaries that are chosen so as to represent gradients in potential stressors. The objective of the study should be to identify thresholds for specific stressors or combinations of stressors and thus to establish more specifically the tolerance thresholds for coho salmon in the Klamath basin.
- The effect on wild coho of fish released in quantity from hatcheries should be determined by manipulation of hatchery operations according to adaptive-management principles. As an initial step, release of hatchery fish from Iron Gate Hatchery (all species) should be eliminated for 3 yr, and indicators of coho response should be devised. Complementary manipulations at the Trinity River Hatchery would be desirable as well.
- Selected small tributaries that have been impaired should be experimentally restored, and the success of various restoration strategies should be determined.
- Success of specific livestock-management practices in improving channel conditions and promoting development of riparian vegetation should be evaluated systematically.
- Relationships between flow and temperature at the junctions of tributaries with the main stem and the estuary should be quantified; pos-

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sible benefits of coordinating flow management in the Trinity and Klamath main stem should be studied.

Recommendation 6. Remediation measures that can be justified from current knowledge include the following (Chapter 8).

- Reestablishment of cool summer flows in the Shasta and Scott rivers in particular but also in small tributaries that reach the Klamath main stem or the Trinity main stem where water has been anthropogenically warmed. Reestablishment of cool flows should be pursued through purchase, trading, or leasing of groundwater flows (including springs) for direct delivery to streams; by extensive restoration of woody riparian vegetation capable of providing shade; and by increase of summer low flows.
- Removal or provision for effective passage at all small dams and diversions throughout the distribution of the coho salmon, to be completed within 3 yr. In addition, serious evaluation should be made of the benefits to coho salmon from elimination of Dwinnell Dam and Iron Gate Dam on grounds that these structures block substantial amounts of coho habitat and, in the case of Dwinnell Dam, degrade downstream habitat as well.
- Prescription of land-use practices for timber management, road construction, and grazing that are sufficiently stringent to prevent physical degradation of tributary habitat for coho, especially in the Scott, Salmon, and Trinity river basins as well as small tributaries affected by erosion.
- Facilitation through cooperative efforts or, if necessary, use of ESA authority to reduce impairment of spawning gravels and other critical habitat features by livestock, fine sediments derived from agricultural practice, timber management, or other human activities.
- Changes in hatchery operations to the extent necessary, including possible closure of hatcheries, for the benefit of coho salmon as determined through research by way of adaptive management of the hatcheries.

COSTS

The costs of remediation actions are difficult to estimate without more detail on their mode of implementation by the agencies. Based on general knowledge of costs of research and monitoring at other locations, an approximate figure for the recommendations on endangered suckers over a 5-yr period is $15–20 million, including research, monitoring, and remedial actions of minor scope. Excluded are administrative costs and the costs of remedial actions of major scope (e.g., removal of Chiloquin Dam), which would need to be evaluated individually for cost. For coho salmon, research, monitoring, and remedial projects of small scope over 5 yr is estimated at $10–15 million. Thus, the total for all three species over 5 yr is $25–35 million, excluding major projects such as removal of dams. These

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costs are high relative to past expenditures on research and remediation in the basin, but the costs of further deterioration of sucker and coho populations, along with crisis management and disruptions of human activities, may be far more costly. A hopeful vision is that increased knowledge, improved management, and cohesive community action will promote recovery of the fishes. This outcome, which would be of great benefit to the Klamath basin, could provide a model for the nation.

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1

Introduction

The United States attempts to reduce the rate of extinction within its diverse and valuable biota primarily through the Endangered Species Act (ESA) of 1973. The ESA prohibits or severely limits the intentional or incidental taking of species that are listed as endangered or threatened. The ESA is ecologically practical in requiring that habitat necessary for each life-history stage (critical habitat) of a species be preserved and, if possible, expanded or enhanced. Among the requirements of the ESA, the prohibition of intentional taking is relatively easy to implement, the prohibition of incidental taking raises many practical difficulties because of its conflict with ordinary human activities, and the requirement for protection of critical habitat can be troublesome in the extreme because it often is in direct conflict with customary and valued uses of natural resources.

The ESA has been applied to the upper Klamath River basin of Oregon and California (Figure 1-1) for protection of the Lost River sucker (*Deltistes luxatus)* and shortnose sucker (*Chasmistes brevirostris)* and for the Klamath basin component of a genetically distinct population of coho salmon (*Oncorhynchus kisutch)* that is designated the southern Oregon/northern California coasts (SONCC) "evolutionarily significant unit" (ESU). The listing of these three fish species has, as required by the ESA, led to an intensive effort on the part of federal agencies and others to identify critical habitat and to propose federal actions that would promote recovery of the species. Analysis of the needs of the species has extended necessarily to private lands and to privately held water rights, given that the fishes range well beyond the boundaries of federal land and water management.

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FIGURE 1-1 Map of the upper Klamath River basin showing surface waters and landmarks mentioned in this report. Source: Modified from USFWS.

Requirements of the endangered and threatened fishes (see Chapter 9 for the difference between these two designations) came into especially sharp focus during 2001, a year of drought, when federal agencies, in an effort to protect these fishes, all but eliminated the distribution of water from Upper Klamath Lake for irrigation. The severe economic consequences of that decision for some segments of the Klamath basin community brought a sense of crisis to a controversy that had already developed around envi-

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ronmental, cultural, and commercial interests in fish as opposed to agricultural and economic interests in the uses of land and water.

This report presents the results of a study conducted by the National Research Council's (NRC) Committee on Endangered and Threatened Fishes in the Klamath River Basin. The committee was formed at the request of the Department of the Interior and the Department of Commerce, whose agencies are responsible for implementing requirements of the ESA in the Klamath River basin. The committee's tasks were to evaluate the scientific merit of federal agencies' proposals or requirements for protection of the endangered and threatened fishes and to analyze the long-term requirements for recovery of these fishes. The committee's final report, which is given here, presents conclusions and recommendations that bear on the requirements of the endangered and threatened fishes. The committee hopes that its report will assist the federal government both in implementing the requirements of the ESA and in minimizing adverse effects of ESA actions on residents of the Klamath River basin.

OVERVIEW OF THE ENVIRONMENT

For purposes of environmental analysis, it is convenient to divide the Klamath River basin into an upper basin, which extends north and east from the Iron Gate Dam on the main stem of the Klamath River, and a lower basin, which extends south and west to the Pacific Ocean (Figure 1-1). The upper basin is dominated by the activity of large volcanoes and active faulting, which controls the location and shape of broad valleys. These fault-bounded valleys contain all of the large natural lakes and large wetlands of the Klamath basin. Crater Lake, the second deepest lake in North America and one of the most transparent of all lakes, is a notable geographic feature of the upper basin, but is irrelevant to the welfare of the endangered and threatened fishes because of its hydrologic isolation. The upper basin has a relatively dry, high desert climate typical of areas that lie east of the Cascade Range. The widespread volcanic rocks of the upper basin produce numerous springs that are important local sources of water.

Within the lower basin, below Iron Gate Dam, the Klamath River is incised deeply into bedrock, forming a narrow canyon. The mountains that surround the lower Klamath, including the Trinity Alps and Coast Ranges, are rugged, with dense conifer and fir forests and steep tributary streams. The climate is quite variable in the lower basin, but is distinguished by its very high annual rainfall and relatively mild temperatures. Some fertile valleys, including those of the Shasta and Scott rivers, are found in the lower basin.

Because the Klamath River flows directly to the Pacific, it is isolated from other inland waters. This isolation, which was compounded in the

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past by separation of the upper and lower parts of the Klamath basin, explains the high degree of endemism in the fish fauna of the basin (Chapter 5). Isolation also accounts for the spectacular ecological success, before human intervention, of the endemic fishes of the upper basin, as shown by formerly great abundances of the shortnose and Lost River suckers, which are adapted for living in a naturally variable high desert environment (Chapter 5). Although isolation has been less absolute for anadromous fishes, which occupy the lower basin and mix with other populations in the Pacific Ocean, the homing characteristics of salmonids in combination with regional selective forces have led to the presence of genetically distinct populations of anadromous fishes, including the SONCC population of coho salmon, in the lower Klamath basin and several adjacent drainages (Chapter 7).

With respect to water management, the upper basin has two parts: (1) waters draining to Upper Klamath Lake and (2) Klamath Lake plus all lands lying between it and Iron Gate Dam, including the Lost River basin. There are no lakes of significance to the endangered suckers above Upper Klamath Lake, but the streams and rivers above Upper Klamath Lake, especially the Williamson and Wood rivers and their tributaries, historically were and still are important for spawning of the endangered suckers (Chapter 6). The Lost River historically was isolated from the rest of the upper basin in all but wet years and has lakes that are or were important to endemic fishes. It is now hydrologically connected to the Klamath River through water management.

The issues of importance above Upper Klamath Lake include physical degradation and blockage of tributaries by dams or water-management structures and misdirection of fish through entrainment. Correction of these problems will involve private parties because most water management in this portion of the basin is not under federal control. As explained more fully in Chapter 2, cattle and irrigated crops are important.

Below the Upper Klamath Lake watershed, Upper Klamath Lake, Gerber Reservoir, Clear Lake, and the now small remnants of Lower Klamath Lake and Tule Lake all are affected by water management through the U.S. Bureau of Reclamation's (USBR) Klamath Project, as are the flows of all tributary waters (most notably the Lost River) that lie below all of these water bodies. Water management in this region is largely federal in that USBR delivers water from Upper Klamath Lake to the Klamath Project and also stores and routes water by using the other lakes and waterways. Thus, any loss of fish caused by hydraulic manipulation or water-management structures of the Klamath Project is the responsibility of USBR as it fulfills its contracts for delivery of water. Private water users, however, determine land use and application methods for water delivered by USBR and use privately managed diversion structures and small dams to regulate the rout-

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ing of water. Thus, both USBR and private water users may affect the suitability of environmental conditions for endangered suckers. Although the details are complex, the general pattern is that water stored in Upper Klamath Lake, Clear Lake, and Gerber Reservoir is diverted for agricultural use, and the unused portion of this diverted water is returned via Tule Lake, Lower Klamath Lake, or the Lost River to the main stem of the Klamath River (Figure 1-2). Approximate quantities of water flow are as shown in Table 1-1.

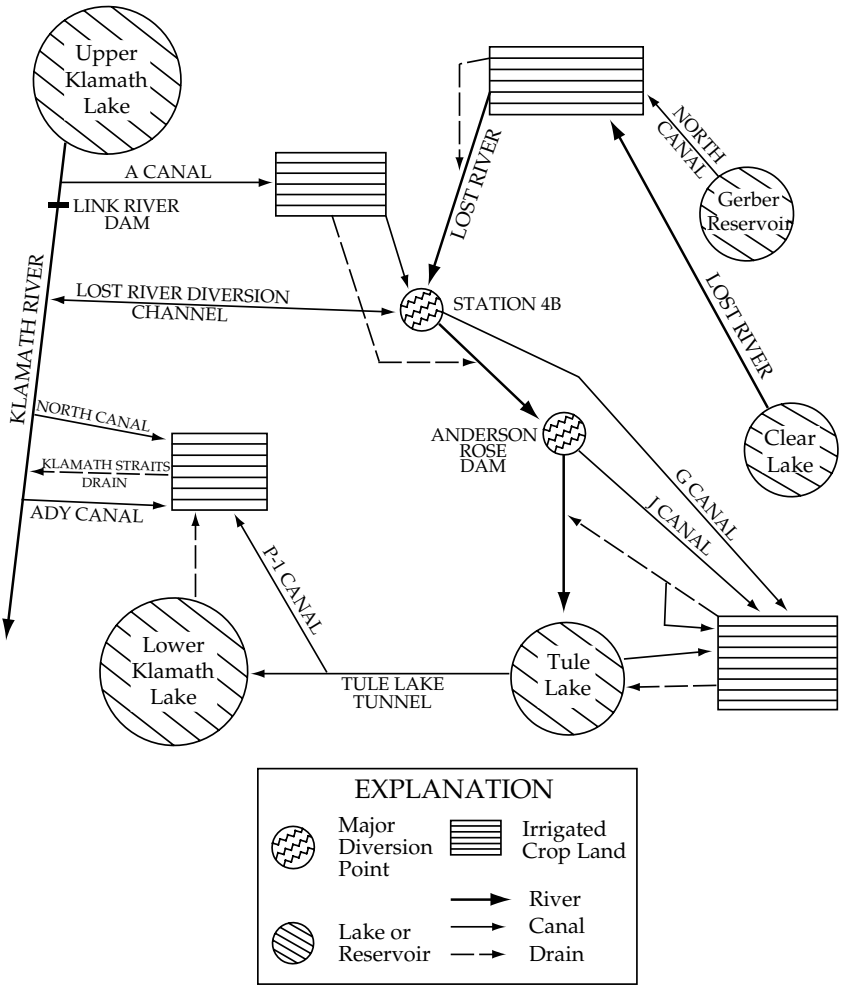


FIGURE 1-2 Water routing diagram for the Klamath Project. Source: Modified from USFWS 2002.

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TABLE 1-1 Flows Under Conditions of Average Water Availability in the Upper Klamath Basin[a]

Location	Amount (acre-ft per yr)
Upper Klamath Lake outflow[b]	1,300,000
Outflow April-September	500,000
Directed to Klamath Project	400,000
Directed downstream	900,000
Clear Lake inflow[b]	117,000
Directed to Klamath Project[c]	36,000
Gerber Reservoir inflow[b]	55,000
Directed to Klamath Project	40,000
Total Klamath Project consumptive use, including refuges[b]	350,000
Total Klamath Project returns to Klamath River[b]	100,000
Nonproject irrigation diversions, upper basin[d]	420,000
Total flow at Orleans[e]	6,000,000
Trinity River flow	3,800,000
Total flow at mouth	13,400,000

[a]Approximate only—actual values differ from year to year.
[b]USBR 2000a.
[c]Evaporative losses are especially high in Clear Lake (long retention time and evaporation at about 3.8 ft/yr).
[d]NMFS 2001 (estimated from percentages).
[e]Near the mouth of the Klamath River, but above the Trinity River.

The upper basin contains seven national wildlife refuges and several other public and private preserves, as shown in Figure 1-3. The abundance of refuges and preserves in the upper basin is an indication of its exceptional value for waterfowl and other forms of life that depend on great expanses of shallow water and wetlands. Refuges and preserves around the lakes can be considered a means of conserving or enhancing wetlands that may be relevant to the welfare of endangered suckers.

Near Lower Klamath Lake and Tule Lake, water management is especially complicated in that the refuge lands within the original inundation zones of these two lakes now are used extensively for agricultural purposes according to agreements that were reached during the early history of the refuges (Chapter 2). The two lakes function hydrologically primarily as drainage conduits; they are not allowed to accumulate water because of governmental commitments to continuing agricultural use of the former lake beds. Thus, both lakes now lack the large populations of shortnose and Lost River suckers that once occupied them, although Tule Lake does still support a small population of endangered suckers (Chapter 6).

Also in the upper basin are six main-stem dams (Figure 1-4). The Link River Dam (completed in 1921), which is near the outlet of Upper Klamath

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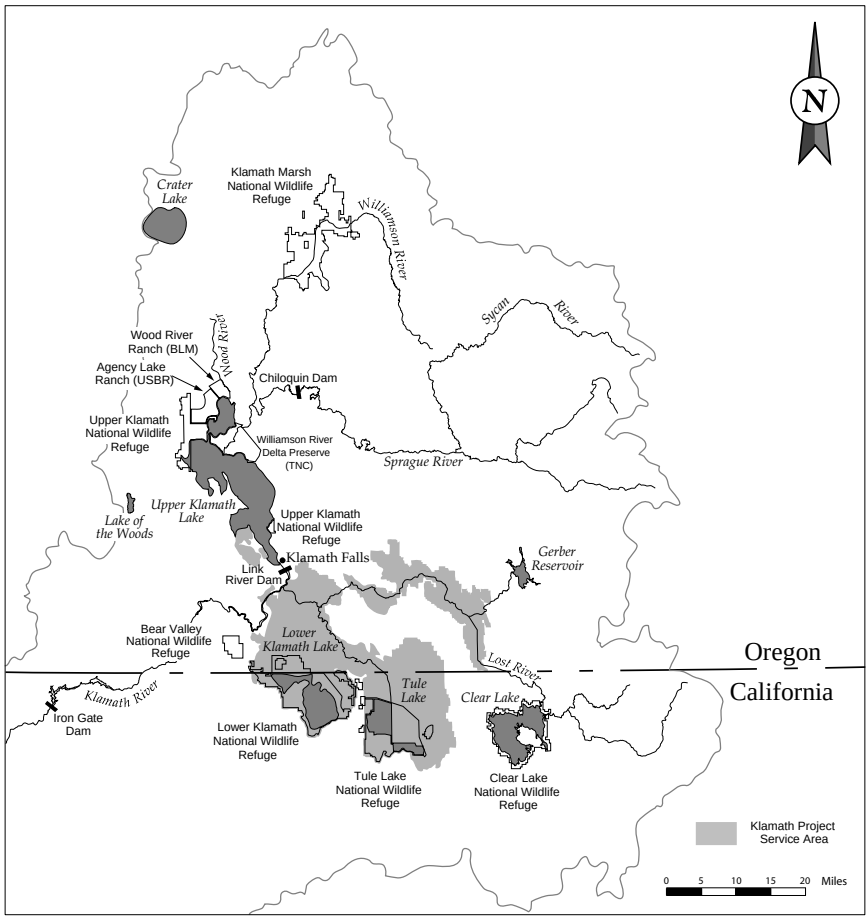


FIGURE 1-3 Map of the upper Klamath basin. Abbreviations: BLM, Bureau of Land Management; TNC, The Nature Conservancy; USBR, U.S. Bureau of Reclamation.

Lake, is used in regulating the level of Upper Klamath Lake for water-management purposes and also produces hydropower. Irrigation water is withdrawn seasonally in large quantities through the A Canal, which is just above the Link River Dam. Principles of operation of the dam are a major point of controversy related to the welfare of the endangered suckers (Chapter 6).

Below the Link River Dam are five additional dams; all the dams except the Keno Dam produce hydropower. All six dams are operated by PacifiCorp, a utility company, through agreements with USBR. Iron Gate Dam, the terminal dam, is used for reregulation of flow to the Klamath River

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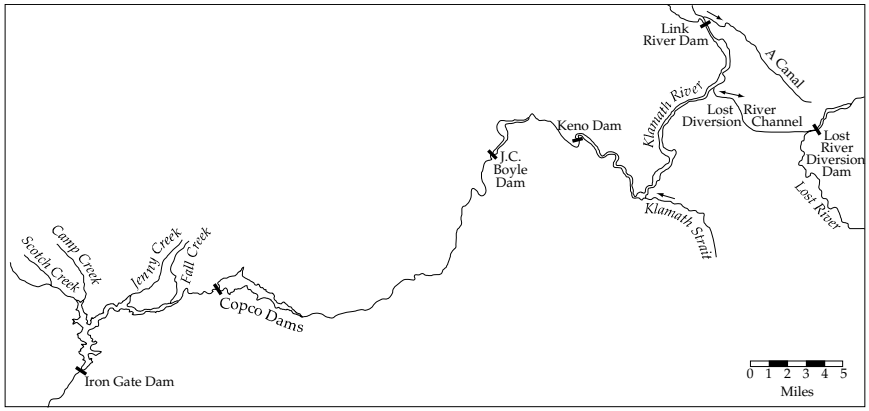


FIGURE 1-4 Main-stem dams on the Klamath River.

main stem. The six dams block access of both endangered suckers and coho salmon to large portions of their historical ranges and can be direct or indirect agents of fish mortality. Through the operation of Link River Dam, endangered suckers have been historically entrained into the A Canal and thus killed (Chapter 6). In addition, the suckers enter the unscreened intakes of the power-production facilities and thus may pass through turbines. Dams also are the means by which ramping of flow (change in discharge over short periods), which is consistent with optimal operation of hydropower production facilities, is achieved; ramping of flow can be detrimental to coho fry, which can become stranded at the river margin when flow decreases rapidly.

In the lower part of the basin (below Iron Gate Dam), the main stem of the Klamath River is the pathway of migration for numerous anadromous fishes and is important for spawning and rearing of some of them (Chapter 7). Flow to the main stem at Iron Gate Dam is reduced and altered seasonally through the operation of the Klamath Project and private water management above Iron Gate Dam and is regulated hourly by PacifiCorp (Chapter 4). Releases can be regulated to some degree by control of storage in Upper Klamath Lake, but irrigation commitments constrain this management flexibility, especially in dry years. Although groundwater flow is substantial in some parts of the Klamath River basin, there appears to be little accrual of groundwater to the Klamath main stem below Iron Gate Dam. Increase in discharge downstream occurs through four large tributaries—the Shasta, Scott, Salmon, and Trinity rivers (Figure 1-1)—and through numerous small tributaries. The large tributaries all are physically altered, and some show severe depletion of flow and are excessively warm because of loss of riparian vegetation and high relative contribution of irrigation

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return flows to total stream discharge (Chapter 4). As explained in Chapters 7 and 8, the small tributaries now provide some of the best habitat for coho salmon. Land and water relevant to the welfare of the coho and other fishes in the lower basin are primarily under private control. Water-management structures interfere with the movement of fish in this part of the watershed, as they do elsewhere.

The Trinity River, which is the largest tributary of the Klamath River, reaches the Klamath about 43 mi from the estuary. In 1964, the Trinity River Diversion began delivering up to 90% of the upper Trinity's flow out of the basin to the Central Valley Project. This diversion and other changes in the watershed were followed by a severe decline in the anadromous fish populations of the Trinity River. Studies of coho salmon and other fishes of the Trinity River have been conducted separately from those of the Klamath River basin through processes prescribed by the National Environmental Policy Act, which involves an environmental impact statement (EIS) rather than ESA procedures. In December 2000, the EIS resulted in a record of decision (ROD) for the Trinity River (USFWS 2000). The ROD called for increased minimum flows, habitat restoration for the benefit of anadromous salmonid populations, and use of an adaptive management approach involving further study and evaluation of the outcomes of flow and habitat manipulations. As a result of judicial decisions, however, a supplementary EIS is still in progress. Recovery of the Trinity River coho populations is important for recovery of the coho in the Klamath basin as a whole; hydrologic linkages between the two rivers are especially important for the migration of coho (Chapters 4, 7, and 8).

The hydrologic characteristics of the Klamath River main stem and its major tributaries are dominated by seasonal melt of snowpack. Summer storms and release of groundwater from springs also make contributions, but they are smaller in aggregate than the snowmelt effect. The schedule of melting differs from year to year, reflecting climatic variability, but a universal feature of hydrographs is a spring pulse in flow followed by recession to a baseflow condition by late summer. These main features of the hydrograph undoubtedly have influenced the adaptations of native organisms, as reflected in the timing of their key life-history features (see Chapters 5 and 7).

Even though water is now managed (Table 1-1), hydrographs of the Klamath River basin still show the dominant influence of snowmelt and spring precipitation on water flow. For example, Figure 1-5 compares the flow near the mouth of the Williamson River, above which there are no major impoundments, with the flow at Iron Gate Dam, above which a great deal of water management occurs. Flows at the mouth of the Williamson River are affected by privately managed irrigation diversions but, given the large total flow in the Williamson, the hydrograph has predominantly natu-

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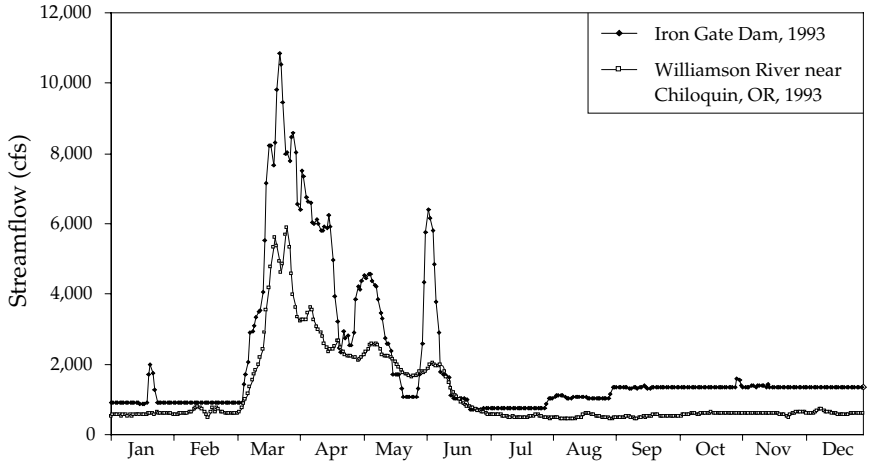


FIGURE 1-5 Flow of the Williamson River, the largest water source for Upper Klamath Lake, and of the Klamath River main stem (at Iron Gate Dam) in a year of near-average water availability. Source: USGS gage records.

ral features. At Iron Gate Dam, the retention of water in reservoirs of the Lost River and in Upper Klamath Lake has the potential to alter the hydrograph more extensively. Alteration is, as expected, more severe during years of drought than years of average flow.

The management of hydrographs, in combination with natural climatic variation, now is a major focus of attention in the analyses of environmental factors that may affect the welfare of the two endangered sucker species and the coho salmon (Chapter 4). Hydrology has environmental effects not only through its direct control of physical attributes of standing and flowing water (mean depth, water velocity), but also because of its indirect control of other aspects of the physical, chemical, and biological environment such as temperature of flowing water, nutrient concentrations in lakes, and extent and type of aquatic vegetation. Even so, numerous influences on the endangered fishes, such as the introduction of nonnative fishes, loss of riparian vegetation, and anthropogenic mobilization of nutrients, involve factors other than hydrology.

THE FISHES

The shortnose and Lost River suckers are large, long-lived fishes of high fecundity. Although they spend most of their lives in lakes, flowing waters are important to them for spawning. Some subpopulations spawn around the perimeter of Upper Klamath Lake, particularly near springs, but

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fish of both species migrate or attempt to migrate into tributaries for spawning. Shortly after hatching, fry return to the lake, where they occupy very shallow water at first and move to progressively greater depths as they mature. The endangered suckers do not spawn until they are several years old (Chapter 5).

The two endangered sucker species were so abundant before colonization that they served as a major food source for Indian tribes (Chapter 2). After the Klamath basin was colonized, the fish were harvested in large numbers commercially. Because they are large and tend to migrate during spawning, they were highly vulnerable, and their numbers were drastically reduced through harvest. Records of the size of spawning runs and sport fishing indicated during the 1980s that both species had declined to such a point that without special protection they might be extirpated. Fishing for the species was eliminated except for very small numbers of fish allocated for ceremonial purposes to Indian tribes. In 1988, both species were listed as endangered under the ESA (53 Fed. Reg. 27130, 18 July 1988).

It was clear in the 1980s and even earlier that prohibition of fishing, although essential, might not be sufficient to produce recovery of the endangered suckers. Factors that probably have contributed to the suppressed abundances of these species include blockage of migration pathways to spawning areas; entrainment of large numbers of fish by water-management structures; poor water quality, especially in Upper Klamath Lake; physical degradation of habitat; and adverse genetic consequences of scarcity and fragmentation (Chapter 6). Mass mortality of large fish in Upper Klamath Lake, although recorded for over 100 yr, caused particular alarm during the 1990s because of its sequential occurrence in 3 yr (1995–1997). The abundance of large adults appears to have been strongly suppressed by fishing, which was banned after 1987, and by mass mortality caused by poor water quality. Although recruitment of young fish has been documented since the listing of the suckers in 1988, there is no indication of recovery in overall abundances (Chapter 6).

Populations of coho salmon in the Klamath River were substantial when commercial salmon fisheries first developed (Chapter 7). Abundances of most anadromous fishes in the Klamath River basin and other Pacific coast basins have declined drastically since then. Decline of the coho salmon in the Klamath River basin led to federal listing of the SONCC ESU as threatened in 1997 (62 Fed. Reg. 24588, 6 May 1997); California listed the ESU as endangered in 2003.

The coho salmon, except in the case of some early-spawning males, has a 3-yr life history that is divided almost equally between marine and freshwater environments. A fall-winter migration brings the fish up the main stem of the Klamath River. Although some spawning may occur in the main stem, the primary spawning occurs in tributaries (Chapter 7). Young fish

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remain primarily in the tributaries or tributary mouths during development, after which they move downstream as smolts undergoing physiological transformation that is essential for life in marine waters. The many factors that are known or suspected to have contributed to the decline of the coho salmon include harvest (which is now prohibited), depletion of flows, anthropogenic warming of water, loss of cover, blockage of migration routes, and adverse water quality. In addition, the release of large numbers of hatchery-reared salmonids (coho and other taxa) introduces increased predation and competition.

Physical and chemical conditions in the tributaries are undeniably bad and can be remedied only through extensive remediation on private lands, either with or without facilitation by federal or state agencies. Examples of private efforts to promote recovery of salmon are already available for some parts of the Klamath basin (Chapter 8). USBR has considerable control over flows in the main stem, however, and the degree to which coho can benefit from changes in water management by USBR has been the subject of much controversy. The coho is strongly oriented toward tributaries for most of its life cycle, but the upstream migration of adults and the downstream migration of smolts involve the main stem. Thus, it is reasonable to ask whether regulation of flow in the main stem is important in holding back the recovery of the coho salmon; the evidence is reviewed in Chapter 8.

REQUIREMENTS OF THE ENDANGERED SPECIES ACT

With the listing of the coho and the two endangered suckers, the ESA introduced a new legal framework that has become the dominant factor in resolving water issues in the Klamath River basin, except for the Trinity River, where EIS procedures predominate. The listing of the two sucker species and the coho salmon triggered a suite of ESA regulatory requirements, as follows:

- Section 4 of the ESA requires the listing agency—the U.S. Fish and Wildlife Service (USFWS) for the endangered suckers and the National Marine Fisheries Service (NMFS) for the coho salmon—to designate "critical habitat" for endangered and threatened species unless exceptions, which are narrow, apply.
- Section 4(f) of the ESA requires the listing agency to develop and implement a "recovery plan" for endangered and threatened species.
- Section 7(a)(1) of the ESA requires all federal agencies, through consultation with the listing agency, to use their authority to carry out programs for the "conservation" of endangered and threatened species.

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- Section 7(a)(2) of the ESA requires all federal agencies, through consultation with the listing agency, to ensure that actions carried out, funded, or authorized by them do not "jeopardize" the continued existence of endangered and threatened species and do not result in "adverse modification" of their critical habitat.
- Section 9(a)(1) of the ESA prohibits all persons subject to U.S. jurisdiction (including federal, state, tribal, and local governments) from "taking" endangered species unless authorized by the listing agency pursuant to appropriate provisions of the ESA; and section 4(d) allows the listing agency to extend the same level of protection to threatened species.

As explained in Chapter 9, some of these requirements have not been fully implemented for the endangered suckers and threatened coho salmon of the Klamath River basin. Nevertheless, primarily through the prohibition in Section 7(a)(2) against federal agencies causing "jeopardy" to listed species, the ESA, after the listings, has affected USBR's operation of the Klamath Project. Primarily through the jeopardy-consultation procedure of Section 7(a)(2), USFWS has influenced USBR's maintenance of water levels in Upper Klamath Lake for the protection of the endangered suckers and NMFS has influenced USBR's releases from Upper Klamath Lake to the Klamath River main stem for protection of the coho salmon.

The full force of the jeopardy opinions manifested itself in the Klamath River basin on April 6, 2001, when, because USFWS and NMFS had concluded in their consultations with USBR that the proposed operation of the Klamath Project for delivery of irrigation water to USBR's water-contract parties would jeopardize the endangered and threatened species, USBR determined that it could not deliver water through the Klamath Project. The social and economic consequences of that decision focused the attention of many observers on two of numerous conclusions given in the USFWS and NMFS biological opinions: that the continued existence of the species would be jeopardized unless USBR maintained the water levels in lakes that USFWS specified and the main-stem flows that NMFS specified. The ESA required USFWS and NMFS to base the jeopardy findings on the "best scientific and commercial data available" (16 U.S.C. 1536(a)(2)). Some observers questioned whether the two agencies had met that standard; others contended that the decision was fully justified.

Application of the ESA to fishes of the Klamath River basin puts into focus one of the central dilemmas of the ESA: the need to reconcile the ESA's legal framework with its scientific foundations. For example, the ESA demands that USFWS and NMFS make clear distinctions as to whether an action will cause jeopardy, but the scientific process is not fully compatible with such sharp distinctions. Biologists studying the status of a species

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are likely to speak in conditional terms and only rarely to express the definitive conclusions that would be most useful for application of the ESA. Moreover, the listing and jeopardy-consultation procedures require that USFWS and NMFS use "best available" data, but such data often do not resemble the products of scientific review processes used by leading scientific journals. It may be possible, therefore, for USFWS or NMFS to satisfy the demands of the ESA with an analysis that would not satisfy the demands of scientific review for publication or other peer-review processes common in modern science. This issue is dealt with further in Chapter 9.

INTERESTED PARTIES

The work of the NRC committee does not involve conclusions or recommendations on economic or social issues, but the various interested parties that are present in the basin provide some context for evaluation of the controversies that have developed around the endangered and threatened fishes and thus the focus of scientific research on specific topics. Ultimately, the interested parties must work together on a sustained basis in order to achieve and maintain recovery of the listed species (Poff et al. 2003).

Indians were the first occupants of the basin; they now operate institutionally as the Klamath tribes (a group of related but formerly separate tribes, including the Klamath, Modoc, and Yahooskin Band of the Snakehead Indians) and the Yurok, Karuk, Shasta, and Hoopa Valley tribes. The tribes extensively used the fish of the Klamath River basin for food before the arrival of colonists, and they have cultural traditions involving the fish. The endangered and threatened fishes of the Klamath River basin, and numerous other fishes not now listed as threatened or endangered (see Chapters 5 and 7), are tribal trust species; the U.S. government has an acknowledged obligation to preserve these fishes for use by the tribes. Preservation of the fishes for use obviously implies water rights. The priority date for these water rights is "time immemorial." Thus, in the seniority system for water rights, tribal water rights related to the protection of fishes are senior to all others. Two practical issues, as yet unresolved, are how to translate the protection of fishes into specific amounts of water at specific points in the basin and the degree to which any such commitment would curtail other uses of water. These legal matters are directly relevant to research on the requirements of the endangered and threatened fishes.

The USBR, another interested party, has been working in the Klamath River basin for about a century. In 1905, Congress, Oregon, and California granted USBR authority to create the Klamath Project, which involved the acquisition of extensive water rights in the upper basin, the construction of storage and distribution systems, and extensive drainage of lakes and wet-

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lands around Tule Lake and Lower Klamath Lake so that agriculture could displace the natural aquatic habitats there (USBR 2000b). The project matured over about a half-century and is considered to have taken its full modern operational characteristics in 1960. Thus, the interval between 1960 and today is often taken as the benchmark period for judging proposals for the future.

The USBR, as a federal agency, must follow all requirements of the federal government, even including those not associated with its mission, but it devotes its energy primarily to the orderly distribution of water in support of agricultural water use. The ESA requires, however, that USBR analyze and put into writing its assessments of the effect of Klamath Project operations on endangered and threatened species and that it enter into consultation about the assessments with USFWS (for suckers) and NMFS (for coho). In 2001, USBR issued two assessments (USBR 2001a, b) acknowledging that some aspects of project operations were harmful to the two endangered sucker species and to the threatened coho salmon. USBR proposed changes in operations that it believed would offset some of the adverse effects. The 2001 biological assessments were succeeded by revised assessments issued in 2002 (USBR 2002a), which proposed a plan of operations to extend over the next 10 yr. The revised assessments, which contain some additional proposals for amelioration of potential damage to the endangered and threatened species, are summarized at the end of this chapter.

The USFWS is charged with issuing biological opinions related to the endangered suckers of the Klamath River basin. It has been in consultation with USBR over the two endangered sucker species since the species were listed, and it has reviewed USBR's biological assessment of 2001 and USBR's 10-yr biological assessment of 2002. The role of USFWS is to analyze environmental information and set requirements for protection of the fishes, to issue the analyses as biological opinions, and through the creation of "reasonable and prudent alternatives" (RPAs), to call for changes in Klamath Project operations as it believes necessary to reduce risk to the endangered suckers.

The USFWS endorsed a number of proposals contained in USBR's assessment of 2001, but it judged the USBR proposals for control of water level to be inadequate overall for protection of the endangered suckers. The reasonable and prudent alternative proposed by USFWS in 2001 included prescriptions for higher water levels in lakes. Although USBR's assessment of 2002 (10-yr operating plan) was revised with respect to water levels, USFWS again found it to be inadequate overall and proposed its reasonable and prudent alternative, as described below.

The NMFS responded to USBR's biological assessment of 2001 on coho salmon and to USBR's 10-yr operating plan as given in its 2002

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biological assessment. NMFS approved of a number of elements in the biological assessments of 2001 and 2002 but differed with USBR on the matter of minimum flows in the Klamath River main stem below Iron Gate Dam. As required by the ESA, NMFS issued a reasonable and prudent alternative prescribing higher flows in the main stem than had been proposed by USBR in 2001 and 2002.

The USFWS and NMFS ("the listing agencies") have the last word in judging the requirements of the endangered and threatened fishes. Thus, as of 2002, the USBR 10-yr proposal, as given in the 10-yr assessment, was in part rejected, and the listing agencies are requiring several new procedures and practices.

The USFWS also plays a second, very different role as manager of refuges in the Klamath basin. On the downstream end of the Klamath Project, the Lower Klamath Lake and Tule Lake refuges receive drainage water from the Klamath Project. The drainage water is used to manage the two refuges within constraints that are set by water availability and requirements for agricultural use of the land in or surrounding the refuges. In this role, USFWS is not able to demand specific amounts of water or specific timing for delivery of water to benefit the refuges. Instead, it negotiates with USBR and with agricultural interests for water to manage the refuges. Thus, although delivery of water to the refuges is required, it has a lower priority than the agricultural use of water or the agricultural use of land near the two lakes. The two uses of water are connected, however, in that some of the water delivered for agricultural use appears downstream for use by the refuges. Thus, curtailment of water for irrigation on the Klamath Project raises questions about the availability of water for the refuges.

Irrigators were present even before initiation of the Klamath Project and came in increasing numbers to use waters of the Klamath Project and waters in parts of the basin not affected by the Klamath Project. About 43% of consumptive use in the upper basin occurs outside the Klamath Project, and 57% occurs through the project, which irrigates about 220,000 acres. There is also a substantial amount of irrigation along tributaries in the lower basin beyond the boundaries of the Klamath Project. Agricultural uses of irrigation water are numerous (Chapter 2), and include extensive production of alfalfa by use of sophisticated water-distribution systems and reuse of irrigation tail water.

Irrigators have consistently been skeptical of reasoning that suggests a need for changing water management for the benefit of endangered and threatened fishes; their consultants have entered the debate about the merits of various hypotheses underlying proposed changes in water use. The experiences of 2001, when the occurrence of a drought coincided with the USFWS and the NMFS biological opinions to make the delivery of irrigation water from the Klamath Project virtually impossible for the first time

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since the creation of the project, sharpened the objections but also have increased the interest of the agricultural community in restoration projects that may benefit endangered and threatened species without curtailing the availability of water (Chapters 2 and 4).

General environmental interests in the Klamath River basin are strong, in part because of the extraordinary value of environmental resources in the basin. Environmental interests have worked toward the moderation of consumptive use and the remediation of past damage to environmental resources. The Nature Conservancy, for example, has purchased a large tract of land on the northern shore of Upper Klamath Lake (Figure 1-3), where it is restoring wetlands (Chapter 2).

Oregon and California also are involved in assessing and forming opinions on endangered and threatened fishes in the upper Klamath basin. The states have placed the two endangered sucker species and the coho under special protection and have supported extensive studies, including those related to the Environmental Protection Agency's (EPA) total maximum daily load (TMDL) requirements, which are administered through the states (e.g., Boyd et al. 2001).

Logging, mining, and commercial fishing are important forces within the basin (Chapter 2). Logging and mining, although reduced from their past maximums, have been cited as sources of habitat degradation, but they operate outside the reach of the Klamath Project. Commercial and sport fishing for salmon and subsistence fishing by the tribes have been drastically curtailed in recent decades, first as a result of declining fish populations and then in a regulatory effort to protect the remaining stocks. The change has caused a loss of income and food for inhabitants of the lower basin.

The biological assessments and biological opinions on the endangered and threatened fishes have focused primarily on the operations of the Klamath Project because federal agencies must operate federal facilities in such a way as to avoid jeopardy to endangered or threatened species (Chapter 9). Other potential threats to the endangered and threatened fishes exist outside the range of the Klamath Project, however, and cannot be remedied solely through requirements related to USBR, which lacks direct control over use of land or water outside the area of the Klamath Project.

THE COMMITTEE

The cessation of water deliveries through the Klamath Project during 2001 as required by the jeopardy opinions on coho salmon and the two endangered sucker species of the Klamath River basin motivated the U.S. Department of the Interior and the U.S. Department of Commerce to seek an outside evaluation of the scientific basis of the requirements set by

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USFWS and NMFS for higher water levels in Upper Klamath Lake and higher main-stem flows in the Klamath River. These federal agencies therefore asked the NRC to create a committee to be charged with external, independent review of the biological opinions and assessments and of the long-term needs of the endangered and threatened fishes in the Klamath River basin. As a result of the request, the NRC formed the Committee on Endangered and Threatened Fishes in the Klamath River Basin.

The committee was provided with a written statement of task, as given in Appendix A. The task has two components. First, the committee was asked to complete an interim report by early 2002. The interim report was to focus on the scientific strength of the biological assessments and opinions issued in 2001 on threatened coho salmon and endangered suckers in the Klamath River basin. The purpose of the interim report was to allow the federal agencies to consider a preliminary external review as they were writing their biological assessments and opinions for 2002, which they needed to do because the assessments and opinions of 2001 extended for only 1 yr.

Second, the committee was to prepare a final report to be issued in 2003. The scope of the final report includes the biological assessments and opinions of 2002 but also extends to all matters related to the long-term welfare of endangered suckers and threatened coho salmon in the Klamath River basin. Like the interim report, the final report focuses on the scientific basis of actions that are proposed or required by federal agencies for the benefit of the endangered and threatened fishes. Another important aspect of the final report is its analysis of the need for additional studies of specific issues about which there is too little knowledge to support confident proposals for remedial action.

The committee's interim report proved controversial. The committee found strong scientific support for all components of the reasonable and prudent alternatives given by USFWS in 2001 for the endangered suckers except for recommendations on maintenance of higher water levels in Upper Klamath Lake, for which the committee found no empirical support. At the same time, however, the committee found that USBR's recommendations, which could have caused mean water levels in Upper Klamath Lake to be lower than in the recent past, also were without scientific support. Thus, the committee's overall conclusion was that there was no substantial scientific evidence to support deviation from the water levels produced by operational principles that were in effect during the 1990s. Similarly, in reviewing the biological opinion of NMFS on the coho salmon, the committee concluded that all components of the reasonable and prudent alternative were supported scientifically except the one calling for higher flows in the Klamath River main stem. The committee found little scientific support for these recommendations in relation to coho salmon, nor did it find any

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scientific justification for the proposals of USBR, which would have allowed the river to be operated at lower mean flows than had been the case for specific categories of water availability applicable during the 1990s.

The committee, in drawing conclusions for its interim report, was bound by its charge to evaluate and comment on the scientific strength of evidence underlying various proposals. Its charge kept it from weighing economic concerns or weighing the advisability of minimizing risk by using professional judgment in place of scientific evidence to support particular recommendations. As explained more fully in Chapter 9, agencies charged with ESA responsibilities can be expected to use professional judgment when no scientifically supportable basis is available for a decision, or where they judge the scientific support to be inadequate. Thus, the agencies may recommend practices for which the committee would find virtually no direct scientific support. The committee acknowledges the necessity of this practice in many situations where information is inadequate for development of scientifically rigorous decisions (Chapter 9).

For its final report, the committee adopted some specific conventions for judging the degree of scientific support for a specific proposal or hypothesis; Table 1-2 gives a summary. Any proposal for specific actions of a remedial or protective nature has an implicit or explicit underlying hypothesis that connects the proposed action with a beneficial effect on a threatened or endangered species. The scientific value of such a hypothesis ranges from negligible to very high, depending on the amount of testing to which it has been subjected. At the low end of the scale of scientific strength is an assertion or proposal that is entirely intuitive and thus without scientific support. For example, the catch phrase "fish need water" has been used as an assertion supporting increased water levels in Upper Klamath Lake and

TABLE 1-2 Categories Used by the Committee for Judging the Degree of Scientific Support for Proposed Actions Pursuant to the Goals of the ESA

Basis of Proposed Action	Scientific Support	Possibly Correct?	Potential to be Incorrect
Intuition, unsupported assertion	None	Yes	High
Professional judgment inconsistent with evidence	None	Unlikely	High
Professional judgment with evidence absent	Weak	Yes	Moderately high
Professional judgment with some supporting evidence	Moderate	Yes	Moderate
Hypothesis tested by one line of evidence	Moderately strong	Yes	Moderately low
Hypothesis tested by more than one line of evidence	Strong	Yes	Low

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increased flows in the main stem of the upper Klamath River. The statement is true, but it does not constitute a scientifically valid argument for specific flows or specific water levels.

Professional judgment has more value than unsupported intuition. It typically is based on knowledge of the importance of various environmental factors or the requirements of various species in other locations or on general experience with or knowledge of the response of a particular category of organism to specific kinds of environmental challenges.

Professional judgment can be used in three ways, and the distinctions among them are quite important in the case of the Klamath River basin. First, for an issue about which there is no information whatsoever, an agency that is charged with protecting a threatened or endangered species can justify the use of professional judgment. Such agencies are charged with reduction of risk to the species; lacking site-specific information on a particular type of risk, they would logically draw analogies with the same or similar risks in other settings or for other species, or they would use general principles related to the known tolerance of particular species or groups of species. Although such an approach is weak in that the transferability of ecological knowledge from one set of circumstances to another is problematic, there is some scientific basis for it, and barring the feasibility of other approaches, it can be said to have weak but not negligible scientific strength.

Second, a resource agency might use professional judgment to endorse various proposals for action when valid scientific information contradicts it. This use of professional judgment is difficult to justify. The agency may hold to its desire to use professional judgment in preference to empirical information of direct significance to a particular issue on the grounds that something is wrong with the empirical information. Scientifically, however, sound and relevant empirical information always trumps speculation or generalization; an agency could argue the reverse only on the basis of a very conservative approach to risk.

Third, an agency might choose to use professional judgment that is consistent with a small amount of direct evidence. In this case, the use of professional judgment is reinforced rather than contradicted, and scientific support for it can be deemed moderate rather than negligible.

A step beyond professional judgment is the empirical testing of scientific hypotheses involving cause and effect. If a properly designed single line of evidence is developed as a means of testing such a hypothesis, and the hypothesis is not invalidated, scientific support for the hypothesis can be considered moderately strong. Ideally, this approach would be extended by the collection of additional, independent evidence through which the hypothesis could be tested in a different way; barring contradiction between the evidence and the hypothesis, the hypothesis could be considered a theory

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of considerable strength to be relied on in proposing and pursuing vigorously the action upon which the hypothesis is based.

The committee has used the six-tiered system summarized in Table 1-2 and described above in assessing the scientific basis of actions that have been recommended in the Klamath basin for protection of the endangered suckers and threatened coho salmon. It found its greatest differences with the resource agencies in the second category: instances in which the agencies have used professional judgment that is contradicted by scientifically valid, relevant evidence. In carrying out its task to categorize the scientific support for specific proposals, the committee would characterize any proposal justified by such means as having negligible scientific support. This does not preclude the resource agency from using such an approach, but the justification for it would involve extreme sensitivity to risk, and in this way might be judged not reasonable.

The committee's charge requires that it estimate the costs associated with its recommendations. For the recommendations involving additional research or monitoring, the committee was able to approximate costs based on the experience of the committee members with similar types of research. Even so, the mode of implementation of a particular research program could cause costs to deviate markedly from the committee's estimates. For example, implementation could involve a much broader or narrower geographic scope than suggested by the committee, or it could involve multiple organizations in a way that would increase costs. The committee also was able to estimate, on the basis of general experience, the costs of selected minor restoration activities. The committee did not attempt, however, to estimate costs for major restoration activities. In most instances these activities must be studied for feasibility prior to the time any commitment is made to them, and their final approval and execution may be complicated to an extent that cannot be meaningfully judged by the committee in terms of cost.

SUMMARY OF THE BIOLOGICAL ASSESSMENTS AND BIOLOGICAL OPINIONS OF 2002

The biological assessments issued by USBR in 2001 and the biological opinions issued by USFWS and NMFS in 2001 all expired after 1 yr, so new assessments and opinions were issued in 2002. The assessments and opinions of 2002 differ from those of 2001 in several respects. First, they cover a 10-yr interval rather than a 1-yr interval. In working with 10 yr rather than 1 yr, the agencies are cooperatively attempting to stabilize and add flexibility to management in such a way as to benefit both water use and environmental remediation. At the same time, consultation between the agencies probably will continue, and requirements of USFWS and NMFS

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probably will be modified within the 10-yr interval as new information becomes available. Reinitiation of consultation is required by ESA Section 7 under some circumstances, and both USBR and NMFS must issue a new biological assessment and opinion in any case because of the ruling of a U.S. District Court (see below). The texts of assessments and opinions of 2002 show that they were influenced to some extent by the committee's interim report. The interim report was not binding on the agencies but provided a basis for additional consultation and appears to have stimulated some new kinds of discussions among the agencies.

Endangered Suckers

The USBR Biological Assessment

The USBR, which in 2001 had prepared two assessments (one for the threatened coho and one for the two endangered sucker species), dealt with all three species in a single document during 2002. This makes sense because water resources at times of scarcity must be shared not only among consumptive uses and listed species but also among the listed species themselves, given that the coho and the suckers occupy different parts of the basin. USBR proposed maintenance of specific water levels in lakes and some other actions previously suggested by USFWS or others, reflecting the consultation process through which gaps between the viewpoints of the agencies are intended to be minimized.

Table 1-3 lists in abbreviated form the commitments that USBR made in its 2002 assessment to accommodate the needs of the endangered suckers. It proposed to manage water levels in Upper Klamath Lake, Clear Lake, and Gerber Reservoir so as to stay within the operating ranges of the 1990s. Specifically, it proposed not to allow water levels to fall below the 1990–1999 minimums for specific water-year categories and not to allow the mean water level for any water-year category to decrease through increased average drawdown. Thus, the water-level proposals in the assessment were responsive to the criticism made by the committee in its interim report (2002) that the USBR proposal of 2001 would have allowed, without any ecological rationale relevant to the suckers, greater mean drawdown within any given water-year category.

A second element of the assessment is a water bank, which USBR proposed to be as large as 100,000 acre-ft. The water bank would provide operational flexibility in meeting multiple needs for water during years of water scarcity and would help USBR to ensure that water-level targets in lakes (or flow requirements at Iron Gate Dam, for coho salmon) would be met.

USBR also proposed a procedure for developing project operations in a particular water year. The procedure would begin in April with classifica-

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TABLE 1-3 Summary of Commitments of the USBR Biological Assessments of 2002 that are Relevant to the Two Endangered Sucker Species

Assessment Commitments
Water levels in Upper Klamath Lake, Clear Lake, and Gerber Reservoir:
Maintain water levels at or above 1990–1999 minimums for specific water-year types[a]
Maintain mean water levels at or above 1990–1999 means for specific water-year types
Establish water bank of about 100,000 acre-ft
Use specific procedure for determining annual operations, including 70% exceedance principle for water availability
Coordinate externally and produce annual report on operations
Reduce entrainment and enhance passage in Link River and at other locations
Enhance water supply
Cooperate with USFWS in operation of refuges

[a]Special concerns and procedures are clarified by subsequent memoranda on Clear Lake and Gerber Reservoir (USBR, unpublished memo, February 21, 2003; USFWS, unpublished memo, March 4, 2003).

tion of the year by water-year type—above average, below average, dry, or critical dry (see Chapter 3 for details)—through the use of forecasts from the National Resource Conservation Service (NRCS). A 70% exceedance factor would be used in applying the forecast; that is, forecasts of the availability of water for the Klamath Project would be conservative in that there would be a 70% chance that the forecast would be equaled or exceeded by actual water availability. Having thus classified a developing water year as belonging to one of the four categories, USBR would follow specifications on minimum water levels for the appropriate water-year category. A second, later calculation would facilitate maintenance of water levels in lakes no lower than the average (rather than the minimum) end-of-month elevations for specific water-year types over the interval 1990–1999.

Another component of the assessment was a commitment to an annual report on operations, which would be useful because of the general interest in operations and the difficulty of discovering the details of operations without an interpretive document. Coordination not only with USFWS, as required through ESA, but also with other groups is a component of this portion of the assessment proposal.

The USBR proposed to reduce entrainment of fish by diversions and to increase fish passage in the Link River. Specifically, entrainment of fish at the A Canal is known to be large. Entrainment of fish above a size of about 30 mm would be reduced by installation of a permanent fish screen by a specified date (April 1, 2004). Salvage operations are included, as are measures to promote fish passage at the Link River Dam to be completed in January 2006. Increase in water supply through increased storage capacity

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and leasing also is a component of the proposals from USBR for 2002, but details are not yet available. Because these measures would require congressional approval and funding, they were not attached to a specific schedule in USBR's assessment.

The USFWS Biological Opinion

In responding to the portion of the USBR assessment dealing with endangered suckers, USFWS, through its biological opinion of 2002, reacted favorably to a number of the USBR proposals, including the water bank and specifically scheduled actions intended to reduce entrainment and improve fish passage. In the text of its opinion, however, USFWS expressed its position that water levels higher than those proposed by USBR would be favorable to the suckers through improvement in water quality and maintenance of habitat (see Chapters 3 and 6). Overall, USFWS found that the operations proposed by USBR would leave the two endangered sucker species in jeopardy and therefore formulated an RPA under which USBR must operate (Table 1-4).

The USFWS concluded that low water levels in the lakes are less favorable than high water levels to the welfare of the suckers. It required that water levels in the lakes not deviate from minimums (for single years) or averages (for groups of years) of the 1990s for specific categories of water years, as proposed by USBR. In addition, USFWS required through its RPA that USBR use a 50% exceedance probability rather than a 70% probability in forecasting water availability. As shown in the USFWS biological opinion, use of a 70% forecast, although favorably conservative for water-management purposes in tending to underestimate water availability, could be unfavorable from the environmental point of view if it were allowed to justify water-level drawdown in lakes more extreme than would be consis-

TABLE 1-4 Summary of Components of USFWS Biological Opinions of 2002 that are Relevant to the Two Endangered Sucker Species of the Klamath River Basin

Component of Biological Opinion[a]
Use 50% rather than 70% exceedance probability for planning water levels in Upper Klamath Lake
Screen power-plant intakes at Link River Dam
Study cause of death and habitat needs of endangered suckers in Upper Klamath Lake
Take actions leading to more favorable water quality and expansion of habitat
Monitor populations of endangered suckers
Produce annual assessment report on suckers
Follow specific implementation schedule

[a]Components shown here are in addition to proposals of the USBR in its biological assessment.

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tent with the actual availability of water. Thus, USFWS justified the 50% exceedance requirement for estimates as a means of ensuring that estimates of water availability would not be biased. Currently, it appears that USBR and USFWS are in agreement that April projections can be corrected as appropriate whenever they later appear to have been in error (USFWS 2002; p. 118).

A second element of the RPA was to reduce entrainment of fish at Link River Dam and hydropower intake facilities. USBR had committed to screening the A Canal, but it did not make the same commitment for the power-production facilities at Link River Dam. Thus, the USFWS RPA appears to extend USBR's commitment to screening. This requirement of the RPA raises questions about the feasibility of requiring USBR to manage entrainment for facilities that are operated by PacifiCorp, a power production company. The application of this feature of the RPA to the Link River Dam will depend on the nature of the federal action that USBR takes with respect to PacifiCorp's operation of the facilities. If USBR has sufficient discretionary authority over PacifiCorp's operation within the meaning of ESA Section 7 (carry out, fund, or authorize operations) for the facilities to be properly within the scope of the interagency consultation, the RPA would be an appropriate component of the USFWS biological opinion. If not, USFWS would need to explore application of ESA Section 9 to PacifiCorp and determine whether PacifiCorp would be in violation of the ESA in the absence of screening and other measures that may be developed between USFWS and PacifiCorp (see Chapter 9). Thus, USFWS and USBR still must clarify the status of the Link River Dam operations under Section 7 of the ESA.

Other requirements of the biological opinion are that USBR study the causes of mass mortality of fish and access of endangered suckers to habitat in Upper Klamath Lake, take actions designed to reduce unfavorable aspects of water quality or limitations in sucker habitat, monitor populations of endangered suckers, and produce an annual assessment report. A detailed implementation schedule and requirements for collaborative work of USBR with other parties accompany this element of the RPA.

Threatened Coho Salmon

The USBR Biological Assessment

In its biological assessment of 2002, the USBR made a number of proposals relevant to coho salmon, as shown in Table 1-5. First, USBR committed itself to maintain river discharges no lower than those observed during 1990–1999 for the categories of water years that it uses in water management. It also committed itself to maintain interannual averages no

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TABLE 1-5 Summary of Components of USBR Biological Assessments of 2002 that are Relevant to Threatened Coho Salmon of the Klamath River Basin

Assessment Component
Discharge of water from Iron Gate Dam
Above-average and below-average years: monthly flow will be no lower than 1990–1999 year minimums or FERC minimums, whichever is greater
Dry and critical-dry years: monthly flow will be no lower than actual 10-yr averages plus pulse of 10,000 acre-ft in April
Establish water bank of about 100,000 acre-ft
Use specific procedure for determining annual operations, including 70% exceedance principle
Coordinate externally and produce annual report on operations
Enhance water supply

lower and sometimes higher than interannual averages of 1990–1999 for specific categories of years, thus answering the concern expressed in the committee's interim report that a commitment to maintain minimums without a commitment to maintain averages would in fact allow future operations to produce lower averages.

As was the case for water levels of Upper Klamath Lake, Clear Lake, and Gerber Reservoir, USBR proposed to use a 70th percentile exceedance factor applied to the April 1 forecast of NRCS for planning annual operations. For above-average and below-average years, USBR proposed to provide flows no lower than the minimums observed during the 1990s and also no lower than the Federal Energy Regulatory Commission (FERC) minimums if the FERC minimums happen to be higher. For the two drier categories of years (dry and critical dry), USBR proposed to provide flows no lower than the observed averages for the 1990s and also to provide 10,000 acre-ft of additional flow during April to facilitate smolt migration. The use of averages rather than minimums from the 10-yr observation period is a commitment of additional water above what had been committed by USBR in its 2001 assessment, as is the 10,000 additional acre-ft for April.

An additional component of the proposed operating plan for any given year is the establishment and operation of a water bank, which also serves the needs of endangered suckers, ultimately to be as large as 100,000 acre-ft. Mechanisms for water banking could involve offstream storage but also could include reduction in irrigation demand with compensation to irrigators and conjunctive use of groundwater and surface water to provide a buffer that would be especially useful in dry years (Chapter 10).

The USBR proposal also made a commitment to coordination extending beyond the ESA implementation agencies to include the tribes, Pacifi-

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Corp, and private water users. Coordination would be supplemented with an annual report documenting the preceding year's activities. Enhancement of water supply, not necessarily limited to the water-banking concept, was also an element of the USBR proposal.

The NMFS Biological Opinion

After consultation with USBR during 2002, NMFS concluded that proposed actions of USBR as presented in its 2002 biological assessment, although containing several constructive components, would leave the threatened coho in jeopardy. Thus, according to the requirements of the ESA, NMFS prepared a biological opinion containing an RPA summarized in Table 1-6. In revising its biological opinion of 2001, NMFS recognized that the Klamath Project accounts for about 57% of the total irrigation-related depletions of flow at Iron Gate Dam. Thus, according to the opinion of 2002, it would not be reasonable to require USBR to provide directly and immediately all increments of flow judged by NMFS to be necessary for improvement of habitat in the main stem of the Klamath River below Iron Gate Dam. Accordingly, NMFS assigned USBR a 57% share in the responsibility for providing flows in the main stem to meet the requirements of the threatened coho as judged by NMFS. In doing so, however, NMFS did not absolve USBR entirely of responsibility for making up the other 43% of flows. The biological opinion requires USBR to facilitate and coordinate a phased effort to provide capacity for the additional flows.

NMFS, as part of the RPA, requires USBR to build a water bank, which USBR has agreed to be its preferred method for meeting its obligation to provide the 57% of flow shortfalls that NMFS will require it to provide for support of the threatened coho salmon (specific flows are shown in Table 9

TABLE 1-6 Summary of Components of NMFS Biological Opinions of 2002 that are Relevant to Threatened Coho Salmon in the Klamath River Basin

Component of Biological Opinion[a]
Apply 57% rule for proportionate USBR direct responsibility for flow at Iron Gate Dam
Use task force to develop the 43% additional flow from nonproject sources
Use phased approach to raising flows and lowering temperatures
Develop water bank (100,000 acre feet) on specific schedule
Adopt water-year types as identified in draft phase II flow study report (Hardy and Addley 2001)
Limit ramping rates below Iron Gate Dam
Conduct designated scientific studies with advice from external experts

[a]Components shown here are in addition to proposals of the USBR in its biological assessment.

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of NMFS 2002 and in Chapter 4 of this report). USBR must create a water bank to 100,000 acre-ft capacity by 2006 according to the RPA. A U.S. District Court judge found during July 2003, however, that reliance on the water bank is unjustifiably speculative until more particulars are given. Thus, USBR soon must issue a new biological assessment in consultation with NMFS, which must issue a new biological opinion.

In its recommendation for flows, NMFS gave greatest emphasis to improvement of the conditions for smolt migration, probably because tributary conditions are most important for spawning and rearing, while the main stem performs a critical and irreplaceable function in smolt migration (Chapter 7).

In prescribing flows, NMFS did not follow the method of USBR in assigning specific water years to categories. NMFS used estimates of unimpaired flows from the Hardy Phase II draft report (Hardy and Addley 2001) and the idea that the shape of the natural hydrograph and a natural range of interannual variabilities should be represented as completely as possible in the flows of the main stem. The five categories and their percentiles used by NMFS in its flow prescriptions for the Klamath main stem are as follows: wet years, 10%; above-average years, 30%; average years, 50%; below-average years, 70%; and dry years, 90%. The percentile in each case indicates the proportion of years that would exceed the unimpaired monthly flows. The RPA provides specific dates by which USBR must meet the flow requirements.

NMFS specified upper limits on ramping rates below Iron Gate Dam. The specifications are more stringent and more detailed than those governing previous operations. As in the case of screening plant intakes, however, the direct responsibility for meeting this requirement may lie with PacifiCorp rather than USBR.

According to the RPA of 2002, USBR is required to convene a panel of experts capable of identifying studies that improve the current understanding of relationships between river discharge and welfare of coho salmon. One specific element of the studies is a test of the effect of various flows on thermal refugia in the main stem of the Klamath River.

Overview of the 2002 Biological Assessments and Opinions

The USBR assessment and the accompanying biological opinions of USFWS and NMFS for 2002 reflect considerable constructive interaction among the agencies between 2001 and 2002. There is still a gap between the assessments and the opinions, but the gap has narrowed from 2001 through some carefully considered movement toward consensus among the three agencies. USFWS and NMFS are requiring some substantial actions beyond those proposed by USBR. In general, however, the actions adhere

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more closely than those given by the listing agencies in 2001 to the relevant available scientific evidence or to professional judgment reinforced by at least some scientific evidence. As explained in this report, USFWS and NMFS in a few instances have made requirements based almost entirely on professional judgment, without direct scientific support, as is their prerogative. In doing so, however, they appear to have made a special effort to frame their requirements in such a way as to cause minimal impairment of Klamath Project operations and, in contrast with 2001, have recognized the inevitable need to include parties other than USBR in modification of environmental conditions for the benefit of the endangered and threatened fishes.

CONTEXT FOR THE COMMITTEE'S REPORT

The NRC committee has evaluated a very extensive accumulation of data collected both in the field and laboratory, historical records of various kinds, opinions and interpretations by individuals intimately familiar with the environmental conditions in the Klamath, and numerical analyses of many kinds. Though the documentation for questions related to endangered and threatened fishes in the Klamath basin is impressive in scope and volume, it must be viewed as a preliminary step toward what eventually can and must be known about the Klamath River basin in support not only of the recovery of endangered fishes but also of the more general restoration of aquatic environments in the Klamath basin. As will be shown by this report, the number of firm conclusions that can be reached about cause-and-effect relationships still is modest, yet these types of conclusions are essential for planning, managing, and predicting the outcomes of actions in the Klamath River basin. The NRC committee sees its own work only as a best effort given the information available; the committee fully expects to see new kinds of data and new tests of ideas yield insights that the committee could not have anticipated based on current information. Effective efforts to cause recovery of the endangered and threatened fishes rest on information, and the committee urges the creation of new information that will place management decisions on increasingly firm ground.

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2

Land Use and Water Management

The Klamath River watershed covers 12,000 mi^2 of northern California and southwestern Oregon and extends more than 350 river mi from its headwaters to its estuary at the Pacific Ocean. The watershed derives its unique character largely from its geology and climate (Mount 1995), which are discussed in the first quarter of this chapter. The rest of the chapter describes land uses and resulting changes in the basin since 1848, the beginning of the gold-mining era. The topography, hydrology, ecosystems, and unusual plant and animal communities of the watershed reflect diverse dynamic processes in the landscape of today and in the past. These features of the watershed are tied to the natural resource economies of the watershed, which include logging, grazing, agriculture, mining, and fisheries. The diversity of land uses and landscape features poses a significant challenge to land managers and those seeking to restore the watershed's aquatic communities. As this chapter shows, simple or uniform approaches to restoration of impaired ecosystems are unlikely to succeed in a watershed as diverse as that of the Klamath River.

DESCRIPTION OF THE KLAMATH RIVER WATERSHED

Geologic Setting

The physiography of the Klamath watershed records the oblique convergence between the North American tectonic plate and the plates that underlie the Pacific Ocean. The Juan de Fuca and Gorda Plates, which lie

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off the shore of Washington, Oregon, and northern California, are being subducted in a northeasterly direction beneath western North America, forming the Cascadia subduction zone (Figure 2-1). A consequence of the subduction is the formation of an extensive north-south oriented chain of volcanoes known as the Cascadia volcanic arc or Cascade Range. The arc includes two of the more prominent volcanoes in the upper Klamath watershed: Mount Shasta and Mount Mazama (the site of Crater Lake). The volcanic arc bisects the Klamath watershed, dividing the upper basin from the lower basin (Figure 2-1). The upper basin, including the large natural lakes and their tributaries, lies in the back-arc of the Cascadia margin. The lower basin—which includes the mountainous, steeper portions of the main-stem Klamath and the Scott, Salmon, and Trinity rivers—lies in the dynamic fore-arc area of the margin. The Shasta River straddles the tectonic boundary between the back-arc and the fore-arc (Figure 2-1); its confluence with the main-stem Klamath occurs in the fore-arc region.

Geophysical and geodetic surveys coupled with geologic mapping efforts have shown that portions of the fore-arc and back-arc regions of the Cascadia margin form discrete crustal blocks, each with its own motion (Wells et al. 1998, McCaffrey et al. 2000). The motion of these blocks and their interactions with each other have dictated the dynamic topography of the region.

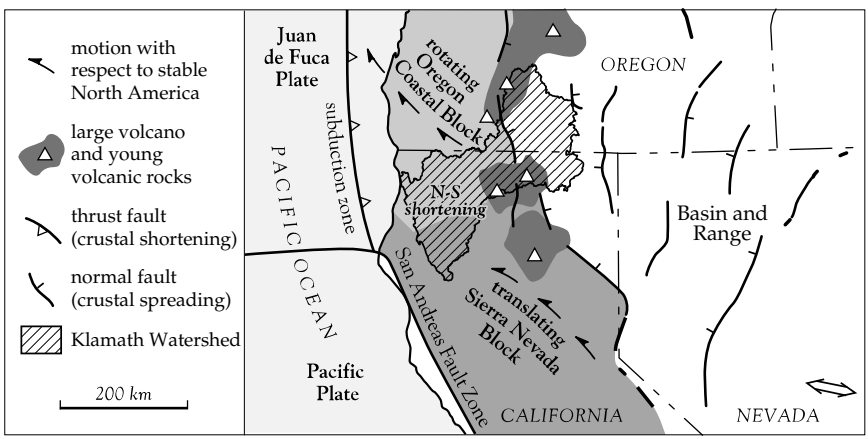


FIGURE 2-1 General tectonic setting for northern California and southern Oregon illustrating the Cascadia subduction zone, the Cascade volcanic arc, the Basin and Range Province, and the Oregon fore-arc and Sierra Nevada blocks. Note that the Klamath watershed occurs at the intersection of these tectonic blocks. Source: Modified from Wells and Simpson 2001.

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Within the Klamath watershed region, the back-arc portion of the Cascadia margin is part of the crustal block known as the Basin and Range Province. Although attached to North America, the province is undergoing east-west extension of as much as 1 cm/yr (Bennett et al. 1998, Magill et al. 1982). Right-lateral shear oriented north northwest-south southeast occurs along the western edge of the province and is superimposed on the east-west extension (Bennett et al. 1998, 1999). This shear has formed the distinctive grabens showing north-northwest south-southwest orientation, which appear topographically as fault-bound troughs and valleys of the Klamath Lake area. The crustal extension of the northwestern basin and range in southern Oregon and northern California has been accompanied by widespread Neogene volcanism that has formed the distinctive volcanic tablelands and broad valleys and marshes of the upper tributaries within the Klamath watershed.

Unlike most watersheds, the Klamath watershed has its greatest relief and topographic complexity in its lower half rather than in its headwaters. This unusual physiography stems from the location of the fore-arc region, which encompasses the lower half of the watershed. The Cascadia fore-arc of northern California is arguably the most dynamic landscape in the region (Mount 1995). The regional compression associated with subduction of the Gorda Plate immediately off shore has produced some of the fastest rates of uplift recorded in California. Additionally, the fore-arc occurs at the poorly defined intersection between two large crustal blocks (Figure 2-1): the Sierra Nevada block and the Oregon fore-arc block (Wells et al. 1998, McCaffrey et al. 2000). The Sierra Nevada block includes the Sierra Nevada-Great Valley of central California and the Klamath Mountains and Coast Ranges of Northern California. The block is bounded on the east by the Basin and Range Province and on the west by the San Andreas-Coast Range Fault system (Wells et al. 1998). Geodetic surveys indicate that the block is moving northwest relative to North America and is rotating in a counter-clockwise manner (Argus and Gordon 1990). The Oregon fore-arc block extends from the Cascadia subduction zone on the west to the Basin and Range on the east. Its southern boundary occurs at the transition to the Sierra Nevada block, roughly in the vicinity of the California-Oregon border. The Oregon fore-arc block is rotating clockwise relative to North America (Wells et al. 1998).

The lower Klamath River watershed, which extends from Iron Gate Dam to the Klamath estuary, traverses the northern portions of the Sierra Nevada block along its transition to the Oregon fore-arc block (Figure 2-1). The steep, rugged watersheds of the lower Klamath, coupled with the bedrock-controlled main stem, reflect the rapid uplift in the region and the constant adjustment of the river to its dynamic landscape (Mount 1995). The patterns of uplift and faulting also control the orientation of most

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tributaries. Because the main tributaries of the lower Klamath River—the Shasta, Scott, Salmon, and Trinity rivers—are important for salmonids, their individual geologic features are of interest.

The Shasta River watershed is at the junction between the Basin and Range Province, in the Sierra Nevada block within the Cascadia volcanic arc. Its watershed, which originates at Mount Eddy, encompasses about 800 mi^2. Like the Scott River watershed to the west, the Shasta has a large central alluvial valley, steep headwaters on the west, and a steep gorge in the lowermost portion of the watershed. The eastern portions of the watershed are dominated by Tertiary and Quaternary volcanic flows and by debris flows associated with Cascade volcanism. The lower gorge and westernmost edge of the basin are underlain by Paleozoic metamorphic rocks of the Sierra Nevada block. The most conspicuous topographic feature of the Shasta Valley is a large Pleistocene volcanic debris avalanche derived from nearby Mount Shasta that creates the unusual hummocky topography in the upper reaches of the valley (Crandall 1989). The north-south orientation of the valley is associated with large basin and range faults similar to those controlling the formation of the upper basin. The hydrology of the Shasta River watershed, unlike that of the other tributary watersheds of the lower basin, is dominated by discharge from numerous springs.

The Shasta subbasin lies within the extensive rain shadow of the Salmon and Marble mountains. Precipitation averages 12–18 in/yr and is as low as 5 in/yr in the vicinity of Big Springs (Mack 1960). The bulk of this precipitation occurs from October to March as snow. Like the upper Klamath basin, the Shasta subbasin has warm summers (mean daily temperatures commonly exceeding 30°C) and cool winters (mean daily temperatures of 5°C). The average length of the growing season in the basin is about 180 days (Mack 1960). As discussed in Chapter 8, climate may change over the coming decades.

The Scott River watershed lies at the transition between the Cascadia volcanic arc and the fore-arc basin (Figure 2-1). The watershed, which is about 820 mi^2, has headwaters nearly 8,000 ft above sea level in the Salmon Mountains along the west side of the watershed. The Scott joins the Klamath River at river mile 142. The physiography of the watershed shows elements of its neighboring watersheds. Like the Salmon watershed, the headwaters of the Scott are heavily forested and have annual precipitation of 50 in or more, high water yields, and extensive snowpack more than 4,000 ft above sea level. Like the Shasta watershed, the Scott has a large, fault-bound alluvial valley in the middle portions of the watershed that supports extensive agriculture and grazing. This valley, like the eastern portion of the Scott watershed, lies in the rain shadow of the Salmon and Marble mountains; mean annual precipitation is about 20 in. The Scott

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River, like the Shasta River, has a steep bedrock gorge downstream of the alluvial valley and above its confluence with the Klamath River. Mean daily temperatures in the valley exceed 32°C during late July or early August (peaks, above 40°C); mean daily temperatures reach 10°C in winter (Rantz 1972, CDWR 2002).

The tributaries of the Scott River strongly affect the hydrology (Mack 1958) and aquatic habitat of the basin. The fourth-order tributaries of the west side of the watershed—including Scott, French, Sugar, Etna, Patterson, Kidder, and Shackleford creeks—are steep-gradient, perennial bedrock tributaries. Several of these tributaries have built coarse-grained alluvial fans where their gradients decrease as they meet the valley floor. In contrast, the East and South Forks of the Scott and the third- and fourth-order creeks of the Scott River Canyon, a tributary of the Scott, enter the river in steep reaches and have no alluvial fans. The relatively dry east side of the watershed has several low-gradient ephemeral tributaries; Moffett Creek is the largest and most important of these.

In its upper reaches and within the canyon, the Scott River is primarily a bedrock river characterized by alternating step-pool and cascade reaches with discontinuous riffle-pool reaches containing narrow alluvial floodplains. Within the Scott Valley, the river has various forms that are controlled principally by grain size, slope, tributary contributions, and channel modifications. In coarse-grained, steep-gradient reaches of the river, the channel appears to be actively braiding. In low-gradient, fine-grained reaches with cohesive banks, the channel alternates between a single-channel meandering river and a multichannel, anastomosing river, albeit with numerous modifications for flood management and irrigation diversions. Some incision within the channelized reach has lowered the channel bed by several feet (G. Black, Siskiyou Resource Conservation District, Etna, California, personal communication, 2002). Sloughs, which indicate historical channel avulsion and cutoff events, apparently were numerous before agricultural development of the valley. Several large sloughs remain in the valley along the west side and receive flow from tributaries and from the main stem during large flow events.

At 750 mi^2 the Salmon River is the smallest of the four major tributaries to the lower Klamath basin (Figure 2-1). The Salmon watershed is steep and heavily forested and, in comparison with its neighboring watersheds, relatively undisturbed. The bulk of the main stem and its tributaries consist of bedrock channels with numerous step-pool and cascade reaches and narrow riparian corridors. The watershed is located entirely within the Cascadia fore-arc region on the Sierra Nevada block. The high uplift rates and the lack of extensional tectonics have prevented the formation of any important alluvial valleys, such as those of the Scott and Shasta drainages. The rugged terrain and the lack of a large alluvial valley have limited some

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of the land-use activities that have affected anadromous fishes in other tributaries.

The Trinity River is the largest tributary to the Klamath River. At 2,900 mi^2 with an annual average precipitation of 57 in, it is also the largest contributor of runoff and sediment to the Klamath River. It is a rugged, step, and heavily forested watershed. Its eastern portions in the Trinity Alps and Coast Ranges reach elevations in excess of 9,000 ft and support thick winter snowpacks. The bulk of the watershed is below 5,000 ft in elevation and is dominated by conifer and mixed conifer and hardwood forests. The confluence of the Trinity and Klamath rivers is located 43 mi upstream of the mouth and exerts considerable influence over conditions in the lowermost Klamath River and its estuary. The Trinity watershed is located entirely within the Sierra Nevada block, west of the Cascade volcanic arc. The basin lies close to the junction between the Cascade subduction zone and the northernmost San Andreas Fault. The physiography of the watershed is controlled by high rates of uplift and a series of large, seismically active northwest trending faults. The eastern half of the basin is composed of rocks of the Klamath Mountains Geologic Province, while the western half is dominated by rocks of the Coast Range Geologic Province. Both provinces contain rock types that are prone to landsliding and high rates of erosion, particularly when disturbed by poor land-use practices. The high rates of uplift, unstable rock types, and high rates of precipitation produce a naturally dynamic landscape and a river with a variable hydrograph and sediment yields.

Uplift in the Trinity watershed has precluded the formation of extensive alluvial valleys such as those found in the Scott and Shasta watersheds. The upper reaches of the main stem and the tributaries support steep-gradient rivers with numerous cascades. In portions of the main stem and the South Fork, however, low-gradient reaches with narrow alluvial valleys occur. These reaches historically supported dynamic, meandering coarse-grained channels that provided ideal spawning and rearing habitat for salmon and steelhead. The size of the Trinity watershed, coupled with its extensive high-quality spawning and rearing habitat, made the Trinity a productive source of coho salmon and other anadromous fishes (USFWS/HVT 1999).

Climate and Historical Hydropattern

The tectonic setting of the Klamath watershed exerts primary control over its irregular distribution of precipitation. The uplift of the Cascadia fore-arc and the formation of the Cascade volcanic arc have produced an important rain shadow in the upper basin and the Shasta Valley. The upper watershed has a relatively low mean annual precipitation (27 in; Risley and Laenen 1999), about half of which falls as snow. Precipitation in the lower

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watershed varies greatly and reaches as much as 100 in/yr in the temperate rain forest close to the coast. The rapid uplift of the fore-arc has produced a series of steep mountain ranges with strong orographic effects. Where mountain ranges exceed 5,000 ft above sea level, they maintain large winter and spring snowpacks in wet years and are associated with very high amounts of runoff during warm winter storms.

Annual runoff, as measured near the mouth of the Klamath River, is approximately 13×10^6 acre-ft. The upper watershed above Iron Gate Dam, which comprises about 38% of the total watershed area, provides only 12% of the annual runoff of the watershed. The low yields from the upper watershed are a product of its location in the rain shadow of the Cascades, its low relief, and its extensive marshes and lakes that increase hydraulic retention times. In contrast, the tributaries of the lower watershed dominate the total runoff of the Klamath watershed. Their high runoff stems from their high relief and the orographic influence of the Coast Ranges, Trinity Alps, and the Marble, Salmon, and Russian mountains. For example, one relatively small tributary, the Salmon River, supplies runoff about equal to that of the entire upper watershed, but from less than one-fifth of the area (Table 2-1).

TABLE 2-1 Runoff, Yield, and Basin Areas for the Klamath Watershed[a]

Location	Average Annual Runoff, 1,000 acre-ft	Drainage Area, mi^2	Runoff, %	Drainage Area, %	Ratio of Average Runoff to Drainage Area, acre-ft/mi^2
Klamath River below Iron Gate Dam	1,581	4,630	12	38	341
Shasta River near mouth	136	793	1	7	172
Scott River at mouth	615	808	5	7	761
Other tributaries	615	709	5	5	867
Klamath River below Scott River	3,020	6,940	23	57	435
Indian Creek at mouth	360	135	3	1	2,667
Salmon River at mouth	1,330	750	10	6	1,773
Other tributaries	1,350	650	10	5	1,500
Klamath River at Orleans	6,060	8,475	47	70	715
Trinity River at Hoopa	3,787	2,950	29	24	1,283
Other tributaries	3,021	675	23	6	4,476
Klamath River at mouth	12,868	12,100	100	100	1,109

[a]Data compiled from reports of the California Division of Water Resources 2002, representing average current conditions (including depletion caused by consumptive use) and gage records of the U.S. Geological Survey. Periods of record for data vary by site from 22 to 50 yr, principally between 1951 and the present, and include both pre- and post-Trinity River Diversion operations.

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The hydropattern, or timing of runoff, varies throughout the watershed. Seasonal runoff from the upper watershed is regulated by the long and complex transport pathways in the basin and, historically, by the natural buffering effect of overflow into the Lost River and Lower Klamath and Tule lakes.

Under unregulated conditions, peak runoff from the upper watershed would typically occur in April and decrease gradually to minimums in late August or early September. Flow regulation and land-use activities in the upper basin have altered the hydropattern. Unlike the upper basin, the lower Klamath basin exhibits two potential flow peaks, depending on the water year. Subtropical storms strike the Klamath watershed with high frequency from late December to early March and are responsible for all peak daily discharges in the Klamath main stem and its tributaries. The short hydraulic retention times of the tributaries to the lower Klamath basin enhance the effect of these storms. The second and more predictable flow peaks are associated with spring snowmelt. The timing of the snowmelt pulse varies, but it usually occurs in April. Historically, the decline in flow from the tributaries to the lower basin was gradual and reached minimums in September. During the low-flow periods in the late summer or early fall when no precipitation occurs, spring-fed tributaries such as the Shasta River and flow from the upper basin constitute the bulk of base flow in the main stem of the lower basin.

Even the Trinity, the largest annual contributor of runoff to the Klamath, historically provided very little flow in the late summer and early fall.

AQUATIC ENVIRONMENTS IN THE UPPER KLAMATH BASIN

The upper Klamath basin encompasses about 5,700 mi^2 (USBR 2000a). Major lakes in the upper Klamath basin include Upper Klamath Lake (now 67,000 acres at maximum lake elevation), Lower Klamath Lake (historical maximum area, 94,000 acres; now about 4,700 acres), Tule Lake (historical maximum area, 110,000 acres; now 9,450–13,000 acres), Clear Lake, and Gerber Reservoir (see Chapter 3).

Upper Klamath Lake, now the largest water body in the Klamath basin, receives most of its water from the Williamson and Wood rivers. The Williamson River watershed consists of two subbasins drained by the Williamson and Sprague rivers. The Williamson River arises in the Winema National Forest, flows to the north through Klamath Marsh, and turns south to Upper Klamath Lake. The Sprague River arises in the Fremont National Forest and flows westward to connect with the Williamson River just below the Chiloquin Dam (Figure 1-1). The Sycan River, a major tributary of the Sprague, drains much of the northeastern portion of the watershed. Both the Williamson and Sprague subbasins are primarily for-

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ested (about 70%). Other important land-cover types are shrub and grassland (14%), agriculture (6%), and wetland (6%; Boyd et al. 2002). The Williamson and Sprague together provide over half the water reaching Upper Klamath Lake (Kann and Walker 2001).

The Wood River is the second largest source of water (16%) for Upper Klamath Lake (Kann and Walker 2001). Annie and Sun creeks join to form the Wood River. The watershed drains an area northeast of Upper Klamath Lake and extends from the southern base of the mountains that surround Crater Lake to the confluence of the Wood River with Upper Klamath Lake by way of the northern arm (Figure 1-3), which is often called Agency Lake. Although primarily forested, the Wood River has extensive agricultural lands and wetlands. The balance of the water reaching Upper Klamath Lake is derived from direct precipitation on the lake and flows from springs, small streams, irrigation canals, and agricultural pumps.

Before development of the Klamath Project, Lower Klamath Lake (Figure 1-3) was often larger than Upper Klamath Lake. Flows from the Klamath River, supplemented by springs around the lake, supported a complex of wetlands and open water covering approximately 80,000–94,000 acres in the spring, during high water, and 30,000–40,000 acres in late summer. The open water provided habitat for suckers, and the variable combination of open water and marsh created important habitat for migratory birds along the Pacific Flyway, making it one of the most important aquatic complexes for waterfowl in the West. By 1924, however, development of the Klamath Project eliminated more than 90% of its open water and marsh. Only about 4,700 acres of open water and wetland remain. Draining the lake led to the extirpation of sucker populations that had been in the lake (USBR 2002a), and also eliminated much of the habitat suitable for waterfowl and other birds.

Connections between the Klamath River and Lower Klamath Lake were severed by development, which changed the hydrology of both the lake and the river in ways that are not entirely clear. Before 1917, when railroad construction blocked the Klamath Straits, "water flowed from Upper Klamath Lake, through the Link River into Lake Ewauna, and then into the Klamath River. Between Lake Ewauna and Keno, the river meandered through a flat, marshy country" (Henshaw and Dean 1915, p. 655) for about 20 mi before descending over a natural rock barrier that stretched across the river at Keno. "Water in the river periodically backed up behind the reef at Keno and spread out upstream, flowing into Lower Klamath Lake through Klamath Straits" (Weddell 2000, p. 1). Today, connectivity between Lower Klamath Lake and the rest of the basin is limited to water pumped through Sheepy Ridge from Tule Lake and water from irrigation channels that lead to the Keno impoundment (USFWS 2001, Figure 1-2).

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Before the Klamath Project, the lake and wetlands probably retained substantial amounts of early spring precipitation and some of the high flow of the river. "By storing and subsequently releasing this water into the river, Lower Klamath Lake would have augmented the effects of groundwater in shifting the Klamath River hydrograph to the river" (Weddell 2000, p. 7). Lower Klamath Lake was "neither an undrained basin nor a thoroughly drained floodplain. At times, its waters flowed into the Pacific Ocean via the Klamath River, yet this drainage was only partial" (Weddell 2000, p. 8).

Before 1924, suckers appear to have been abundant in Lower Klamath Lake, even after its connection to the river was severed in 1917. Suckers migrated into the lake from Sheepy Creek, a spring-fed tributary on the western edge of the lake, in numbers large enough to support a fishery (Coots 1965, cited in USFWS 2001).

Before the Klamath Project, Tule Lake (Figure 1-3) varied from 55,000 to over 100,000 acres, averaging about 95,000 acres (making it often larger than Upper Klamath Lake). Like Lower Klamath Lake, Tule Lake was connected seasonally to the Klamath River. During periods of high runoff, water from the Klamath River flowed into the Lost River slough and down the Lost River to Tule Lake. The direction of the river's flow is now determined by operators of the Klamath Project, depending on irrigation needs. Most of the former bed of Tule Lake has been drained for agriculture, leaving about 9,450–13,000 acres of shallow lake and marsh.

The fluctuation in surface area of Tule Lake afforded by its connections to the Klamath River may have been critical in maintaining the high aquatic productivity of Tule Lake and its wetlands (ILM 2000). Tule marshes on the north and west sides of the lake supported populations of colonial nesting water birds and summer resident waterfowl. The large fish populations in the lake supported what was probably the largest concentration of nesting osprey in North America (ILM 2000). Much of the historical variability in lake and marsh habitats has been lost as a result of management. Nevertheless, well into the 1960s and early 1970s, Tule Lake National Wildlife Refuge was considered the most important waterfowl refuge in North America; duck populations exceeded 2.5 million at their peaks. Siltation caused by agriculture and loss of wetland productivity has occurred in the last several decades, however, and waterfowl populations have declined (ILM 2000).

Historically, suckers in Tule Lake and the Lost River were abundant enough to support cannery operations along the Lost River (USFWS 2001). After the Klamath Project drained most of Tule Lake for agriculture and diversion dams of the project blocked the access of suckers to spawning areas in the Lost River, sucker populations declined substantially (Scoppettone et al. 1995, USBR 2002a).

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The hydrology of Tule Lake and of the Klamath River first changed in 1890, when settlers built a dike across the Lost River slough in an attempt to protect lands near Tule Lake from flooding (USFWS 2001). The dike prevented Klamath River floodwaters from overflowing into the Lost River drainage and ultimately draining into Tule Lake. As is the case with respect to Lower Klamath Lake, the amount of water that flowed from the Klamath River into Tule Lake and the effect of this overflow on the historical hydrograph of the Klamath River are unclear. Estimates of historical Klamath River flows are derived from measurements recorded before Lower Klamath Lake was disconnected from the Klamath River, but the measurements were taken after Tule Lake was disconnected from the river.

The Lost River drains Clear Lake and flows north toward the Klamath River (Figure 1-3). The structure and hydrology of the Lost River have been highly modified by the Klamath Project. Historically, the Lost River was connected to the Klamath River during periods of high flow via the Lost River slough. There is now no direct outlet to the Klamath River, although diversion canals can be used to send water into the Klamath Project (Figure 1-2).

Aquatic habitats have been modified throughout the upper Klamath basin, but the Lost River watershed has been particularly altered by development of the Klamath Project. The Lost River, once a major spawning site for suckers, today supports few suckers (Chapter 6). According to the U.S. Fish and Wildlife Service (USFWS), the Lost River "can perhaps be best characterized as an irrigation water conveyance, rather than a river. Flows are completely regulated, it has been channelized in one 6-mi reach, its riparian habitats and adjacent wetlands are highly modified, and it receives significant discharges from agricultural drains and sewage effluent. The active floodplain is no longer functioning except in very high water conditions" (USFWS 2001, III-2-24). New lakes have been created and old lakes drained, new waterways have been dug and old rivers turned into irrigation ditches, and new sucker habitat has been created while original sucker habitat has been eradicated.

Before 1910, a natural lake, marsh, and meadow complex occupied what is now Clear Lake (Figure 1-3). Water from this lake drained into the Lost River and then to Tule Lake (USBR 2000a). In most years, the Lost River below the present Clear Lake dam ran dry from June through October. To hold back floodwaters from Tule Lake and store seasonal runoff for irrigation later in the season, a dam was constructed at Clear Lake in 1910, impounding the waters of the Lost River and creating a larger lake.

Where Gerber Reservoir now stands (Figure 1-3), 3,500 acres of seasonal wetlands existed before the Klamath Project, but there was no lake. Construction of Gerber Reservoir in 1926 for flood control and irrigation created new sucker habitat and a population of suckers persists there (USBR 2002b, Chapter 5).

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AQUATIC ENVIRONMENTS IN THE LOWER KLAMATH BASIN

The lower Klamath River, including the Trinity River, is the largest of the coastal rivers of California (Figure 1-1). The lower Klamath basin historically was dominated by large runs of anadromous fishes with diverse life-history strategies (Chapter 7), some of which penetrated into the headwaters of tributary streams and into the rivers feeding Upper Klamath Lake. Four major tributaries to the Klamath River—the Salmon, Scott, Shasta, and Trinity rivers—were major salmon and steelhead producers. The Shasta River in particular, with its cool summer flows, was once one of the most productive streams of its size for anadromous fish in California (Chapter 7).

Historically, most of the aquatic habitat in the lower Klamath River consisted of streams with moderate to high gradients and cool water in summer, although the main-stem Klamath River may have been fairly warm during late summer. Similar conditions existed in the Trinity River (Moffett and Smith 1950). The flows in tributary streams were high in winter and spring from rain and snowmelt and low in summer. Native fishes of the lower basin are mainly anadromous but also include a few nonanadromous stream fishes (Chapter 7).

Many small tributaries enter the main-stem Klamath between Iron Gate Dam and Orleans. These creeks largely drain mountainous watersheds dominated by forest. Most creeks are affected to some degree by logging, mining, grazing, and agriculture. Water withdrawal leads to reductions in summer base flows in many of these tributaries. Water quality has not been extensively studied, but these tributaries may be particularly important in providing cold-water habitats for salmonids (Chapter 4).

As described below, the watershed has been drastically altered by human activities. The anadromous fishes have been in decline since the 19th century, when dams, mining, and logging severely altered many important streams and shut off access to the upper basin. The declines continued through the 20th century with the development of intensive agriculture and its accompanying dams, diversions, and warm water. Commercial fishing also contributed to the declines.

HISTORY OF LAND USE IN THE KLAMATH BASIN

For at least 11,000 yr, ancestors of the Klamath and Modoc Indians inhabited the upper Klamath basin (OWRD 2000). Most of the year, the Klamath and Modoc tribes lived near creeks, springs, riparian areas, and marshes (Cressman 1956). Their family groups were small, so they were able to extract enough resources for survival on a sustainable basis. Family groups came together during seasons of resource abundance for communal

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hunts, for celebrations, and to take advantage of seasonal concentrations of suckers and riparian plants (Cressman 1956).

The Klamath Indian name for Lost River suckers is *tchwam*; shortnose suckers are referred to as *kuptu* (L. K. Dunsmoor, Klamath Tribes, Chiloquin, Oregon, personal communication, September 3, 2002). Suckers in general became known to settlers as mullet. Lost River suckers in particular were once a staple food of the Modoc and Klamath tribes; they provided important protein in the spring, when food reserves had been depleted (Cope 1879, USFWS 2002). Gilbert (1898) reported them as the most important food fish in the Klamath Lake area, and Stern (1965) estimated an artisanal harvest of 50 tons/yr, which would correspond to 13,000 fish at an average weight of 3 kg.

The Klamath and Modoc tribes manipulated the wetlands and riparian areas to increase their resources. For example, the Klamath burned riparian areas because women preferred to weave baskets with the supple young stems that sprouted after a fire. They burned wet meadows in fall to increase production of root plants, to lure animals that were attracted to the protein-rich shoots that grew after fire, and to protect their shelters from wild grassland fires. Intensive digging, particularly for roots, also altered riparian areas (C. Burnside, Malheur National Wildlife Refuge, personal communication, 1997).

Four tribes occupied the lower Klamath basin. The Yurok lived along the Pacific coast from about 15 mi south of what is now Crescent City down to Trinidad Bay and up the Klamath River to Bluff Creek, a few miles past the junction with the Trinity River. The Hupa people lived along the Trinity River, where 13 villages were concentrated in a 7-mi reach called Hoopa Valley. The Karuk lived along the Klamath River upstream of the Trinity to a point beyond Happy Camp. Above Happy Camp, the Shasta Nation occupied the upper reaches of the Salmon, Klamath, Scott, Shasta, and McCloud rivers (Beckman 1998).

The Yurok, Hupa, and Karuk were closely allied with the sedentary cultures of the northwest coast; the Shasta showed cultural traits more akin to those of the migratory tribes of the inland West (Beckman 1998). The Yurok, Hupa, and Karuk spoke languages of three very different language groups—Yurok is Algonquian, Hupa is Athapaskan in origin, and Karuk is Hokan and thus associated with old languages of Mexico—but their cultural habits were similar (Beckman 1998). In contrast with the tribes down river, the Shasta did not occupy permanent villages, and their traditions were closer to those of the tribes of the upper Klamath basin.

The Yurok and Hupa, unlike tribes in the drier inland regions, were able to be almost completely sedentary because of salmon runs (Nelson 1988). As Beckman (1998) noted, their resources were so plentiful that they had the free time to nurture the arts and crafts in a way that was uncommon in California

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and that gave them a hierarchy of status and wealth. Unlike most other California nations, the Yuroks recognized no chiefs and had no organized political society. They were unique in believing in individually owned land; a family's wealth was measured by the amount of land that it owned, and land could be sold. The Hupa were strictly a river people, whereas the Yurok were divided between river and coastal villages. Most Yurok, however, lived along the Klamath River and relied on riverine resources (Waterman 1920), even though they used coastal resources, such as shellfish, surf fish, and seals. Anadromous fish that brought the abundant energy of the Pacific Ocean upstream were the Yurok's, Hupa's, and Karuk's most important resources and were critical resources for the Shasta as well.

Fur Trapping

When fur trappers from the Hudson Bay Company of Canada arrived in the Klamath basin in the 1820s, tribes throughout the basin coexisted in relative peace with them. Trappers were not seeking to establish permanent settlements in the basin that might threaten tribal rights. Rather, in an attempt to discourage Americans from laying claim to the region, Hudson Bay Company's written policy was to trap fur-bearing animals from streams south of the Columbia River to extinction. In July 1827, George Simpson of the Hudson Bay Company stated the policy clearly, writing that the best protection from Americans was to keep the "country closely hunted" (Williams 1971, p. xiv). Peter Skene Ogden, the trapper who opened up much of the basin to white exploration, followed that policy. By the summer of 1828, Ogden wrote of the region that "almost every part of the country is now more or less in a ruined state, free of beaver" (Ogden 1971, p. 98). During the next spring, he wrote that "it is scarcely credible what a destruction of beaver by trapping at this season, within the last five days upwards of fifty females have been taken and on average each with four young ready to litter. Did we not hold this country by so slight a tenure it would be most to our interest to trap only in the fall, and by this mode it would take many years to ruin it" (Ogden 1971, p. 17).

Ironically, it was the removal of beaver by fur trappers that helped create the basis for ranching. When beaver were removed, their dams fell into disrepair and the small wetlands behind the dams were drained and became the fertile meadows that were soon to sustain ranchers' cattle (Elmore and Beschta 1987).

Mining

Although the tribes were able to coexist with trappers, the miners who followed them proved disastrous to the Indian nations. Far more than

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trappers, miners transformed the basin's rivers and wetlands, partly because of mining activities in the rivers and streams and also because of their indirect encouragement of permanent white settlements. Miners created a new market for food and supplies and thus attracted farmers and ranchers to the region. Many of the settlements in the lower Klamath River basin originated from the mining boom of the middle 1800s (NMFS 2001). Miners also depended upon federal troops and Indian agents to cope with the problems that mining generated; they created a U.S. Army presence in the basin that further destabilized relations with the tribes (Malouf and Findlay 1986).

Mining in the 19th century was particularly destructive of fish habitat along the lower Klamath basin. In 1853, miners discovered a way to excavate gold-bearing placer deposits by using blasts of water to wash away gravel. Mining companies soon diverted creeks into reservoirs that fed water at high pressure to huge nozzles that could deliver water at up to 30,000 gal/min. The jets of water could level entire hillsides and their use rearranged much of the riparian landscapes of California. The waterborne debris was directed into sluices containing mercury, which captured the gold. Before a court ruling halted the practice in 1884, hydraulic miners released 1.6×10^9 yd^3 of sediment into California waterways, while hardrock miners produced another 3×10^7 yd^3 of tailings, and dredgers left behind about 4×10^9 yd^3 of debris—a total of about 5.6×10^9 yd^3 for the entire state (Krist 2001).

Water was diverted and pumped for use in sluicing and hydraulic operations that resulted in increased turbidity and siltation. Silt from mining harmed benthic invertebrates, covered salmon redds, suffocated salmon eggs, and filled pools that were used by salmon. Wood for equipment and structures, railroad tracks, housing, and fuel was obtained through deforestation, often on steep slopes, and caused erosion, flooding, fires, and loss of animals. Miners also reduced freshwater resources by overfishing, damming, and diverting streams (Malouf and Findlay 1986).

The gold rush brought extensive changes to the Scott River watershed, particularly the main stem and South Fork and Oro Fino, Shackleford, and French creeks. Placer mining began as early as 1851 and expanded to widespread hydraulic mining in 1856 (Wells 1881). Large Yuba dredges that operated in 1934–1950 (Sommerstram et al. 1990) left some of the most visible effects of mining in the basin. They excavated material 50–60 ft below the river bed and created tailings piles more than 25 ft high downstream of the town of Callahan. The processing of the sediment by Yuba dredges left much of the coarsest material (typically boulders) at the top of the piles, effectively armoring the finer sediments. Early surveys in the basin (Taft and Shapovalov 1935) noted the severe damage that the dredging had caused to fish habitat. To support the mining, numerous

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ditches were constructed along the margins of the valley to intercept tributary flows, and these ditches eventually became sources of irrigation water for early agricultural development.

The Salmon and Trinity rivers were also severely affected by mining. Along the Salmon River, during the late 1800s and into the 1990s, extensive placer gold mining and some hydraulic gold mining were conducted in the main stem and the South and North Forks. The main stem of the Trinity River was severely impaired by placer mining within the channel and by hydraulic mining and extensive dredging.

One of the most problematic effects of the gold rush was the release of mercury into the environment; the consequences continue today. Mercury was critical in the mining and processing of gold; it is estimated that at least 2.6×10^7 lb of elemental mercury were used between 1850 and 1900 in gold mining. Much of the mercury remains in soils and sediments, and some of it has been converted into methyl mercury, which is particularly dangerous for humans because it travels through the food chain into fish and becomes a threat for those who eat fish. In addition to contamination from mercury used in gold mining, mercury contamination comes from mercury mines, some of which were in the Klamath basin. Most of the mines are now abandoned (Krist 2001).

By the late 1850s, gold mining in California was a large-scale industry that required infusions of capital for construction of mills, rail lines, dams, flumes, and smelters. Miners used two major processes to extract gold: stamp mills and hydraulic placer mining. Both methods used a great deal of mercury. Stamp mills pounded gold-bearing ore into dust that then was washed across mercury-coated plates; the gold sank and stuck to the mercury, and the less dense debris was carried away. The mercury-gold amalgam then was heated in furnaces, which vaporized the mercury and left the gold. Some of the evaporating mercury was captured in a condensation chamber for reuse, but much escaped into the air or was crushed by the stamp mill and released into the water. Hydraulic placer mining released even more mercury into the environment—perhaps as much as 1 lb of mercury for every 3 or 4 oz of gold recovered, or about 1.3×10^7 lb of mercury in the 19th and early 20th centuries (estimate by Ronald Churchill of the California Division of Mines and Geology, cited in Krist 2001).

Because salmonids achieve most of their growth in the marine environment, mercury accumulation in adult salmon presents less of a health risk to humans than would mercury accumulation in other kinds of large predatory fish. Nevertheless, mercury contamination may affect the coho salmon themselves. Young salmon are sensitive to mercury released by placer mining (USFWS 1991). Early life stages of coho salmon are harmed by low concentrations of methyl mercury (Buhl and Hamilton 1991, Devlin and

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Mottet 1992), and placer mining releases contaminants that can be toxic to early life stages of salmonids (Buhl and Hamilton 1990).

The deleterious effects of mining on salmonid habitat were so rapid and intense that in 1852, only 4 yr after Sutter's discovery of gold in the foothills of the Sierra Nevada, California enacted its first salmon statute, which required "'all good citizens and officers of justice' to destroy man-made obstructions to salmon migration, except those erected by Indians." That statute did little to stem habitat destruction. In the 1880s, all obstructions to salmon migration, including those built by Indians, were banned by state law (Lufkin 2000).

The gold rush struck all California tribes hard (Heizer 1978, White 1991). Within a year after Sutter's 1848 discovery, at least 80,000 miners and others came to California, overwhelming governmental and military authority. In the quarter-century from 1845 to 1870, the Indian population in California declined from about 150,000 to 30,000 largely because of direct and indirect effects of the gold rush (Franzius 1997).

In 1851–1852, 18 treaties were negotiated with California tribes, including the Yurok, Hupa, and Karuk. The treaties set aside 7,466,000 acres of lands for the tribes and promised agricultural and educational assistance. But in 1852, California's new state senators refused to ratify the treaties.

Among the tribes of the lower Klamath basin, violent resistance to miners and to the California legislature's increasingly repressive policies erupted in 1860–1872. The Hupa were more successful than many other California nations in resisting encroachments of settlers on their land. When federal troops entered the Hoopa Valley, the Hupa were able to withstand the troops and force them into a stalemate. On August 12, 1864, the Treaty of Peace and Friendship was signed between the Hupa and the U.S. government; it promised the Hupa a reservation that included about 90% of their original homeland. In 1891, President Harrison signed an executive order joining the Hupa and Yurok reservations. The Karuk and Shasta, however, never gained legal ownership of their homeland. Most land occupied by the Karuk was claimed by the government with little compensation, and much of it became part of the national forest system. Timber development in the 20th century brought some measure of prosperity to the Hupa and Yurok reservations. For example, seven new sawmills were constructed in the Hoopa Valley during the 1950s, and timber income was distributed throughout the tribe. Yet this was also the "Termination Era," when federal Indian policy shifted toward the termination of tribal rights and the breakup of Indian land holdings (Nelson 1988).

As miners, ranchers, and the army came to the Klamath basin in the 1850s, confrontations erupted, culminating in the Modoc Indian War of 1872. In 1864, the Klamath and Modoc tribes and the Yahooskin band of Snake Indians met with federal officials to sign a treaty that relinquished

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more than 19 million acres of their homeland, reserving about 2.5 million acres for the Klamath Indian Reservation. This land was soon substantially reduced through correction of a federal survey error (Gearheart et al. 1995). The treaty of 1864 specified the Klamath Tribes' exclusive right to hunt, fish, and gather on Klamath Indian reservation lands. Although the Klamath tribes lost their reservation land following termination of the reservation in 1954 (Haynal 2000), they retained their water rights and their right to harvest a number of fish species designated as tribal trust species, reflecting their traditional practices.

Ranching

After the Modoc Indian War, open hostilities between whites and Indians diminished in the upper basin, and white immigration to the basin increased. Early white settlement in the upper Klamath basin centered on ranching rather than farming because without irrigation, precipitation often was insufficient for growing most crops (Blake et al. 2000). The General Allotment Act of 1887 allowed Indian lands to pass into white ownership, and much of the best grazing land on the reservation was bought by whites.

In the upper Klamath basin, as throughout the entire inland portion of the West, cattle increased in abundance during the 1870s and 1880s until by the late 1880s overgrazing became a political and ecological issue. In 1875, the Central Pacific Railroad completed a shipping facility at Winnemucca, Nevada, giving cattle operations relatively rapid access to San Francisco beef markets. With an efficient transportation infrastructure in place, ranchers brought more animals to the open range. When prices were low, few ranchers sold their young cattle, and herd sizes rose while ranchers waited for better prices (Gordon 1883). Overgrazing was the result.

The federal government responded to overgrazing with the Gordon report, the product of a study motivated in part by the disastrous winter of 1879–1880, when extraordinary cold led to high mortality of cattle across the West. Gordon noted that overgrazing meant that wetlands and riparian meadows were becoming critical habitat for cattle, especially in southeastern Oregon. Ranchers fenced riparian areas and planted them with alfalfa for winter feed. That took some of the pressure off the land, but only for a short time (Gordon 1883). The result, as the 1883 edition of *West Shore* magazine reported, was a landscape "almost bare of grass except for a few clumps under the dense, scraggly sage brush" (Lo Piccollo 1962, p. 115).

In the wake of the 1879–1880 disaster, cattle and sheep populations were rebuilt until a combination of dry summers and cold winters occurred in the late 1880s (Simpson 1987). Cattle prices collapsed in 1885 and 1886, and ranchers held their stock from market, hoping for higher prices. In 1889, when the geologist Israel Russell toured southern Oregon, streams

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throughout the region that Ogden had described as level with the surrounding landscape in the 1820s had begun to incise their channels, and Russell (1903, p. 63) concluded that this was caused by "the introduction of domestic animals in such numbers that the surface covering of bunch grass was largely destroyed, and in consequence the run-off from the hills accelerated."

Government inspectors who were sent to the region warned that overgrazing was ruining the very source of the region's prosperity. The inspectors recommended that the only solution was to provide more grass by draining wetlands and planting them with hay so that there would be less competition for a dwindling resource (Griffiths 1902). Ranchers did exactly that as they began diking and draining wetlands in the 1890s along the borders of Upper Klamath Lake to provide more forage for cattle.

Good government records of numbers of cattle in the upper Klamath basin begin with the 1920s, when 30,000 cattle occupied Klamath County, which makes up only part of the watershed (Walker 2001). In the 1960s, the cattle population in Klamath County peaked at 140,000 head (Figure 2-2); by 1999, there were 120,000.

To accommodate cattle, ranchers turned to flood irrigation of pastures and drainage of wetlands. Early methods of flood irrigation did not always degrade riparian and wetland habitat, but a switch to nonnative species for production of hay in the 1950s required changes in irrigation practices that, while increasing efficiency, severed riparian connections to the landscape (Langston 2003). In 1998, the Environmental Protection Agency's Index of Watershed Indicators estimated that at least 110,000 acres of the watershed

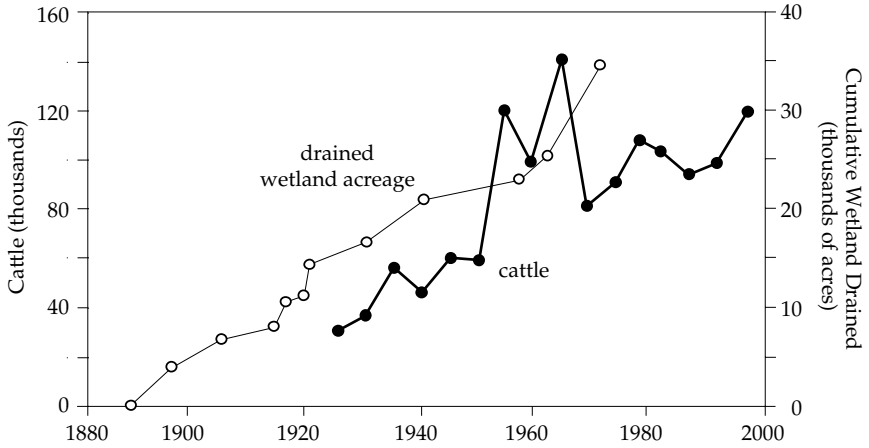


FIGURE 2-2 Changes in numbers of cattle and cumulative acres of drained wetland in Klamath County, Oregon. Source: Modified from Eilers et al. 2001.

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had been converted to irrigated pasture or other agricultural activities; Risley and Laenen (1999) estimated an 11-fold increase in acreage of irrigated land between 1900 and the 1990s.

While numbers of cattle were only slightly lower in the 1990s than in the 1960s, the acreage of land being grazed declined much more substantially. The U.S. Bureau of Reclamation (USBR) estimated that by 2000 only 35% of the Upper Klamath Lake watershed was grazed (USBR 2002a). By 2002, nearly 100,000 acres of irrigated agriculture had been retired, and some of this was restored to wetland. Thus, production intensity appears to have increased. Transport of cattle to California during the winter was part of the method for keeping cattle production high while the acreage of irrigated pastureland declined.

The effects of grazing in the watershed were probably profound but are impossible to quantify. Overgrazing in riparian zones can harm fish by degrading riparian vegetation (Chapter 4). Grazing can mobilize nutrients and sediments, both of which are of concern in the upper Klamath basin (Stubbs and White 1993). By 1900, native perennial grasses were being replaced with annual grasses and forbs that, when combined with soil compaction from cattle, may have resulted in higher erosion and greater peak flows (NMFS 2001). For example, on Fishhole Creek, cattle had destroyed streambank vegetation, resulting in erosion and lowered water tables (Thompson et al. 1989). Conditions are similar in the Wood River valley and in some of the Sprague River watershed. Season-long grazing in the past probably contributed to reduction of spawning habitat for trout and suckers in the Sprague River, increased stream temperatures, and increased transport of sediment and nutrients. These changes led the Oregon Department of Environmental Quality to identify the Sprague River as one of the highest-priority streams in Oregon for control of non-point-source pollution (Stubbs and White 1993). Cattle do not always lead to such adverse effects; well-managed riparian pastures can be consistent with good stream conditions.

Irrigated pasture required water diversions from Klamath basin tributaries, and the diversions have played a substantial role in the decline of suckers in the upper basin and of salmonids in the lower basin (Chapters 5 and 7). The Chiloquin Dam on the Sprague River near Chiloquin, Oregon, constructed in 1914–1918 for water diversion and timber milling, is one example.

Timber

Much of the blame for poor watershed conditions is placed on agriculture, but nearly 80% of the Upper Klamath Lake watershed is forested, and much of the forest land has been harvested under federal, tribal, and private

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management (Gearheart et al. 1995). According to the Oregon State Water Resources Board (cited in Gearheart et al. 1995), over 73% of the forest land in the upper Klamath basin is subject to severe erosion. Therefore, timber management may well have contributed to the decline of suckers and salmonids.

Commercial logging began in the upper basin in 1863 when the U.S. Army constructed a sawmill. The pace of logging accelerated during the late 1910s, when ponderosa pine became an important timber resource for the nation (Langston 1995). By 1918, large amounts of reservation timber were being sold to private parties; by 1920, annual harvest rates had increased to 120 million board ft. Peak lumber production occurred in 1941, when 22 lumber mills processed a total of 808.6 million board ft within the upper basin. Harvest has dropped to about 400 million board ft in recent years (Eilers et al. 2001, Gearheart et al. 1995).

Poorly designed roads and damaging harvest practices on pumice and volcanic soils and on steep slopes probably contributed to loss of fish habitat. When stripped of vegetative cover, steep slopes are subject to erosion. In the lower basin, road construction has increased erosion and also created barriers to fish passage (USBR 2001b). Log storage on the Klamath River below Klamath Falls also has affected fish habitat. After fish kills in the late 1960s, log storage was greatly reduced on the river, but it continues (Stubbs and White 1993).

Forest management and fire suppression over the last century changed forest composition in the Klamath basin. The change may have altered flow regimes in the rivers and nutrient movement in the watershed. Before the 1920s, the upper basin forest was composed largely of old-growth ponderosa pine except at high elevations, and frequent, low-intensity fires minimized understory growth. Logging and fire suppression have led to a much denser understory populated with grand fir (Risley and Laenen 1999). As forest composition has changed, the risk of intense fires has increased substantially. Such fires can contribute damaging amounts of sediments and nutrients to streams and rivers. Moreover, intensive clearcutting may have increased peak flows, and the increased understory and denser forests may have decreased total water yield (Risley and Laenen 1999).

In the lower Klamath basin, timber harvesting began in the 1850s in the Scott River watershed commensurate with the growth in mining. As in most northern California watersheds, logging activity reached a peak in the 1950s (Sommerstram et al. 1990). The construction of roads and trails in the watershed has been a major source of fine sediment in the basin, particularly on decomposed granite soils. About 40% of the Scott River watershed that is underlain by such soils was harvested in 1958–1988; more than 288 mi of logging roads and 191 mi of skid trails were constructed (USFS data, summarized in Sommerstram et al. 1990). Sedi-

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ments have adversely affected spawning and rearing habitat of coho (West et al. 1990).

Along the Salmon River, logging has been substantial, particularly since the 1950s. Road networks have been identified by the U.S. Forest Service (USFS) and the California Department of Fish and Game (CDFG) as an important source of sediment in the basin, and road crossings have been identified as affecting salmonid habitat (CDFG 1979a). Also, the heavily forested Salmon River watershed is susceptible to large wildfires. Since the early 1900s, more than 50% of the basin has burned, and most of the fires have been intense crown fires (USFS data, summarized in Salmon River Restoration Council 2002). Although poorly funded, federal fuel-management efforts are under way in the basin in cooperation with the Salmon River Watershed Council.

In the Trinity River watershed, logging practices, described as "abusive" by the Secretary of the Interior in a 1981 decision regarding flow releases on the Trinity, has had significant effects on the quality of salmonid habitat on the Trinity (USFWS/HVT 1999). Extensive logging road networks, coupled with highly erosive soils, have produced high yields of fine sediment within the basin. Very large floods on the Trinity River in December of 1964 introduced especially large volumes of fine sediment that caused severe degradation of spawning and rearing habitat in the South Fork and main stem of the Trinity.

Agriculture in the Upper Basin

Serious efforts at irrigation and drainage in the Klamath basin started in about 1882; by 1903 about 13,000 acres in the upper Klamath basin were irrigated by private interests. Land speculators urged USBR to consider the Klamath basin for irrigation, and a USBR engineer estimated in 1903 that irrigation could water 200,000 acres of farmland.

California and Oregon had acquired Lower Klamath Lake through the Swamp Lands Act of 1860, but their efforts to stimulate drainage and reclamation had failed. In 1904 and 1905, California and Oregon ceded the lake back to the federal government for use by USBR. Oregon gave USBR the right to the water of the Klamath River (Jessup 1927). In February 1905, Congress approved the Klamath Project, and work began.

USBR engineers focused their early efforts on Lower Klamath Lake and Tule Lake. The project would dry up these two lakes so that the land under them could be farmed. The government would then construct two new lakes to hold water for irrigation (behind Clear Lake and Gerber dams, Figure 1-3). A dam and canal would divert the Lost River to the Klamath River. Headworks would take water from Upper Klamath Lake into an elaborate irrigation system. USBR would fund construction of

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irrigation works; people (mostly veterans) would buy land irrigated by those works from the federal government in parcels of up to 80 acres and would pay for the land and improvements over 10 yr. The federal government sold the land, but not the water rights, to Klamath Project irrigators; irrigators were promised use of sufficient water for irrigation each year for a modest fee.

Meanwhile, just three months after Congress authorized the Klamath Project in early 1905, conservationists discovered the basin's extraordinary abundance of avian life. During the summer of 1905, just a few months after Congress approved the Klamath Project, the conservationist William Finley toured the marshlands in the lower Klamath basin. He was awed by what he found, including extraordinary concentrations of pelican rookeries and what he believed to be the greatest feeding and breeding ground for waterfowl on the Pacific Coast. By 1908, Finley had persuaded President Roosevelt to create the Lower Klamath Lake National Wildlife Refuge (Figure 1-3), thus preserving nesting grounds for migratory waterfowl. It was to be one of the largest wildlife refuges ever authorized, one of the first on land of any agricultural value, and the first to be established in a watershed being transformed by USBR. In 1911, President Taft established the Clear Lake National Refuge and in 1928 President Coolidge established Tule Lake National Wildlife Refuge. The Biological Survey would manage the refuges, and land within refuge boundaries would not be made available for settlement.

President Roosevelt's designation created inherent conflicts. The refuges were to be managed by the Biological Survey, which could not function with full independence because the refuges were on land of USBR, which also controlled the water reaching the area. To USBR, wetlands and riparian areas were wastelands waiting for conversion (reclamation) to agriculture (Langston 2003).

President Roosevelt had intended no settlement within the boundaries of the refuge, but USBR interpreted refuge boundaries as encompassing only land covered by water all year. Thus, if USBR drained the lakes and wetlands, it would no longer be refuge land, and it could be sold or leased.

Before draining Lower Klamath Lake, USBR commissioned soil surveys to see whether the area would be good farmland. C. F. Marbut, a government soil scientist with the U.S. Department of Agriculture (USDA), completed a report indicating that the lakebed would be utterly worthless for agriculture. "We can not cite an example of the successful cultivation of a soil of similar character," admitted Copley Amory, an economist with USBR, in response to that discouraging report (Amory 1926, p. 80). Moreover, the report stated, wetlands surrounding the lake would have only a slim chance of supporting agriculture because the underlying peat, once drained, would be subject to smoldering fires and subsidence.

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Despite Marbut's report, USBR authorized $300,000 for drainage of Lower Klamath Lake. Conservationists challenged USBR's plans in court, and President Wilson in 1915 reduced the Lower Klamath Lake National Wildlife Refuge from 80,000 acres to 53,600 acres, freeing up the rest for drainage and sale or lease.

The federal government signed an agreement with railroad companies according to which the companies would construct an embankment across the marshes with a gate that would close Klamath Straits. The gates were closed in 1917, cutting off flow of water from the Klamath River into the lake (Jessup 1927). Within a year, the flooded area of the lake decreased by about 53%, from 76,600 acres to 36,000 acres; within 5 yr, most of the waters of the lake had evaporated (Weddell 2000). USBR entered into contracts in 1917, first with California-Oregon Power Company, selling it water rights to the river for power generation, and then to a drainage and land-speculation company, the Klamath Drainage District. The shrinkage of the lake greatly reduced waterfowl populations. The peat beds of the wetlands began to burn and collapse, farm efforts failed, and, by 1925, homesteaders were going bankrupt. By 1925, nearly everyone involved agreed that the project was a failure.

After USBR had drained Lower Klamath Lake, it leased what remained of the refuges for grazing. The ornithologist Ira Gabrielson (1943, p. 13) described the situation in 1920:

> The water table on the lake has been lowered several feet by closing the gates which control the inflow from the Klamath River. This action, made under agreement with the water users' association, has uncovered large areas of alkali flats without thus far benefiting the settlers adjoining the lake or opening up additional land suitable for agriculture. Its future as a refuge is seriously jeopardized. This is an understatement of the wildlife tragedy involved in the loss of one of the two greatest waterfowl refuges then in existence.

Near Tule Lake National Wildlife Refuge, water from drained wetlands was being pumped into headwater ditches, used for irrigation, and then collected in the Tule Lake Sump on the refuge, where it was allowed to evaporate. Farmers wanted the land under the sump for farming, but the Tule Lake Sump was overflowing with irrigation return flows as more and more farmers irrigated reclaimed lands.

A reclamation engineer, J. R. Iakish, proposed to pump the irrigation return flows from the Tule Lake Sump through a 6,600-ft tunnel beneath the ridge to Lower Klamath Lake to put out the fires and restore the wetland. Such a plan, Iakish argued, would create more farmland by draining the sump and more wetland for birds by putting out the fires on Lower Klamath. In 1941, the tunnel was finished, and in the next year, water

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flowed once again into Lower Klamath Lake. Some of the Lower Klamath Lake wetlands began to refill, and some of the abandoned farmlands were reclaimed when developers figured out how to use the irrigation wastewater, in conjunction with deep drains, to leach alkali out of soils. Lower Klamath, people argued, could indeed be farmed profitably, so waters intended for restoration were instead used for farming (Blake et al. 2000).

In 1946, USBR authorized new allotments on lands north of Tule Lake (shrunk by use of the tunnel) and held a lottery drawing for World War II veterans. The federal government urged thousands of veterans to apply for these new homesteads, promising them as much water as they would ever need for irrigation. Some of the land on the refuges was given to veterans. A total of 22,000 acres was leased to farmers for agriculture in what became known as the lease-land program. For example, nearly half the 39,000 acres of the Tule Lake National Wildlife Refuge became cropland (Kemper 2001). Japanese and Japanese-American citizens who had been interned at the Tule Lake Camp during World War II were the first to farm much of this land, and their labor helped make it ideal farmland for returning veterans.

Agriculture in the Lower Basin

During the early 1900s, farmers and ranchers removed riparian vegetation and valley forests along the lower Klamath River and its tributaries (CDFG 1934). For example, the U.S. Army Corps of Engineers, in conjunction with the National Resource Conservation Service (then known as the Soil Conservation Service), conducted a series of projects on the main stem and tributaries of the Scott River, including removal of riparian vegetation on the middle reaches of the valley, drainage of remaining wetlands, and construction of a series of flood-control and bank-stabilization projects (Scott River Watershed CRMP Council 1997). Today, the Scott Valley supports more than 30,000 acres of farms and irrigated pasture (CDWR, Red Bluff, CA, unpublished material, 1993; Scott River Watershed CRMP Council 1997). The principal crops are alfalfa (33,000 acres) and grain (2000 acres). There are 153 registered diversions in the Scott Valley; 127 are listed by the Siskiyou County Resource Conservation District (SRCD) as active. Fish screens have been installed on 65 of the diversions; another 38 have been funded but not yet built.

In the Shasta River watershed, after the gold rush in the late 1800s, most of the land cover of the Shasta Valley was converted for agriculture and range. About 28% of the watershed is irrigable land that supports a mix of alfalfa, irrigated pasture, and some grain (CDWR 1964). Nonirrigable land supports range and limited dryland farming. The mix of agricultural uses has remained relatively constant in the basin. Mining and timber harvesting are limited and do not substantially affect the river.

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Significant urbanization, however, is taking place in the watershed. Most development is occurring in the vicinity of Yreka, the county seat of Siskiyou, and Montague, in the northern portions of the Shasta Valley. There is also increasing pressure to develop in the upper watershed, particularly around the town of Weed and near Lake Shastina (Dwinnell Dam).

FISHING AND ATTEMPTS TO REGULATE LOSS OF FISH

Mining, timber management, dams, and agriculture have degraded fish habitat, but overharvesting also has affected fish populations (Chapters 5 and 7). In the upper Klamath basin, tribal harvests of suckers for family consumption were augmented by commercial harvests beginning in the 19th century, including a cannery that processed Lost River suckers captured from the Lost River near Olene, Oregon, in the late 1890s (53 Fed. Reg. 27130 [1988]). Before the drainage of Tule Lake and Sheepy Creek in the 1920s, suckers were taken in large numbers from Sheepy Creek for consumption by both humans and livestock (Coots 1965). A recreational snag fishery for suckers developed as early as 1909; it focused on fish that were moving into tributary rivers to spawn and secondarily on fish attempting to spawn around the edges of Upper Klamath Lake. The snag fishery remained unregulated until Klamath suckers were declared game species in 1959.

Commercial harvests of salmon intensified with the development of canning technology. Commercial harvesting of salmon began later in the Klamath River basin than in other basins in California and the Pacific Northwest partly because of the inaccessibility of much of the terrain. Nevertheless, by the early 20th century, habitat destruction combined with commercial harvests had resulted in serious salmon depletion on the Klamath River (Pacific Watershed Associates 1994). Cobb (1930) estimated that the peak of the Klamath River salmon runs occurred in 1912; Snyder (1931, p. 7) observed substantial declines in the 1920s. As Snyder observed, "in 1912 three [canneries] operated on or near the estuary and the river was heavily fished, no limit being placed on the activities of anyone."

Millions of juvenile coho salmon, Chinook salmon, and steelhead are released into the Klamath and Trinity rivers each year by the Iron Gate and Trinity River hatcheries, which were built to mitigate the salmonid losses created by large dams. These hatcheries were intended to maintain fisheries for coho and Chinook salmon, but they may have had adverse effects on wild populations of salmonids in the basin (Chapters 7 and 8).

WETLAND TRANSFORMATIONS

Even before the Klamath Project, the actions of humans in the upper basin were concentrated on wetlands. Cattle ranching had been concen-

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trated on the margins of wetlands, extensive efforts to drain wetlands began in 1889, and drainage accelerated with the Klamath Project; restoration began in the 1990s. Figure 2-3 shows the cumulative drained acreage by year for Upper Klamath Lake. The drop in drained wetland acreage after 1990 reflects wetland restoration efforts in the upper basin. In Tule and Lower Klamath lakes, original wetlands were estimated at 187,000 acres; about 25,000 acres remain (Gearheart et al. 1995).

Reclamationists and farmers drained wetlands by building dikes to isolate them hydrologically, constructing a network of drainage ditches within them, and pumping surface water and shallow groundwater (Snyder and Morace 1997, Walker 2001). One effect of lowering the water tables in this way was an increase in aerobic decomposition of peat soils, which liberated nutrients and removed organic deposits. Disking and furrowing can introduce oxygen into the soils, and increase the rate of peat decomposition and nutrient release. Cattle grazing, in contrast, can compact drained soils and slow their decomposition (Walker 2001).

Some scientific work in the upper basin suggests that drained wetlands can become a substantial source of phosphorus (Snyder and Morace 1997), which can lead to increased nutrient loading in the Upper Klamath Lake (Bortleson and Fretwell 1993, Walker 2001). Extensive efforts to restore wetlands, partly to improve nutrient retention, have taken place in the upper basin in the last two decades. Above Upper Klamath Lake, an area of about 101,136 acres has been removed from irrigated agriculture and con-

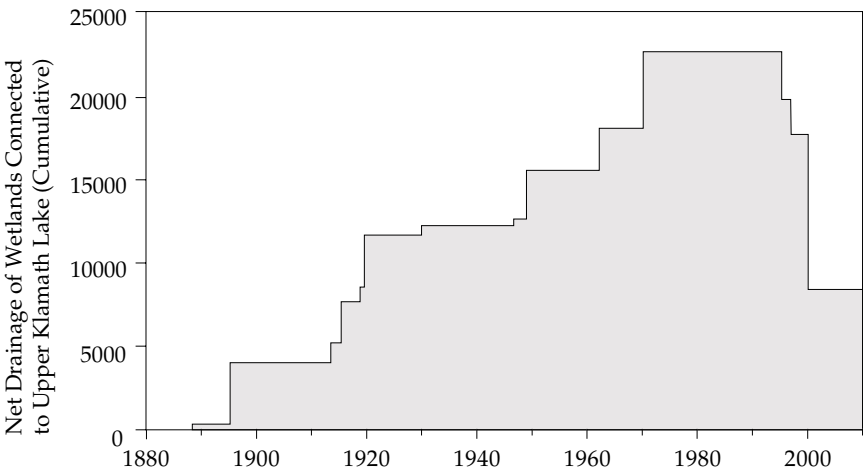


FIGURE 2-3 Net loss, through drainage, of wetland connected to Upper Klamath Lake. A decrease beginning in the 1990s indicates the effects of restoration. Source: Modified from Boyd et al. 2001, p. 48.

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verted to artificial wetlands since the 1980s (E. Bartell, The Resource Conservancy, Inc., Fort Klamath, Oregon, unpublished report, 2002). The effects of these conversions on water quality are unclear.

Although wetlands of different types often are lumped in analyses of wetland change in the basin, different kinds of wetlands may have different effects on water quality. Geiger (2001) argues that wetlands in the littoral zone of Upper Klamath Lake may have had particularly important effects on water quality because they were connected to the lake and contributed humic substances that may have played a role in suppressing algae (see Chapter 3). Drainage efforts and subsidence have had pronounced effects on those wetlands. For example, the littoral wetland of Upper Klamath Lake once comprised 51,510 acres of the total lake area (46.2% at maximum elevation). By 1968, after diking and draining, littoral wetland had decreased to 17,370 acres (22.4% of total lake area). The littoral wetland area was reduced by 66.3%, and the wetland area at minimum storage volume (4,136 ft vs the earlier minimum of 4,140 ft) had shrunk from 20,320 acres to 0 acres (Geiger 2001). Some 34,140 acres of former wetland now is isolated behind dikes on Upper Klamath Lake. A total of 17,553 acres of former wetlands behind dikes is now being reclaimed, but subsidence has meant that, even after being restored, these areas remain disconnected from the lake and do not function as the littoral wetlands once did. Once dikes are removed, subsided areas become open-water habitat rather than littoral wetlands (Geiger 2001). Even so, reconnection of the littoral perimeter with open water would lead to the return of processes and functions that have been lost through severance of much of the littoral zone from the offshore areas of the lake.

The conversion of wetlands and associated channelization of riparian habitat have had deleterious effects on sucker habitat (Chapters 5 and 6). For example, sucker larvae historically moved through a meandering Williamson River into the delta area and the adjacent shoreline areas of Upper Klamath Lake. Since 1940, the Williamson River has been channelized, and the delta and adjacent shoreline have been diked and drained, leaving little of the wetlands and riparian vegetation (Klamath Tribe, Chiloquin, Oregon, unpublished material, 1993, cited in Gearheart et al. 1995). As a result, nursery areas have been greatly reduced. Larvae reach the lake sooner, exposing them to poor water quality at an earlier age and for longer.

Substantial wetlands remain in the basin. Klamath Marsh, a 60,000-acre basin underlain by pumice, is one example; 37,000 acres is protected as a federal wildlife refuge. A total of 23,000 acres of the Sycan Marsh was purchased by The Nature Conservancy in 1980 and is undergoing restoration. The largest wetland still connected to Upper Klamath Lake is Upper Klamath Marsh, a federal wildlife refuge on the northwest edge of Upper

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Klamath Lake; this refuge is the remnant of an emergent and open-water marsh system that once covered 60,000 acres of the Wood River valley (Gearheart et al. 1995).

THE ECONOMY OF THE KLAMATH BASIN

This section provides an overview, without conclusions or recommendations, of the structure of the economy of the Klamath basin on the basis of data from the Bureau of Economic Analysis (BEA) and the IMPLAN (impact planning) modeling process (Minnesota IMPLAN Group, Inc.). It is divided into discussions of the upper and lower basin economies, which differ substantially. Special attention is given to sectors of the economy oriented toward natural resources, including agriculture in both the upper and lower basin and commercial fisheries in the lower basin. It should be noted that this analysis only includes economic and employment values associated with commodities and services that are traded in markets. Nonmarket values, such as those associated with existence of species, preservation of environmental quality or maintenance of a particular lifestyle, are not reflected directly in the economic values reported here.

Upper Basin

The upper Klamath basin includes parts of five counties in Oregon and California. Almost all the Oregon portion of the basin is in Klamath County, and the basin covers most of the county, including the county seat, Klamath Falls (population about 21,000), which is the major regional population center. In California, the basin covers the northwest corner of Modoc County, not including the county seat, Alturas (population, about 3,000), and the northeast corner of Siskiyou County, including the county seat, Yreka (population, about 7,500). The economy of the upper Klamath basin, which is home to about 120,000 people, in 1998 produced $4 billion worth of output, added $2.3 billion in value to purchased inputs, and had almost 60,000 jobs (Weber and Sorte 2002). This section, which is adapted by permission from Weber and Sorte (2002), describes the upper basin economy.

Over the last 30 yr, full- and part-time employment in the upper Klamath basin has increased from 40,000 to 60,000 jobs, while employment in Oregon as a whole has more than doubled. The composition of the regional economy has changed dramatically over that time. The sectors that grew most rapidly were wholesale trade and services (Table 2-2). Employment in several other sectors declined: military, transportation and public utilities, and manufacturing. Employment in farming, mining, and federal civilian employment grew, but increased more slowly than the regional average

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TABLE 2-2 Structural Change in the Upper Klamath Basin Economy, 1969–1999

Sector	Employment 1969	% of Total	Employment 1999	% of Total	Employment Change 1969–1999	% Change
TOTAL FULL- AND PART-TIME EMPLOYMENT	40,392	100.0	60,101	100.0	19,709	48.8
Wage and salary employment	31,751	78.6	44,257	73.6	12,506	39.4
Proprietors' employment	8,641	21.4	15,844	26.4	7,203	83.4
Farm proprietors' employment	2,466	6.1	2,723	4.5	257	10.4
Nonfarm proprietors' employment	6,175	15.3	13,121	21.8	6,946	112.5
Farm employment	4,144	10.3	4,592	7.6	448	10.8
Nonfarm employment	36,248	89.7	55,509	92.4	19,261	53.1
PRIVATE EMPLOYMENT	27,563	68.2	44,926	74.8	17,363	63.0
Agricultural services, forestry, fishing and other	1,090	2.7	1,678	2.8	588	53.9
Mining	70	0.2	71	0.1	1	1.4
Construction	1,442	3.6	2,528	4.2	1,086	75.3
Manufacturing	7,171	17.8	5,883	9.8	–1,288	–18.0
Transportation and public utilities	3,084	7.6	2,474	4.1	–610	–19.8
Wholesale trade	876	2.2	2,388	4.0	1,512	172.6
Retail trade	6,291	15.6	10,213	17.0	3,922	62.3
Finance, insurance and real estate	1,965	4.9	3,573	5.9	1,608	81.8
Services	5,574	13.8	16,118	26.8	10,544	189.2
GOVERNMENT AND GOVERNMENT ENTERPRISE	8,685	21.5	10,583	17.6	1,898	21.9
Federal, civilian	1,665	4.1	1,856	3.1	191	11.5
Military	2,369	5.9	30	0.5	–2,049	–86.5
State and local	4,651	11.5	8,407	14.0	3,756	80.8

Source: Modified from Weber and Sorte 2002.

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over the last three decades. Because of the more rapid growth in other sectors, the share of jobs in farming declined from 10.3% to 7.6%. Thus, over the last three decades, the basin's economy has grown slowly, has become more specialized in sectors that are growing rapidly in Oregon as a whole (services and wholesale trade), has shown little proportionate change in some slowly growing sectors (farming and federal civilian employment), and has become less specialized in other slow-growth sectors (manufacturing and transportation, public utilities).

Table 2-3 presents estimates of some basic economic indicators of the regional economy and their distribution among sectors for 1998. The four sectors with the largest shares of output in 1998 were wood products, consisting of forestry, logging, and manufacturing of wood products (15.5%); agriculture, consisting of food, beverage, and textile manufacturing (11.1%), construction (8.1%), and health care and social assistance (7.8%). The four sectors with the largest shares of value added were wood products (11%), retail trade (8.8%), real estate (8.7%), and public administration (8.6%). The four sectors with the largest employment shares were retail trade (11.1%), agriculture (10.7%), educational services (10.1%), and health care and social assistance (9.9%). These measures provide a perspective on the distribution of the regional economic activity among sectors. None of them identifies, however, how much the regional economy depends on each sector.

Table 2-4 summarizes the contribution of each sector to total regional employment and is based on an analysis using the upper Klamath basin input-output model. Such models use estimates of exports from each industry and multipliers for each sector to generate estimates of the dependence of the regional economy on each sector's exports. The procedure used to derive the estimates in Table 2-4 is described in Waters et al. (1999). The table compares the employment in a sector with employment that depends on a sector's exports. The jobs under "Sectoral Employment" are within the sector. The jobs under "Export-Dependent Employment" are from all sectors that depend on the exports from a sector. As an example, there were 4,328 jobs in the wood-products manufacturing sector, but 7,018 jobs in the region were dependent on wood products exports.

Of these, 3,089 jobs were directly dependent on the export of wood products from the county where they were produced; these jobs were related to direct purchases from wood-products firms by households, firms, and governments outside the region. In addition, 2,126 jobs were indirectly dependent on wood-products exports; these jobs were created when wood-products firms purchased inputs (such as logs) from firms in the county and when the suppliers purchased from other businesses in the county. Yet another 1,803 jobs were induced by exports of wood products; these jobs were in retail trade, real estate, and health care and were created when

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TABLE 2-3 Output, Value Added, and Employment in the Upper Klamath Basin, 1998

Industry	Output		Value Added		Employment	
	$ Million	(%)	$ Million	(%)	Jobs	(%)
Agriculture and related[a]	320	7.9	169	7.3	5,964	10.0
Forestry and logging	30	0.7	16	0.7	248	0.4
Mining	4	0.1	2	0.1	33	0.1
Construction	327	8.1	119	5.1	3,357	5.7
Manufacturing—food, beverages, textiles and related	128	3.2	20	0.9	407	0.7
Manufacturing—wood products, paper, furniture and related	598	14.8	241	10.3	4,328	7.3
Manufacturing—high technology and related	17	0.4	3	0.1	94	0.2
Manufacturing—other (for example, sheet metal products)	113	2.8	35	1.5	844	1.4
Transportation and warehousing	263	6.5	139	6.0	2,257	3.8
Utilities	128	3.2	80	3.4	429	0.7
Wholesale trade	142	3.5	97	4.2	2,036	3.4
Retail trade	235	5.8	205	8.8	6,568	11.1
Accommodation and food services	163	4.0	92	4.0	4,785	8.1
Finance and insurance	197	4.9	138	5.9	2,179	3.7
Real estate, rental, and leasing	279	6.9	202	8.7	1,535	2.6
Other services	186	4.6	84	3.6	3,733	6.3
Information	100	2.5	55	2.3	1,241	2.1
Administrative and support services, and so on	28	0.7	16	0.7	936	1.6
Arts, entertainment, and recreation	31	0.8	19	0.8	1,133	1.9
Health care and social assistance	316	7.8	194	8.3	5,859	9.9
Professional, scientific, and technical services	38	0.9	26	1.1	865	1.5
Educational services	182	4.5	170	7.3	6,010	10.1
Public administration	200	5.0	200	8.6	4,551	7.7
Inventory valuation adjustment	7	0.2	7	0.3	0	0
Total	4,032	100.0	2,327	100.0	59,390	100.0

[a]Technically, this is agriculture, fishing, and related. However, the IMPLAN database for the upper Klamath basin identifies only 48 of 5,964 jobs (0.8%) in fishing. Thus, the sector is renamed "agriculture and related."
Source: Weber and Sorte 2002.

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TABLE 2-4 Export Based Employment, Upper Klamath Basin, 1998[a]

Sector	Sectoral Employment		Export-Dependent Employment				
	No. Jobs	%	Direct	Indirect	Induced	Total	Dependency Index (%)
Agriculture and related	5,964	10.0	4,531	1,052	1,004	6,587	11.1
Forestry and logging	248	0.4	243	144	52	439	0.7
Mining	33	0.1	27	5	9	41	0.1
Construction	3,357	5.7	2,809	1,128	1,139	5,076	8.6
Manufacturing—food, beverages, and related	407	0.7	374	865	288	1,527	2.6
Manufacturing—wood products, paper, furniture, and related	4,328	7.3	3,089	2,126	1,803	7,018	11.8
Manufacturing—high technology, and related	93	0.2	30	24	11	65	0.1
Manufacturing—other (for example, sheet-metal products)	844	1.4	728	320	272	1,320	2.2
Transportation and warehousing	2,257	3.8	1,103	518	619	2,240	3.8
Utilities	429	0.7	36	26	27	89	0.2
Wholesale trade	2,035	3.4	352	76	104	532	0.9
Retail trade	6,568	11.1	423	22	82	527	0.9
Accommodation and food services	4,785	8.1	1,541	189	227	1,957	3.3
Finance and insurance	2,179	3.7	139	35	43	217	0.7
Real estate, rental, and leasing	1,535	2.6	95	50	26	171	0.3
Other services	3,733	6.3	1,110	238	235	1,583	2.7
Information	1,241	2.1	143	49	48	240	0.4
Administrative and support services	936	1.6	48	6	7	61	0.1
Arts, entertainment, and recreation	1,133	1.9	27	5	3	35	0.1
Health care and social assistance	5,859	9.9	371	65	122	558	0.9
Professional, scientific, and technical services	865	1.5	77	10	23	110	0.2
Educational services	6,010	10.1	4,546	86	1,208	5,840	9.8
Public administration	4,551	7.7	4,551	34	1,492	6,077	10.2
Households (social security)	—	—	11,952	1,947	3,185	17,084	28.8
Total	59,390	100.0	38,345	9,020	12,029	59,394	100.0

[a]Export includes any activity that brings dollars to the Klamath economy. The dependency index is the percentage of jobs that are dependent on payments to households from outside the lower Klamath basin.
Source: Weber and Sorte 2002.

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households respent income earned in all of jobs generated directly and indirectly by export of wood products. The spending and respending of money brought into the region by export of wood products generated a total of 6,922 jobs.

Table 2-4 indicates the dependence of the basin's regional employment on two natural-resources sectors. Agriculture (agriculture and related plus food-products manufacturing) supports 13.7% of the region's jobs, and wood products (forestry and logging plus wood products manufacturing) supports 12.5%.

Table 2-4 also identifies the dependence of the regional economy on two sectors that often are the focus of local economic development efforts. Although the tourism sector (accommodation and food services; arts, entertainment, and recreation) is responsible for 10% of the total jobs in the region, it contributes only 3.4% of the export employment base. Retail trade, the sector with the largest employment share (11.1%), provides only 1% of the export employment base.

Table 2-4 also shows that regional employment is more dependent on income of households outside the region than on any single sector. Household income from government transfer payments (for example, social security), dividends, commuters' income, rental payments, and other sources of income originating outside the region supported 17,084 jobs (28.8%) in 1998.

The dependence of the basin's economy on federal and state government and educational institutions also is evident in Table 2-4. Almost one-fifth of the jobs in the region depend on federal and state funding for such services as education and other public services. Public administration, which supports 10.1% of jobs, includes federal and state payments to local governments (for example, federal payments in lieu of taxes, federal forest payments, and state-shared cigarette and highway revenues) and to government personnel (in USFS, USDA, and USFWS, for example). State and federal funding of educational services (such as K-12 schools, the community college in California, and the Oregon Institute of Technology) and tuition payments by nonresidents support 9.8% of the region's jobs.

There were 2,239 farms in the upper Klamath basin in 1997 (Table 2-5). A farm is defined as "any place from which $1,000 or more of agricultural products were produced or sold, or normally would have been sold, during the census year" (USDA 1999, p. VII). Farms thus include many places that do not depend significantly on farm income. Indeed, as shown in Table 2-5, 29% of farm operators work more than 200 days per year off the farm, and only 60% consider farming their primary occupation. Just over half the farms (57%) have more than $10,000 in annual sales.

Farms averaged 896 acres; 78% had some irrigation, and 27% of the region's farmland is irrigated. Most farms (82%) are sole proprietorships,

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TABLE 2-5 Characteristics of Upper Klamath Basin Farms and Farm Operators, 1997

Farm Characteristic	Klamath, OR	Siskiyou, CA	Modoc, CA	Upper Basin Total
Number of farms	1,066	733	440	2,239
Land in farms (acres)	713,534	628,745	662,927	2,005,206
Average size of farm (acres)	669	858	1,507	896
Farms with sales >$10,000 (%)	54	55	69	57
Farms with irrigation (farms)	851	556	337	1,744
Irrigated land (acres)	243,205	139,534	159,219	541,958
Market value of agricultural products sold ($000)	100,622	74,244	63,797	238,663
Net cash return from agricultural sales for the farm unit ($000)	20,104	16,389	11,249	47,742
Average net cash return per farm ($)	18,859	22,359	25,556	21,323
Government payments received ($000)	817	1,420	666	2,903
Farms receiving payments (%)	16	21	25	19
Average government payments per farm receiving payments ($)	4,750	9,467	6,055	6,720
Farms with hired labor (farms)	380	259	206	845
Farms with hired labor (%)	37	35	47	38
Number of hired farm workers (workers)	1,779	2,795	1,664	6,238
Workers working 150+ days (%)	37	17	21	24
Hired farm labor payroll ($000)	9,745	11,309	6,169	27,223
Average annual pay per hired farm worker ($)	5,478	4,046	3,707	4,364
Sole-proprietor farms (%)	83	82	82	82
Farm operators living on farm operated (%)	82	78	72	78
Operators with farming as primary occupation (%)	58	61	65	60
Farm operators working more than 200 days off-farm (%)	33	27	23	29

Sources: USDA 1999, Weber and Sorte 2002.

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and 78% are operated by the person living on the farm. About one-third of the farms (38%) hire farm workers. The average annual pay per hired farm worker was $4,364. About one-fourth (24%) of the 6,238 farm workers worked 150 days or more in 1997.

Net cash return per farm from agricultural sales in the upper Klamath basin averaged $21,323 in 1997. Net cash return equals the value of agricultural products sold minus operating expenses (not including depreciation). Almost one-fifth of the farms (19%) received government payments in 1997, which averaged $6,720.

Table 2-6 reports the value of agricultural production by commodity for each upper Klamath basin county and for the region. The regional value of total agricultural production in 1998 was estimated to be $283 million. Cattle, hay, and pasture accounted for 58% of the value of production, but potato production was also important (15%).

Farm income in the upper Klamath basin, as elsewhere, varies considerably from year to year and from county to county. BEA provides county-level estimates of realized net income from farming, farm proprietors' income, and farm-labor income. Realized net income is equal to total cash receipts from marketing plus other income (including government payments, such farm-related income as custom work and rent, and imputed rent for farm dwellings) minus total production expenses (including depre-

TABLE 2-6 Value of Agricultural Production (Thousands of Dollars) in Upper Klamath Basin, 1998, by County

Commodity	Klamath, OR	Siskiyou, CA	Modoc, CA	Upper Basin Total	Share of Total Value of Production, %
Alfalfa hay	30,726	25,203	12,825	68,754	24.3
Cattle	32,850	23,635	9,000	65,485	23.2
Potatoes	14,217	19,323	7,866	41,406	14.6
Pasture and range	n/a	13,005	7,560	20,565	7.3
Other hay	4,856	3,713	3,588	12,157	4.3
Barley	5,225	3,280	2,187	10,692	3.8
Onions	n/a	2,862	2,464	5,326	1.9
Wheat	1,660	2,805	859	5,324	1.9
Dairy	13,112	2,442	n/a	15,554	5.5
Horseradish	n/a	n/a	896	896	0.3
Sugarbeets	3,832	n/a	3,284	7,116	2.5
Nursery products	n/a	17,271	n/a	17,271	6.1
Other	1,000	5,319	5,973	12,292	4.3
Total	107,478	118,858	56,502	282,838	100

Abbreviations: n/a, not applicable.
Source: Oregon State University Extension Service, California Agricultural Statistics Service.

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ciation). In 1997, realized net income in the upper Klamath basin was $30 million, and incomes were positive in all counties. In 1998 (not shown in Table 2-5), realized net farm income in the upper Klamath basin was less than in 1997 (about $1.2 million), and in Klamath County it was negative (–$7 million). BEA estimates farm labor income at $24 million for 1997 and $26 million for 1998 (the 1997 Census of Agriculture estimates hired farm-worker payroll at $27 million).

Farm employment is not as variable as farm income. BEA estimates that there were 2,601 farm proprietors in 1997 and 2,702 in 1998. The Census of Agriculture reports only 2,239 farm operators in 1997 (Table 2-5, USDA 1999). BEA estimates full- and part-time farm wage and salary employment at 1,812 in 1997 and 1,491 in 1998. The Census of Agriculture reports more than 4 times as many hired farm workers (6,238) in the upper Klamath basin in 1997 (Table 2-5, USDA 1999). The Oregon Employment Department estimate of total agricultural (worker) employment in Klamath County in 1997 was 1,490, twice the BEA estimate of 784, suggesting that BEA substantially undercounts farm workers.

The Klamath Reclamation Project provides water to 63% of the 2,239 farms and to 80% of the irrigated farms in the upper Klamath basin (Table 2-7). The Klamath Project contains 36% of the region's irrigated acreage. Farms served by the Klamath Project produce almost half (45%) the value of agricultural sales in the region.

Lower Basin

Except for regulation of releases at Iron Gate Dam, USBR's Klamath Project is disconnected from the lower basin, but the economic implications of measures that may be necessary to facilitate the recovery of coho and benefit other fishes along the Klamath main stem may be considerable for the lower basin.

As explained in this chapter, irrigation-based economies are important in the Shasta and Scott rivers and in the Trinity River, which has been studied specifically with reference to water transfers that generate economic benefits outside the watershed. Changes in irrigation practices and facilities may be necessary for the benefit of the coho and other species, and any such changes in the lower basin would need to be carried out with the cooperation of private water providers and private landholders. As will be shown in Chapters 7 and 8, present timber management and mining practices may also be inconsistent with the welfare of the coho salmon and may require modification, which could affect both public entities and private parties. Commercial fishing is involved economically in the restrictions on take, which are a disadvantage in the short term, and in efforts at restoration, which potentially provide long-term benefits.

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TABLE 2-7 Farms in the Klamath Reclamation Project and in the Upper Klamath Basin

Irrigated Farms, 1997		Irrigated Acres, 1997 (1,000s)		Value of Sales, 1997 ($000)	
Basin	Project	Basin	Project	Basin	Project
1,744	1,400	542	195	$238,663	$108,539

Sources: USDA 1999; and Tables 1 and 2 from Burke 2002.

The lower Klamath basin includes parts of three counties in northwestern California: Del Norte, Humboldt, and Trinity. The Klamath River flows from the upper basin in Klamath County, Oregon, into Modoc and Siskiyou counties, California, and then to the lower basin in northern Humboldt County. It continues through southern Del Norte County before reaching the Pacific Ocean near Requa, California. Although the Klamath River itself does not flow through Trinity County, the county is drained mostly by the Trinity River, which is the largest tributary of the Klamath River. The basin does not include Crescent City, the county seat in Del Norte County, or the region's most populous area, Humboldt Bay (including Eureka and Arcata) in Humboldt County. Because demographic and economic statistics are gathered for government jurisdictions, the analysis that follows includes all three relevant counties. Humboldt County dominates the region demographically and economically; it has three-fourths of the region's population and over three-fourths of its full- and part-time jobs. The economy of the lower Klamath basin, which is home to about 167,000 people, in 1998 produced $5.9 billion worth of output, added $3.3 billion in value to purchased inputs, and had more than 84,000 jobs.

Much of the information given below is derived from a report by Sorte and Wyse (in press) and like information on the upper Klamath basin, is based on longitudinal data from BEA; profiles of farm numbers, type, and production from the 1997 Census of Agriculture (USDA 1999) and California County agricultural commissioners' reports; and information from a proprietary input-output economic IMPLAN model constructed by the Minnesota IMPLAN Group, Inc. The IMPLAN model was edited by using agricultural-production data from the California Agricultural Statistics Service, employment data from BEA's Regional Economic Information Service, and fisheries data from Hans Radtke and Shannon Davis of The Research Group, Corvallis, Oregon. Because a number of data sources were used, there is some variation in the categories used to aggregate the industrial sectors and to estimate the number of jobs in each sector.

From 1969 to 1999, full- and part-time employment in the lower Klamath basin increased by 171% from 49,000 to 84,000 jobs. Over the same

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period, employment in California increased by 211%, and U.S. employment by 180%. As in the upper basin, the composition of the regional economy changed substantially over this time. A summary of the changes is provided in Table 2-8. In the lower basin, the sectors that grew most were construction and services. The share of jobs in construction grew from 2.9% to 5.4% of the total; jobs in services grew from 16.6% to 29.9%. Modest growth occurred in agricultural services, forestry, fishing, and other; retail trade; and finance, insurance, and real estate. Employment declined in the mining, manufacturing, and military sectors. Lower than average growth occurred in the farming, transportation and public utilities, wholesale trade, and federal civilian sectors.

Table 2-9 gives estimates of some basic economic indicators and their distribution among sectors for 1998. This table, which is based on data from Minnesota Implan Group's Input-Output IMPLAN Model, varies slightly from Table 2-8, which is based solely on Bureau of Economic Analysis data. The sectors with the largest shares of output in 1998 were combined wood products including forestry and logging and manufacturing—wood products, etc. (19.8%), construction (8.4%), retail trade (6.8%), and combined agriculture including agriculture, fishing and related and manufacturing—food, etc. (6.5%). The four sectors with the largest shares of value added were wood products (12.4%), retail trade (10.4%), educational services (9.8%), and health care and social assistance (9.4%).

Retail trade (12.8%), educational services (12.2%), and health care and social assistance (11.8%) had the greatest shares of jobs in the economy.

As noted for the upper-basin economy, output, value added, and employment measures indicate the magnitude and distribution of economic activity among sectors in a region. The magnitude of economic activity in a sector, however, does not necessarily reflect the extent to which the sector sustains economic activity in the region.

Table 2-10 summarizes the contribution of each sector to total regional employment, and is based on an analysis that used the Lower Klamath Basin Input-Output Model, which was developed for this report. The jobs under the sectoral employment columns are within the sector, whereas the jobs in the export-dependent columns are from all sectors that depend on the exports from a sector. For example, there were 5,017 jobs in the construction sector but 6,941 jobs in the region depended on construction exports (for example, building homes for retirees from outside the region or construction roads for federal or state governments). Of those, 3,886 jobs depended directly on the exports of construction services from the region; these jobs were related to direct purchases from construction firms from household, firms, and governments outside the region. In addition, 1,687 jobs depended indirectly on construction exports; these jobs were created when construction firms purchased inputs (for example, building materials)

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TABLE 2-8 Structural Change in the Lower Klamath Basin Economy, 1969–1999

	Employment		Employment		Employment Change	
Sector	1969	%	1999	%	1969–1999	%
TOTAL FULL- AND PART-TIME EMPLOYMENT	49,107	100.0	84,192	100.0	35,085	71.4
Wage and salary employment	40,867	83.2	64,298	76.4	23,431	57.3
Proprietors' employment	8,240	16.8	19,894	23.6	11,654	141.4
Farm proprietors' employment	917	1.9	1,166	1.4	249	27.2
Nonfarm proprietors' employment	7,323	14.9	18,728	22.2	11,405	155.7
Farm employment	1,517	3.1	2,320	2.8	803	52.9
Nonfarm employment	47,590	96.9	81,872	97.2	34,282	72.0
PRIVATE EMPLOYMENT	37,780	76.9	66,238	78.7	28,458	75.3
Agricultural services, forestry, fishing, & other	1,176	2.4	2,859	3.4	1,683	143.1
Mining	105	0.2	50	0.1	–55	–52.4
Construction	1,429	2.9	4,531	5.4	3,102	217.1
Manufacturing	12,747	26.0	7,986	9.5	–4,761	–37.3
Transportation and public utilities	2,936	6.0	3,077	3.7	141	4.8
Wholesale trade	1,219	2.5	1,968	2.3	749	61.4
Retail trade	7,667	15.6	15,498	18.4	7,831	102.1
Finance, insurance, and real estate	2,332	4.7	5,098	6.1	2,766	118.6
Services	8,169	16.6	25,171	29.9	17,002	208.1
GOVERNMENT AND GOVERNMENT ENTERPRISE	9,810	20.0	15,634	18.6	5,824	59.4
Federal civilian	1,007	2.1	1,235	1.5	228	22.6
Military	1,495	3.0	473	0.6	–1,022	–68.4
State and local	7,308	14.9	13,926	16.5	6,618	90.6

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TABLE 2-9 Output, Value Added, and Employment in Lower Klamath Basin, 1998

Sector	Output		Value Added		Employment	
	$ Million	Share (%)	$ Million	Share (%)	Jobs	Share (%)
Agriculture, fishing & related	186.034	3.2	120.316	3.6	4,055	4.9
Mining	9.013	0.2	4.583	0.1	56	0.1
Construction	496.378	8.4	179.237	5.4	5,017	6.0
Manufacturing—food, beverages, textiles & related	192.714	3.3	31.680	1.0	934	1.1
Forestry and logging	180.966	3.1	75.554	2.3	1,286	1.5
Manufacturing—wood products, paper, furniture & related	983.314	16.7	335.536	10.1	5,175	6.2
Manufacturing—high technology and related	12.676	0.2	4.280	0.1	67	0.1
Manufacturing—other	129.025	2.2	43.022	1.3	936	1.1
Transportation and warehousing	258.081	4.4	111.594	3.4	2,730	3.3
Utilities	300.116	5.1	132.448	4.0	853	1.0
Wholesale trade	181.920	3.1	124.520	3.8	2,196	2.6
Retail trade	399.214	6.8	346.514	10.4	10,623	12.8
Accommodation and food services	208.678	3.5	115.597	3.5	6,486	7.8
Finance and insurance	264.670	4.5	194.334	5.9	2,887	3.5
Real estate, rental, and leasing	389.385	6.6	283.234	8.5	1,444	1.7
Other services	252.268	4.3	139.735	4.2	6,997	8.4
Information	133.216	2.3	64.861	2.0	1,179	1.4
Administrative and support services, and so on	44.278	0.8	26.773	0.8	1,225	1.5
Arts, entertainment, and recreation	31.921	0.5	19.466	0.6	1,189	1.4
Health care and social assistance	522.509	8.9	312.115	9.4	9,799	11.8
Professional, scientific, and technical services	126.789	2.2	87.384	2.6	2,812	3.4
Educational services	354.574	6.0	326.439	9.8	10,162	12.2
Public administration	238.337	4.0	238.337	7.2	5,113	6.1
Inventory valuation adjustment	0.301	0.0	0.301	0.0	0	0.0
Total	5,896.375	100.0	3,317.859	100.0	83,220	100.0

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TABLE 2-10 Export Based Employment, Lower Klamath Basin, 1998

	Sectoral Employment		Export Dependent Employment				
Sector	No. Jobs	%	Direct	Indirect	Induced	Total	Dependency Index
Agriculture, fishing, and related	4,055	4.9	2,815	461	662	3,937	4.7
Mining	56	0.1	55	14	25	95	0.01
Construction	5,017	6.0	3,886	1,687	1,368	6,941	8.3
Manufacturing—food, beverages, textiles & related	934	1.1	617	491	210	1,319	1.6
Forestry and logging	1,286	1.5	641	549	291	1,482	1.8
Manufacturing—wood products, paper, furniture, and related	5,175	6.2	4,525	3,126	2,393	10,044	12.1
Manufacturing—high technology and related	67	0.1	31	18	15	64	0.1
Manufacturing—other	936	1.1	913	403	393	1,708	2.1
Transportation and warehousing	2,730	3.3	849	425	418	1,691	2.0
Utilities	853	1.0	262	349	274	885	1.1
Wholesale trade	2,196	2.6	367	72	110	549	0.7
Retail trade	10,623	12.8	2,570	95	457	3,123	3.8
Accommodation and food services	6,486	7.8	1,676	170	202	2,048	2.5
Finance and insurance	2,887	3.5	705	96	188	988	1.2
Real estate, rental, and leasing	1,444	1.7	227	90	61	377	0.5
Other services	6,997	8.4	3,819	402	574	4,794	5.8
Information	1,179	1.4	184	78	56	317	0.4
Administrative and support services, and so on	1,225	1.5	229	90	61	380	0.5
Arts, entertainment, and recreation	1,189	1.4	255	20	26	301	0.4
Health care and social assistance	9,799	11.8	3,500	565	841	4,906	5.9
Professional, scientific, and technical services	2,812	3.4	809	76	192	1,077	1.3
Educational services	10,162	12.2	9,645	112	2,605	12,362	14.9
Public administration	5,113	6.1	5,113	43	1,487	6,643	8.0
Inventory valuation adjustment	0	0.0	0	0	0	0	0.0
Households (for example, social security)[a]	0	0.0	12,268	2,032	2,891	17,191	20.7
Total	83,220	100.0	55,960	11,460	15,800	83,220	100.0

[a]Households do not represent an industry sector with employees so have zero sectoral employment. They do spend a portion of their transfer payments on goods and services (e.g., food and health care) within the region, so they have an induced effect on the economy.

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from firms within the region and when the suppliers purchased from other businesses in the region.

Another 1,368 jobs were induced by exports of wood products; these jobs were in sectors like retail trade, real estate, and health care that were created when households respent income earned in all the jobs generated directly and indirectly by exports of wood products. The spending and respending of money brought into the region by exports of construction generated a total of 6,941 jobs.

Table 2-10 shows that the lower-basin economy depends on the natural-resources sectors, although not to the same extent as that of the upper basin. The combined agricultural sectors support 6.3% of the region's jobs, and the combined wood products sectors support 13.9%. Together, these two natural-resources sectors make up about 20.2% of the lower-basin economy. In the upper basin, the agricultural sector supports 14% of the region's jobs, and wood products supports 12.5%, for a total of about 27% of the economy. Table 2-10 also identifies the dependence of the lower-basin regional economy on four other sectors that often are the focus of local economic development efforts, particularly in rural economies oriented to natural resources. Specifically, these are the sectors that include substantial activity related to tourism associated with visitors from outside the region, such as retail trade, accommodation and food services, other services, and arts, entertainment, and recreation, which together contribute 12.5% of the export employment base (slightly more than in the upper basin). Still, these tourism sectors remain primarily service sectors. For example, the retail-trade sector's share of sectoral employment is 12.8%, and it provides just 3.8% of the export employment base.

The lower basin's employment, like the upper basin's, depends heavily on income to households. Household income from government transfer payments (such as social security), dividends, commuters' income, rental payments, and other sources of income originating outside the basin is the most important part of the export base. In 1998, 17,191 jobs, or 20.7%, depended on those payments.

The dependence of the basin's economy on federal and state government and educational institutions is also evident in Table 2-10. Almost one-fourth of the jobs in the region depend on federal and state funding for services, such as education and other public services. Public administration supports 8.0% of all jobs in the basin; this sector includes federal and state payments to local governments (such as federal payments in lieu of taxes, federal forest payments, and state-shared cigarette and highway revenues) and to government personnel (USFS, USDA, and USFWS, for example). State and federal funding for educational services plus tuition payments by nonresidents support 14.9% of the region's jobs.

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Two important industries based on natural resources, agricultural crop and livestock production and fisheries, are aggregated and summarized in the tables as the agriculture, fishing, and related sector. Because they are both so strongly affected by water resources in the Klamath basin, some additional review of these industries follows.

Using the same definition of a farm as in the upper basin, there were 974 farms in the lower Klamath basin in 1997, that is about 40% of the number of farms in the upper basin (Table 2-11). As noted in the discussion regarding the upper basin, farms include many places that do not depend on their farm operations as their major source of income. Indeed, as shown in Table 2-11, 35% of farm operators work more than 200 days/yr off the farm, and only 51% consider farming their primary occupation. Fewer than half the farms (45%) have more than $10,000 in annual sales. Farms averaged 653 acres; 39.5% had some irrigation and 3.7% of the region's farmland is irrigated. Over half the farms (61%) are sole proprietorships, and 72% are operated by the person living on the farm. About one-third of the farms (35%) hire farm workers. The average annual pay per hired farm worker was $6,754. Thus, the number of farm workers in the lower basin is about one-third the number in the upper basin, but the average pay per worker is greater in the lower basin. About half (44%) the 2,183 farm workers worked 150 or more days in 1997.

Net cash returns per farm from agricultural sales in the lower Klamath basin averaged $23,016 and were similar to those of the upper basin ($21,323) in 1997. Net cash returns equals the value of agricultural products sold minus operating expenses (not including depreciation). Very few farms (3.1%) received government payments in 1997, which averaged $2,000.

Table 2-12 reports the value of agricultural production by commodity for each of the counties in the lower Klamath basin and for the region. The regional value of total agricultural production in 1998 was estimated to be $114 million, compared with $283 million in the upper basin. Dairy and nursery products are the principal agricultural products of the region, together accounting for 75.6% of the value of agricultural-commodity production. Cattle and livestock products are also important; they account for 13.7% of the value of agricultural commodity production.

Fishing is an important part of the culture of the lower-basin culture and the economy. Table 2-13 provides information on catch and value for the fishing industry in 1997–2001. The catch information reflects only ocean-related commercial fishing, not fishing in rivers. The lower Klamath basin input-output model explicitly considers ocean fishing in the agriculture, fishing, and related sectors because the catch is sold directly for processing or consumption. River fishing is included only indirectly in the model; that economic activity and other activities related to fish in the

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TABLE 2-11 Characteristics of Lower Klamath Basin Farms and Farm Operators, 1997

Farm Characteristic	Del Norte County	Humboldt County	Trinity County	Lower Basin Total
Number of farms	66	792	116	974
Land in farms (acres)	13,303	584,538	118,252	716,093
Average size of farm (acres)	202	738	1019	653
Farms with sales >$10,000 (%)	41	49	22	45
Farms with irrigation (farms)	24	301	70	395
Irrigated land (acres)	6,323	17,630	2,212	26,165
Market value of agricultural products sold ($000)	20,797	75,475	1,797	98,069
Net cash return from agricultural sales for the farm unit ($000)	5,229	17,700	–489	22,440
Average net cash return per farm ($)	79,234	22,320	–4,216	23,016
Government payments received ($000)	0	54	6[a]	60
Farms receiving payments (%)	0	3.4	2.6	3.1
Average government payments per farm receiving payments ($)	0	2,000	2,000[a]	2,000
Farms with hired labor (farms)	32	279	32	343
Farms with hired labor (%)	48	35	28	35
Number of hired farm workers (workers)	652	1,345	186	2,183
Workers working 150+ days (%)	47	47	18	44
Hired farm labor payroll ($000)	5,579	8,690	476	14,745
Average annual pay per hired farm worker ($)	8,557	6,461	2,559	6,754
Sole proprietor farms (%)	64	59	78	61
Farm operators living on farm operated (%)	70	73	80	72
Operators with farming as primary occupation (%)	50	53	43	51
Farm operators working more than 200 days off farm (%)	33	35	38	35

[a]Information not disclosed by the Census of Agriculture because few farms (three) received assistance. Average payment of $2,000 was estimated because in 1992 the average was $2,236 for Trinity County and in 1997 the average was $2,000 for Humboldt County.
Source: USDA 1999.

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TABLE 2-12 Value of Agricultural Production in the Lower Klamath Basin, 1998

	Value of Agricultural Production, $000				
Commodity	Del Norte $	Humboldt $	Trinity $	Lower Basin Total $	Share of Total Value of Production %
Dairy	10,578	39,028	0	49,606	43.5
Nursery products	13,322	23,277	37	36,636	32.1
Cattle and livestock products	3,495	11,074	1,088	15,657	13.7
Hay and pasture	1,351	8,179	463	9,993	8.8
Vegetables	75	676	32	783	0.7
Sheep, lambs, and wool	38	116	8	162	0.1
Fruit and nuts	435	91	105	631	0.6
Other	472	20	49	541	0.5
Total	29,766	82,461	1,782	114,009	100.0

Source: California Agricultural Statistics Service.

Klamath River main stem are reflected primarily in the tourism sectors. Thus, the actual effects of fish migration through the Klamath basin are difficult to estimate accurately. As Table 2-13 indicates, commercial fishing had a value of $12.4 million in 2001, which was less than in prior years and continues to steadily decline.

In relative terms, commercial fishing accounts for about 10% of the value of agriculture in the lower basin. The most valuable components of the catch are groundfish ($5.5 million in 2001) and crab and lobster ($4.1 million in 2001). Salmon (Chinook) landings were valued at about $0.2 million in 2001.

The economic effects of eliminating or reducing any of the ocean fisheries in the lower-basin economy can be calculated with the same procedure used earlier to determine the export dependency indexes. Using the detailed multi-sector version of the Lower Klamath Basin Input-Output Model, which is based on the 1998 IMPLAN model, to be consistent with the upper basin analysis, the effect of removing all the salmon catch in 2001 ($107,887), assuming that the catch is exported from the region, is a total loss to the regional economy of $164,507. This effect, though relatively small in comparison to the commercial fishing industry or the total regional economy, did extend across 193 of the 204 sectors in the regional economy. Commercial fishing has a multiplier of approximately 1.5 on both employment and output in the region. Thus, for every dollar or job directly involved in commercial fishing there is approximately another fifty cents or

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TABLE 2-13 Fisheries Characteristics of Ports of Eureka (Humboldt County) and Crescent City (Del Norte County)

Species Group	Round Pounds 1997	1998	1999	2000
Groundfish	16,246,794	13,888,084	12,036,198	10,116,024
Pacific whiting	13,958,624	12,614,230	2,881,997	10,988,772
Salmon (troll chinook)	16,675	26,450	34,500	26,450
Crab and lobster	6,454,585	7,425,668	7,122,922	4,764,952
Shrimp	12,441,711	1,460,207	3,658,543	2,170,063
Coastal pelagic	176,167	161,285	46,246	14,168
Highly migratory	2,222,487	727,022	647,952	823,779
Halibut	9,007	477	891	289
Sea urchins	63,624	2,357	36,532	3,735
Other	1,822,974	564,703	597,413	841,699
	53,412,648	36,370,483	27,063,194	29,793,910

Source: Hans Radtke and Shannon Davis, unpublished.

half a job lost as suppliers or businesses that sell to those working in fishing, or for the suppliers or businesses experiencing reduced sales. The current economic effects of the commercial salmon catch may significantly understate the potential contribution of the salmon fishing to the economy of the lower Klamath basin. Salmon landings at the ports of Eureka and Crescent City have declined by more than 95% since the 1970s. If the average 1976–1980 landings from the two ports of 2,547,000 round lb could be reached, and they were sold at 2001 prices of $1.47 per lb, the combined output from the salmon fishery would be $3,744,090. The estimated value-added component of that level of output in 2001 dollars would be $2,476,908. Returning to that level of output would require an estimated 67 direct jobs in the commercial fishing sector. The multiplied effect of these jobs on commercial fishing to businesses that supply the fisheries sector and from household expenditures in service sector businesses could be an additional 30 jobs, for a total of 97 jobs. These estimates of the economic effects of increased salmon harvest assume the catch is exported outside the region and that the effects are not reduced by changes that might be necessary to achieve the increases (e.g., shifting water from irrigated agriculture to increase stream flows).

In summary, the economics of the upper and lower basins display characteristics common to many rural economies, including heavy reliance on natural resources sectors, such as agriculture and wood products. Together, the entire basin showed economic activity valued in 2002 at $10.5 billion. Of that, about 26% (or $2.7 billion) was derived from sectors based

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	Value (Nominal), $				
2001	1997	1998	1999	2000	2001
8,708,018	9,309,576	6,615,305	6,308,414	6,631,668	5,461,928
5,081,398	581,399	391,780	115,275	764,851	170,967
73,600	21,298	41,427	61,577	42,795	107,887
1,719,814	11,132,662	12,193,371	13,210,063	9,403,268	4,073,747
3,447,869	5,020,462	951,542	1,982,483	1,172,213	1,236,641
148,548	93,398	39,260	11,365	7,879	52,975
1,414,603	1,870,065	764,542	630,488	841,564	1,155,138
8	17,866	790	1,669	723	16
22,595	35,352	825	26,438	3,224	12,279
388,929	509,044	227,912	217,430	262,536	138,378
21,005,382	28,591,122	21,226,754	22,565,202	19,130,721	12,409,956

on natural resources. Reliance on such sectors is slowly declining across both the upper and lower basins.

OVERVIEW

The Klamath basin is exceptionally diverse geomorphically because it has been strongly influenced by both crustal movement and volcanism. Geomorphic diversity in the basin has produced a wide variety of aquatic habitats, including extensive wetlands, large shallow lakes, swiftly flowing main-stem waters, and various tributary conditions. The watershed is not densely populated but shows strong anthropogenic influences of several kinds. Management of water for irrigation, which has been in progress for more than a century, has altered the basic environmental conditions for aquatic life, including the hydrographic features of flowing waters, the distribution and extent of wetlands, and the extent and physical characteristics of the lakes that were found originally in the basin. Of the total economic activity in the Klamath basin ($10.5 billion), about 26% is derived from natural resources, including mostly agriculture, wood products, and ocean fishing. Irrigation and agricultural practices have blocked or diverted fish from migration pathways, caused adverse warming of waters, and augmented nutrient transport from land to water. Commercial fishing also has left a mark through depleted stocks of some species and, although now controlled, may have had legacy effects that are difficult to reverse. Timber harvest and mining along tributaries have caused, and in some cases

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continue to cause, severe physical impairment of aquatic habitats. Although aquatic habitats now are regarded as valuable for the maintenance of native species, remediation of damage to habitat presents great difficulties because of the extent and diversity of changes that have occurred in the basin over the last century.

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3

Current Status of Aquatic Ecosystems: Lakes

INTRODUCTION

Natural lakes that were suitable for occupation by suckers before land-use development and water management included Upper Klamath Lake, Lower Klamath Lake, Tule Lake, and Clear Lake (Figure 1-3). All of these lakes have been changed morphometrically and hydrologically and are now used in the Klamath Project water-management system for storing and routing water. Gerber Reservoir is also part of the water-management system, but its location was previously occupied by a marsh rather than by a lake. Other lakes relevant to the welfare of suckers include those lying behind five main-stem dams that, except for Keno Dam, incorporate hydroelectric production facilities (Figure 1-3, Table 3-1). The last in the sequence of main-stem dams, Iron Gate Dam, provides reregulation capability for the main stem of the Klamath River as explained below.

Of the lakes used for storage and routing, Upper Klamath Lake, Clear Lake, and Gerber Reservoir support the largest populations of listed suckers (see Chapter 6 for a detailed treatment of the suckers), and these three lakes have been the main focus of ecological and limnological analysis related to the welfare of suckers. Upper Klamath Lake has been studied especially intensively because it potentially would support the largest population of suckers and shows the greatest number of environmental problems, as indicated by episodic mass mortality of adults and probable hardships in all life-history stages. Clear Lake and Gerber Reservoir afford a useful comparison with Upper Klamath Lake because the sucker populations there have not suffered mass mortality and are generally more stable

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TABLE 3-1 Basic Information on Lakes of Upper Klamath Basin[a]

Lake Name	Size Before 1900 (acres)		Size Since 1960 (acres)		Volume[b] (acre-ft)	Mean Depth[b] (ft)	Hydraulic Residence Time[b] (days)
	Minimum	Maximum	Minimum	Maximum			
Lakes and reservoirs used for water storage and routing							
Upper Klamath[c]	78,000	111,000	56,000	67,000	603,000	9	180
Lower Klamath[d]	85,000	94,000	4,700	4,700	<20,000	<4	<70
Clear Lake[d]	15,000	15,000	8,410	25,700	527,000	20	1,600
Tule Lake[d]	55,000	110,000	9,500	13,000	50,000	4	180
Gerber Reservoir[d]	n/a	n/a	1,100	3,900	94,000	24	600
Reservoirs used for power production							
Keno[e]	n/a	n/a	2,470	2,470	18,500	7	6
J.C. Boyle[e]	n/a	n/a	420	420	1,700	4	1.2
Copco No. 1[e]	n/a	n/a	1,000	1,000	46,900	47	12
Copco No. 2[e]	n/a	n/a	40	40	70	2	0.02
Iron Gate[e]	n/a	n/a	950	950	58,800	62	16
Total	233,000	330,000	82,120	116,710	1,420,000	—	—

[a]Lake Ewauna, which is named on some maps, is part of the Keno impoundment; Agency Lake (Figure 1-3) is treated here as part of Upper Klamath Lake.
[b]At maximum depth. Mean depths and hydraulic residence times typically are lower than shown in table, which is based on maximum volume.
[c]From Welch and Burke 2001, Table 2-1. Current maximum corresponds to water level of 4143.3 ft above sea level. Area and volume data from USFWS (2002).
[d]From USBR 2002a, Table 4.1.
[e]From PacifiCorp 2000, pp. 2-16 to 2-17; Keno has no turbines.
Abbreviations: n/a, not applicable.

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than the populations of Upper Klamath Lake. The hydroelectric reservoirs on the main stem have been studied sparingly and are of less interest than other lakes from the viewpoint of listed suckers.

The lakes shown in Table 3-1 do not serve as habitat for coho salmon, which are blocked by Iron Gate Dam from entry into the upper Klamath basin. Limnological characteristics of the waters behind Iron Gate Dam are potentially important to the coho salmon, however, in that waters released from the dam have a large influence on the water-quality characteristics of the Klamath River main stem, especially near the dam. Reflecting the relative amounts of research or monitoring and the apparent ranking of lakes with respect to their importance for the endangered and threatened fishes, this chapter devotes most of its attention to Upper Klamath Lake, some to the other lakes that are used for storage and routing of water, and some to waters above Iron Gate Dam that hold non-reproducing populations of listed suckers and have the potential to affect coho downstream; the remnants of Tule Lake and Lower Klamath Lake provide little lacustrine habitat at present, but offer potential for restoration.

UPPER KLAMATH LAKE

Description

Upper Klamath Lake is the largest body of water in the Klamath basin and is one of the largest lakes in the western United States (about 140 mi^2). The lake and its drainage lie on volcanic deposits derived in part from the nearby Crater Lake caldera, which took its present form as a result of the eruption of Mount Mazama (about 6,800 BP). The lake also shows a strong tectonic influence, however, as is evident from a pronounced scarp along its southwestern edge (Figure 3-1). Although Upper Klamath Lake has a very low relative depth (ratio of depth to mean diameter), it has substantial pockets of water over 20 ft deep (maximum, 31 ft at a water level of 4,141.3 ft above sea level; USBR 1999 as cited in Welch and Burke 2001). The northern, southern, and eastern portions of the lake and Agency Lake, which is connected to Upper Klamath Lake and is here treated as part of it, are uniformly shallow; they offer water little deeper than 6 or 7 ft at mean summer lake elevation (4,141.3 ft above sea level). Even though specific runoff for the watershed of Upper Klamath Lake is relatively low (about 300 mm/yr), the hydraulic residence time of Upper Klamath Lake is only about 6 mo because the lake is shallow (there is considerable interannual variability). The flat bathymetry of the lake also causes its surface area to be quite sensitive to changes in water level.

Before the construction of Link River Dam, which was completed in 1921, the water level of Upper Klamath Lake fluctuated within a relatively

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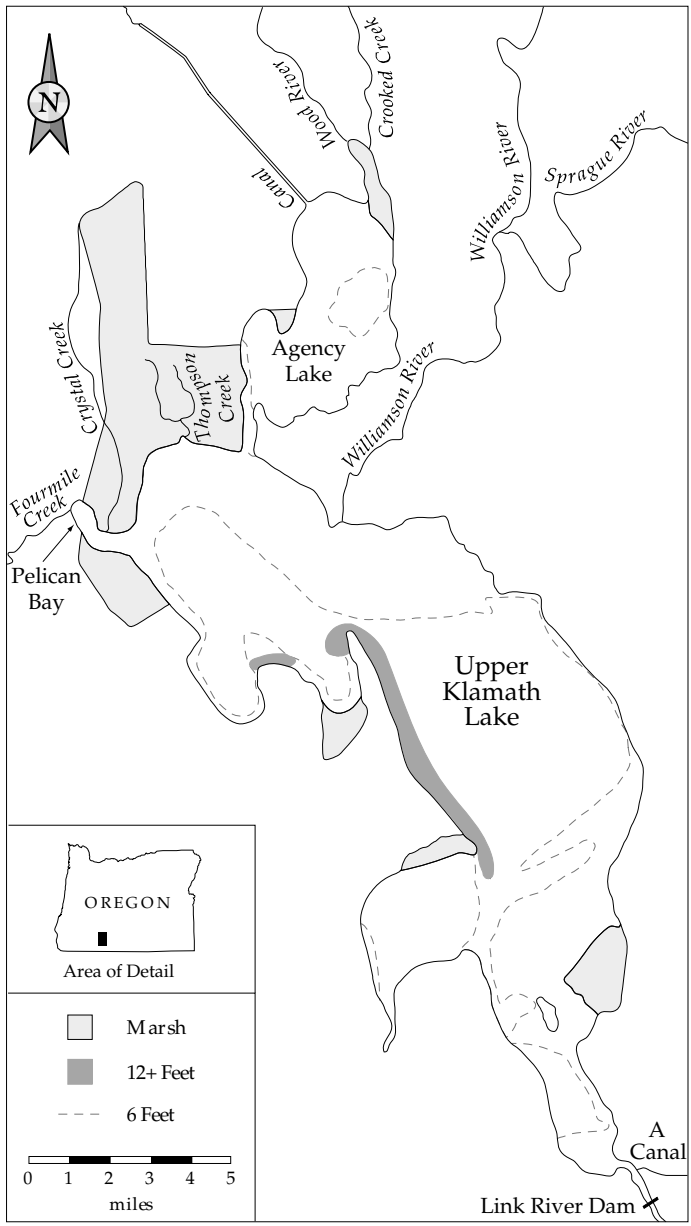


FIGURE 3-1 Bathymetric map of Upper Klamath Lake and Agency Lake showing depths at the mean summer lake elevation of 4,141 ft above sea level. Contours are from data of U.S. Bureau of Reclamation (1999) as reported by Welch and Burke (2001). Source: Welch and Burke 2001.

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narrow range (about 3 ft), as would be expected for a natural hydrologic regime (Figure 3-2). Although irrigation was under way in the basin at that time, there was no means of using the lake for storage. Water level in the lake was determined by a lava dam at the outlet (4,138 ft above sea level; USFWS 2002). Even under drought conditions, the lake level remained above the level of the natural outlet, except briefly during oscillations caused by wind (USFWS 2002).

When Link River Dam was constructed, the natural rock dam at the outlet of Upper Klamath Lake was removed so that the storage potential of the lake could be used in support of irrigation. Thus, since 1921, lake levels have varied over a range of about 6 ft rather than the natural range of about 3 ft (Figure 3-2). Drawdown of about 3 ft from the original minimum water level of the lake has occurred in years of severe water shortage (1926, 1929, 1992, and 1994). The operating range of the lake in the context of mean depth and contact between the lake and its wetlands has raised numerous questions about the environmental effects of water-level manipulations, especially under the most extreme operating conditions (USFWS 2002).

The U.S. Bureau of Reclamation (USBR 2002a) has proposed operating Upper Klamath Lake over the next 10 yr according to guidelines that reflect recent historical operating practice (Figure 3-2; Chapter 1). The open question for researchers and for the tribes and government agencies charged with evaluating the two endangered suckers is whether the USBR proposal for future operations is consistent with the welfare of listed suckers in Upper Klamath Lake. In a biological opinion issued in response to USBR's proposals, the U.S. Fish and Wildlife Service (USFWS 2002) has concluded that operations should involve limits on water levels that are more restrictive than those proposed by USBR. USFWS has temporarily accepted the water-level criteria proposed by USBR (2002a), but has required a revised approach to predicting water availabilities in any given year (Chapter 1).

The USBR 10-yr plan is based on a commitment of USBR not to allow Upper Klamath Lake to fall in any given year below the minimum water levels that were observed in 1990–1999 for four hydrologic categories of years and not to allow the interannual mean water levels for these categories to fall below recent interannual means (1990–1999). Figure 3-2 shows the March 16–October 30 operating range based on interannual means for each of the four hydrologic categories. The database for the definition of the categories included water years 1961–1997 (USBR 2002a, p. 39). The calculations were based on the outflow from Upper Klamath Lake for April–September. Years above the mean outflow, which is 500,400 acre-ft, are designated "above average." Those within one standard deviation below the mean are designated "below average"; the expected long-term frequency for these years is 34% (on the basis of a normal distribution). Curve-fitting was not suitable for evaluating years of lower flow, however.

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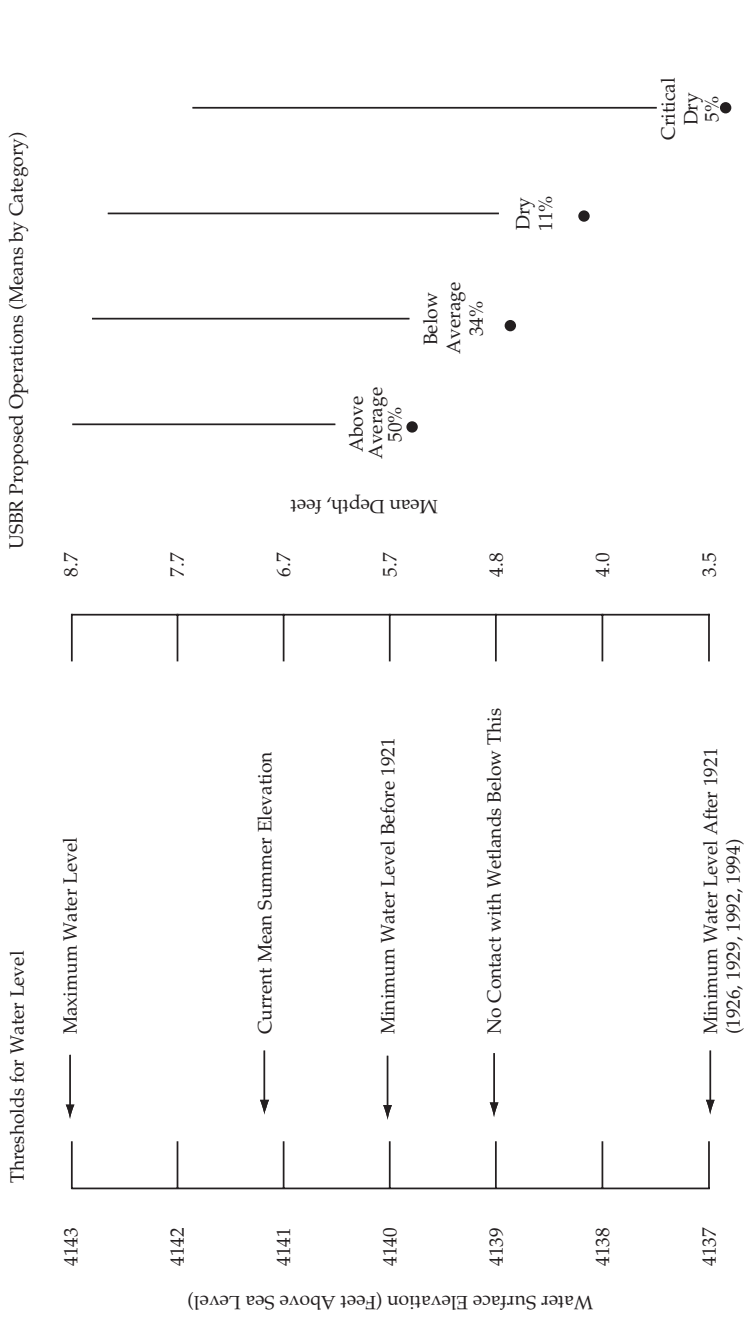


FIGURE 3-2 Water level of Upper Klamath Lake and mean water levels proposed by USBR for years of varying water availability. The vertical lines on the right show interannual mean operating range for an entire season (March 16–October 30). Minimums for specific years can reach below the interannual means; absolute minimums are shown as dots. Source: USBR 2002a.

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Two extreme years, 1992 and 1994, were designated "critical dry" and account for about 5% of the total. By difference, a fourth category, designated "dry," is defined; it accounts for about 11% of years.

For each category of years, the maximum water levels occur in the spring. Water levels typically begin relatively high as of mid-March and then rise slightly, after which they fall because of the cumulative effects of drawdown and, after June, the reduced volume of runoff (Figure 3-3). Operations for the four hydrologic categories differ most notably in their lower extremes, which occur after July. In comparison with a baseline condition, which USBR defines as lacking Klamath Project operations but with all project facilities in place, proposed operations typically produce water levels that are above the baseline between March and the end of June and below the baseline during the last half of the summer or fall (USBR 2002a).

Upper Klamath Lake receives most of its water from the Williamson River (including its largest tributary, the Sprague River) and the Wood River. Additional water sources include precipitation on the lake surface, direct drainage from smaller tributaries and marshes, and springs that bring water into the lake near or beneath the water surface. The waters of the lake have only moderate amounts of dissolved solids (interseasonal median, about 100 μS/cm) and the same is true of alkalinity (interseasonal median, about 60 mg/L as calcium carbonate). As described below, the lake is naturally eutrophic, but concentrations of nutrients in the water column may have increased over the last several decades. The fish community of the lake could be described as a diverse array of nonnative species superimposed on a previously abundant but now reduced group of native fishes,

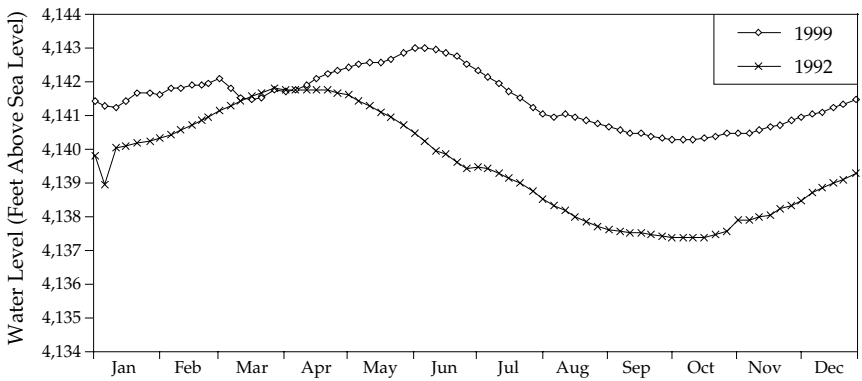


FIGURE 3-3 Water level in Upper Klamath Lake in year of near-average mean water level (1999) and year of extremely low water level (lowest 5%; 1992).

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most of which are endemics (Chapter 6). The biota in general has undergone considerable change in the last few decades.

Upper Klamath Lake has several large marshes at its margins. The area of the marshes has been greatly reduced (loss of about 40,000 acres from the lake margin; USFWS 2002). The remaining marshes are most strongly connected to the lake at high water and are progressively less connected at lower water levels down to about 4,139 ft above sea level, at which point they become disconnected.

Poor water quality in Upper Klamath Lake causes mass mortality of listed suckers and may suppress the suckers' growth, reproductive success, and resistance to disease or parasitism. Potential agents of stress and death include high pH, high concentrations of ammonia, and low dissolved oxygen (USFWS 2002). Extremes in these variables are explained by the presence of dense populations of phytoplankton (primarily the cyanobacterial taxon *Aphanizomenon flos-aquae*), especially in the last half of the growing season (Kann 1998, Welch and Burke 2001). Because phytoplankton populations annually reach abundances exceeding 100 μg/L of chlorophyll *a*, the lake can be classified as hypertrophic (or, equivalently, hypereutrophic) according to standard criteria for trophic classification of lakes (OECD 1982: peak chlorophyll over 75 is hypertrophic). Hypertrophic lakes often show extremes in chemical conditions resembling those observed in Upper Klamath Lake.

The main subjects of interest with respect to Upper Klamath Lake proper (discounting the tributaries, which are dealt with in the next chapter) include factors that have been suspected by researchers or by government agencies of being potentially harmful to the endangered suckers. Where water quality is concerned, the causes of the current trophic status of the lake are of great interest, as is the current predominance of a single algal species, *Aphanizomenon flos-aquae,* in the phytoplankton. Within the suite of variables affected by trophic status, special attention must fall on pH, ammonia, and dissolved oxygen, all of which have the potential to be directly or indirectly harmful to the welfare of the endangered suckers. For all water-quality variables, associations between water level and water quality are of special interest because USBR has the potential to modify operations so as to control water level. Finally, physical habitat, especially as affected by water level, is of concern and will be dealt with here.

Nutrients and Trophic Status of Upper Klamath Lake

Nutrient limitation of phytoplankton in lakes usually is seasonal and almost always is associated with nitrogen, phosphorus, or both of these elements. Typically, phosphorus and nitrogen are readily available during winter because demand is low. In spring, the most available forms are taken

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up, and nutrient limitation often ensues. If the most readily available forms are available in quantities above about 10 μg/L, there is a strong implication that no limitation is occurring (e.g., Morris and Lewis 1988); at lower concentrations, nutrient limitation is possible but may be delayed by internal storage. Nutrient limitation often is relieved in the fall by deep, continuous mixing of the water column, declining irradiance, and lower metabolic rates caused by lower temperatures.

Nitrogen limitation can be defeated by some taxa of bluegreen algae (cyanobacteria) capable of fixing nitrogen (converting N_2 to NH_3). Nitrogen gas (N_2) is present in considerable quantity in water, and the overlying atmosphere acts as a large reservoir that can replenish removal of nitrogen gas by nitrogen fixation. The heterocystous bluegreen algae—which have a special cell, the heterocyst—fix nitrogen readily, although the fixation process requires high intensities of light (Lewis and Levine 1984). Heterocystous bluegreen algae do not grow well in some situations, however, for reasons that are only partly understood (Reynolds 1993). Thus, nitrogen depletion sometimes can occur without inducing growth of nitrogen fixers. Nitrogen fixers grow well in most warm, fertile waters of high pH. When phosphorus is abundant in such waters but nitrogen is scarce, nitrogen fixers have a competitive advantage and often become dominant elements of the phytoplankton. This is the situation in Upper Klamath Lake. For the phytoplankton as a whole in Upper Klamath Lake, nitrogen is limiting (see below), but *Aphanizomenon* has circumvented nitrogen limitation through nitrogen fixation and thus dominates the community.

Typically, the most effective way to control phytoplankton abundance in lakes is to restrict phosphorus supply. Restriction of nitrogen supply is not as effective, because it may lead to the development of nitrogen fixers that are able to offset restrictions in nitrogen supply. Thus, the most obvious way of attempting to control phytoplankton populations in Upper Klamath Lake is to restrict phosphorus supply. As explained below, Upper Klamath Lake presents special difficulties for strategies involving control of phosphorus.

Phosphorus in Upper Klamath Lake

The watershed of Upper Klamath Lake is geologically rich in phosphorus (Walker 2001). Springs have a median phosphorus content of about 60 μg/L as soluble reactive phosphorus, which Boyd et al. (2001, citing Walker 2001) take as an estimate of the background discharge-weighted mean phosphorus concentration. This may be an underestimate, given that springs typically have little or no particulate phosphorus or soluble organic phosphorus, both of which would be present in natural runoff from the watershed. In contrast, watersheds of granitic geology often have discharge-

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weighted mean total P concentrations of 20 μg/L or less (inorganic P about 5 μg/L), provided that they are not disturbed by human activity (e.g., Schindler et al. 1976, Lewis 1986).

Because background concentrations of phosphorus reaching Upper Klamath Lake are quite high, the lake probably supported dense populations of phytoplankton before land-use development. Early observations indicate that the waters were green, and thus eutrophic, at a time when water quality would have been changed little from the natural state. If, as suggested by Boyd et al. (2001), phosphorus reaching the lake would have had originally a discharge-weighted mean phosphorus concentration of about 60 μg/L, phosphorus in lake water would have been somewhat below 60 μg/L (because of sedimentation of some phosphorus) in the absence of internal loading (net increase originating from sediments). On the basis of empirical relationships between chlorophyll *a* and phosphorus (OECD 1982), the mean chlorophyll *a* in the growing season with total phosphorus at 60 μg/L would have been in the vicinity of 20 μg/L, which would have corresponded to short-term maximums of 40–60 μg/L, or about 20% of the current maximums. The concentrations of phosphorus in the lake could have been higher, however, if substantial internal loading from sediments occurred under natural conditions, in which case chlorophyll could also have been higher.

Monitoring of phosphorus entering the lake has shown that the current discharge-weighted mean phosphorus concentration in waters entering Upper Klamath Lake is near 100 μg/L, about 40% of which is considered to be anthropogenic (Boyd et al. 2001). Concentrations in the lake during spring are only about 50 μg/L (Boyd et al. 2001, Figure 2-6; there is considerable variation from year to year); the difference between the supply water and the concentrations in spring is accounted for by sedimentation of the particulate fraction of incoming phosphorus and by mechanisms that convert incoming soluble phosphorus to particulate phosphorus that can undergo sedimentation. The currently observed total phosphorus concentrations in spring, if not supplemented by any other sources, would support mean algal abundances during the growing season corresponding to chlorophyll *a* at 20 μg/L or less, according to equations developed by the Organization for Economic Co-Operation and Development (OECD 1982).

When the growing season begins (in about May), Upper Klamath Lake shows a steady rise in concentrations of total phosphorus culminating in summer concentrations of 200–300 μg/L (Boyd et al. 2001, Figure 2-6; there is considerable variation from year to year). These concentrations greatly exceed the discharge-weighted mean concentrations in inflowing water (about 100 μg/L) and also greatly exceed the concentrations in the lake during spring (about 50 μg/L, Figure 3-4). Thus, the great increase in

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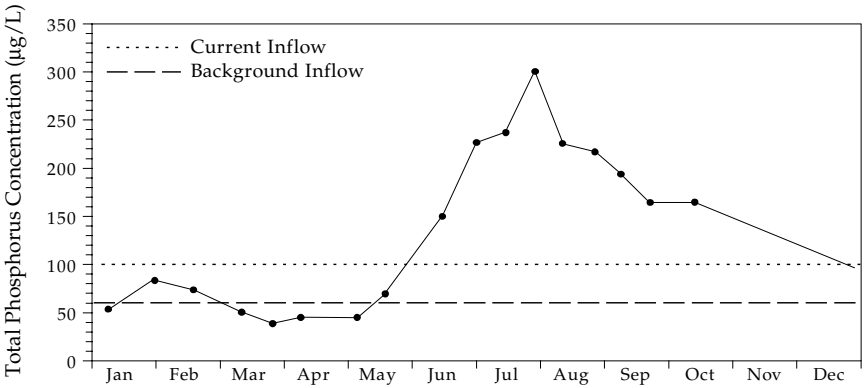


FIGURE 3-4 Total phosphorus concentrations in Upper Klamath Lake during 1997 (an arbitrarily chosen year) and approximate discharge-weighted mean total phosphorus for inflow for background and for current conditions. Source: Data from Walker 2001.

concentrations of phosphorus during the growing season must be attributed to an internal source (sediments).

Concentrations of soluble phosphorus in sediments of Upper Klamath Lake were studied by Gahler and Sanville (1971), as reported by Bortleson and Fretwell (1993). Sediment samples taken at one location in 1968–1970 showed a median soluble phosphorus concentration in the interstitial waters of about 7,000 µg/L, or about 25 times the maximum concentrations observed in the overlying lake water (another location showed less extreme deviation from lake water). Thus, for at least some portions of the lake, sediment pore waters contain substantially more soluble phosphorus than the overlying lake water and can serve as an internal source of phosphorus if the phosphorus leaves the sediments. This is a common situation in fertile lakes.

The efficiency with which phosphorus is released from sediments varies greatly according to the conditions in a particular lake. There are four potential mechanisms of release: (1) If the sediments are disturbed by wind-driven currents or by other means (organisms or degassing), interstitial phosphorus can be transferred to the water column simply by agitation. (2) Decrease in the redox potential (increase in availability of electrons) in the surficial sediments caused by intensive microbial respiration, as would be the case for highly organic sediment, can cause biogeochemical changes that result in accelerated release of mineralized or soluble organic phosphorus from the sediments to the overlying water, even if the sediments are immobile. (3) High pH at the sediment surface may cause release of adsorbed phosphorus from sediments, with or without agitation of sediments.

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(4) In shallow lakes, phytoplankton cells may, under calm conditions, sink to the sediment surface, where phosphorus is more concentrated than in the water column, and then be resuspended either by wind or by buoyancy control mechanisms after assimilating phosphorus, thus bringing phosphorus from the sediments to the water column. Internal loading in Upper Klamath Lake is caused by one or more of these four mechanisms, which are not mutually exclusive.

Chlorophyll concentrations in Upper Klamath Lake increase in parallel with concentrations of total phosphorus in the water column from May to July (Boyd et al. 2001). Thus, the data indicate that phytoplankton are assimilating an internal phosphorus load leading to an increase in their biomass. The growth process culminates in concentrations of phytoplankton chlorophyll *a* typically near or above 200 μg/L (Boyd et al. 2001). At such high abundances, phytoplankton approach the maximum sustainable biomass based on light availability (self shading) rather than nutrients (Welch and Burke 2001). The specific limit for phytoplankton biomass based on light rather than nutrients depends on physical conditions in a lake and physiological characteristics of the dominant algae (Wetzel 2001).

Because internal loading increases the phosphorus inventory of the water column in Upper Klamath Lake, thus sustaining high populations of bluegreen algae, its mechanisms are of special importance to the nutrient economy and trophic status of the lake and therefore to water-quality conditions that affect fish.

The simplest mechanism of release of phosphorus from the sediments is disturbance of the sediments. As proposed initially by Bortleson and Fretwell (1993), that mechanism is highly feasible in Upper Klamath Lake because of the lake's low relative depth (a low ratio of depth to area), which is an indication that sediments will easily be mobilized by strong winds, at least over the large expanses of shallow water. Thus, decomposition processes in the sediments may liberate phosphorus from particulate form, and this phosphorus can be transferred to the water column simply by wind-generated sediment movement. Release of gas bubbles from the sediment or invertebrate activity (bioturbation) can produce similar effects. The role of sediment movement in mobilizing phosphorus in Upper Klamath Lake is unknown, but the ability of the wind to move sediments readily over much of the lake bottom is generally acknowledged (Bortleson and Fretwell 1993).

Release of phosphorus from sediments also can occur without any movement of the sediments. If there is a substantial concentration gradient of soluble phosphorus between the sediment pore waters and the overlying water, the potential exists for diffusion of phosphorus from the pore waters to the overlying lake water and distribution of the released phosphorus by eddy diffusion or bulk mixing of the water column. The key requirements

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for the process include presence of a substantial concentration gradient (which exists in at least some places in Upper Klamath Lake, as indicated by the study cited above) and absence of any physical or chemical barrier to diffusion of soluble phosphorus.

It is well known that iron in the ferric state can bind phosphorus, thus restricting its movement from sediments to water (Mortimer 1941, 1942). Loss of the precipitated (ferric) iron from the surface of lake sediments occurs when sediments are anoxic for long intervals, by conversion of iron to a soluble (ferrous) state. Loss of ferric iron facilitates exchange between the sediment pore waters and the overlying water and releases phosphorus bound by ferric iron. The result can be release of large amounts of phosphorus from the sediments (internal loading). The release of phosphate from sediments caused by changes in the oxidation state of iron is most likely in lakes that show prolonged anoxia at the sediment-water interface. Unlike deeper lakes, Upper Klamath Lake does not remain stratified for the entire growing season, but rather for periods of only days or at most weeks at a time, so a key role for the redox mechanism seems less likely than it would in some other lakes, but it cannot be ruled out.

The adsorption of phosphate by ferric complexes is influenced by pH. Phosphate may pass from a sediment surface to the overlying water if the pH is high (> 8; literature reviewed by Marsden 1989), even without conversion of ferric to ferrous iron. Thus, internal loading in Upper Klamath Lake may involve iron and phosphate under oxic conditions at the sediment surface if pH is high. This mechanism is considered by some researchers to be of special importance in Upper Klamath Lake (summary in Boyd et al. 2001).

Biogeochemical mechanisms (loss of oxygen and high pH) involving release of phosphorus from sediments typically are described in terms of abiotic reactions involving iron, but there is some evidence that bacterial metabolism also accounts for binding or release of phosphorus at the sediment-water interface (Davison 1993). Bacteria also control the oxidation conditions on the sediment surface.

Phosphorus mobilization from sediments of Upper Klamath Lake also may involve direct contact between the algae and the sediments. *Aphanizomenon* contains pseudovacuoles that function as buoyancy-control mechanisms. Under some circumstances, which may coincide with nutrient deficiency, the algae may show higher specific gravity than at other times and thus show an increased tendency to sink. Because nutrients typically are more available in deep water than in shallow water, sinking, which would be notable primarily under calm conditions, can allow algae to reach nutrient reserves that otherwise are not available. In Upper Klamath Lake, a small amount of sinking could allow a substantial fraction of the algal population to have direct contact with the sediments, where phosphorus

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supplies are rich. Thus, algae may be mobilizing phosphorus through direct contact with the sediments (cf. Ganf and Oliver 1982).

Nitrogen in Upper Klamath Lake

The total nitrogen load to Upper Klamath Lake has been calculated for total-maximum-daily-load (TMDL) purposes as 663,000 kg/yr (Boyd et al. 2001, Walker 2001). Thus, the mass ratio of nitrogen to phosphorus for loading under present circumstances is about 3.6:1. This ratio is extreme in the sense that mass transport of nitrogen and phosphorus from watersheds to lakes typically involves mass ratios well in excess of 5:1 (OECD 1982). Although human activities tend to cause higher relative enrichment with phosphorus than with nitrogen, even disturbed watersheds typically have much higher nitrogen transport than phosphorus transport.

The ratio of nitrogen to phosphorus typically is evaluated with respect to phytoplankton growth by reference to the Redfield ratio, which is an empirically determined value for the relative amounts of nitrogen and phosphorus that are needed by phytoplankton for growth (Harris 1986). The Redfield ratio is 16:1 on a molar basis and 7.5:1 on a mass basis. In environments that show ratios far above the Redfield ratio, strong and persistent phosphorus limitation is expected. Where the reverse is true, all taxa of algae are likely to be nitrogen-limited except those capable of nitrogen fixation. Thus, where the nitrogen:phosphorus ratio is low, as it is in Upper Klamath Lake, the nutritional conditions are ideal for dominance by nitrogen-fixing bluegreen algae, such as *Aphanizomenon flos-aquae*. The fixation of nitrogen by *Aphanizomenon flos-aquae* has the effect of raising the nitrogen:phosphorus ratio by adding atmospheric nitrogen to the lake through the fixation process. While the nitrogen:phosphorus ratio still is low, a rise in this ratio due specifically to *Aphanizomenon* has increased the ability of the lake to produce algal biomass.

Explanations of Dominance by Aphanizomenon

A recent analysis showed that akinetes, which are resting cells of *Aphanizomenon flos-aquae*, are concentrated in recently accumulated sediments but not in sediments of an earlier era corresponding to predisturbance conditions (Eilers et al. 2001). Eilers et al. concluded that the strong dominance of the algal flora in Upper Klamath Lake by heterocystous bluegreen algae is a byproduct of human presence. Historical observations of phytoplankton, as summarized by Bortleson and Fretwell (1993), are consistent with the paleolimnological conclusions. A brief overview of the chronology of observations on phytoplankton is as follows (condensed from Bortleson and Fretwell 1993): In 1906, ice from Upper Klamath Lake was

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deemed unsuitable for consumption because of high organic matter and green color; in 1913, summer phytoplankton samples showed diatoms dominant and bluegreen algae accounting for only 12% of cells; in 1928, water samples showed abundant algae but no dominance by bluegreens; in 1933, *Aphanizomenon* was reported for the first time but not as a dominant; in about 1939, *Aphanizomenon* was abundant but not dominant; in 1957, *Aphanizomenon* was 10 times more abundant than in 1939 but not yet overwhelmingly dominant; and in the 1960s and later, *Aphanizomenon* constituted almost a monoculture during most of the growing season.

It would be tempting to attribute the low ratio of nitrogen to phosphorus reaching Upper Klamath Lake to anthropogenic augmentation of phosphorus supply. From the TMDL mass-balance analysis, however, it is clear that Upper Klamath Lake probably had an even lower ratio of nitrogen to phosphorus in its predisturbance state (Boyd et al. 2001) because it has an unusually rich geologic source of phosphorus. Thus, nutritional conditions in Upper Klamath Lake favorable to nitrogen-fixing bluegreen algae such as *Aphanizomenon* are not new. The combination of high phosphorus concentrations under background conditions and the low ratio of nitrogen to phosphorus would have created ideal nutritional conditions for the growth of bluegreen algae before human alteration of nutrient loading, yet *Aphanizomenon* blooms appear to be a byproduct of human activity.

The conditions in Upper Klamath Lake prior to anthropogenic change could have involved some factor that prevented the population growth of bluegreen algae, even though nutrient conditions favored nitrogen-fixing algae such as *Aphanizomenon*. It has been suggested, for example, that organic acids (designated here as limnohumic acids and consisting mainly of humic and fulvic acids) present in wetland sediments are capable of chemically suppressing the growth of bluegreen algae (Eilers et al. 2001, Geiger 2001), although the phycological literature on limnohumic acids contains little indication of such effects (Jones 1998, but see also Kim and Wetzel 1993). Drainage of wetlands and hydrologic alteration in the watershed of Upper Klamath Lake probably has reduced the transfer of limnohumic acids to the lake. It is unknown, however, whether limnohumic acids or other substances derived from wetlands would have been present in sufficiently high quantities to inhibit the growth of bluegreen algae under the original conditions of the lake or why this inhibition would have been operating selectively on *Aphanizomenon*, given that other algae were abundant.

Another possibility, apparently not proposed for Upper Klamath Lake (although listed by Geiger 2001), has to do with light climate as influenced by limnohumic acids. A record from 1854 (unpublished document of the state of Oregon, as given by Martin 1997) states suggestively that the water of Upper Klamath Lake "had a dark color, and a disagreeable taste occa-

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sioned apparently by decayed tule." Limnohumic acids, which can originate in large quantities from some types of wetlands (especially those of low alkalinity), absorb light strongly at short wavelengths (Thurman 1985) and may substantially affect the light climate of phytoplankton (Jones 1998). For example, Morris et al. (1995) and Williamson et al. (1996) showed that the depth of 1% light declined from 12 m to 2 m as dissolved organic carbon (mostly limnohumic acids) increased from 2 to 10 mg/L in a series of 65 lakes of varied latitude. An increase in absorbance of such magnitude could substantially cut the amount of light reaching phytoplankton. Some diatoms are better adapted to deal photosynthetically with low light availability than most bluegreen algae (Reynolds 1984), but the high light requirement of nitrogen fixation may be even more important. Among the bluegreens, the Nostocales (including *Aphanizomenon*) have especially high light requirements (Weidner et al. 2002, Havens et al. 1998). Thus, a change in light climate rather than a change in nutrient loading or other chemical effects could have been responsible for the shift from diatoms to bluegreen algae. This is only one of several possibilities, however.

Yet another possibility has to do with biotic changes in Upper Klamath Lake. *Aphanizomenon* grows relatively slowly and so is especially vulnerable to grazing, as shown by Howarth and colleagues in marine environments (Howarth et al. 1999, Marino et al. 2002, Chan 2001; see also Ganf 1983). It is conceivable that the intensity of grazing by zooplankton on algae has been altered by the introduction of fishes that are efficient zooplanktivores. In the absence of so many efficient planktivores, zooplankton populations could have been much higher and thus capable of working selectively against *Aphanizomenon* and other nitrogen fixers. Contradicting this hypothesis is the abundance of a large and efficient zooplankton grazer, *Daphnia* (Kann 1998). In fact Kann (1998) proposes that *Daphnia* may promote *Aphanizomenon* by grazing preferentially on its competitors.

Although it seems fairly certain that *Aphanizomenon* has come into dominance in Upper Klamath Lake through human influences, the causal mechanisms of this undesirable change in phytoplankton dominance remain unclear.

Seasonal Development of Algal Biomass

Regular sampling of phytoplankton biomass at multiple stations in 1990–1998 has provided a substantial amount of information on the time course and interannual variability of biomass development of *Aphanizomenon* in Upper Klamath Lake (Kann 1998, Welch and Burke 2001). As is typical of phytoplankton populations, the phytoplankton of Upper Klamath Lake, of which over 90% is *Aphanizomenon* at peak algal abundance, shows a burst of growth in spring followed by decline. The progres-

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sion of abundance is irregular, however, in that an initial period of rapid growth may be interrupted or delayed, and a period of general decline may lead to renewed growth (Figure 3-5).

The growing season for phytoplankton in Upper Klamath Lake begins generally in April. Wood et al. (1996) proposed that water temperature would show the most direct control on the rate of increase in early spring, when other conditions for growth are favorable, and thus might be a good predictor of the elapsed time between the beginning of the growing season and any particular biomass threshold that might be considered an algal bloom. This concept was investigated by Kann (1998), who showed a statistically significant association between degree days and elapsed time between the beginning of the growing season and the time coinciding with development of a specific biomass. According to Kann's analysis, days elapsed between April 1 and a biomass threshold of 10 mg/L of wet mass could be predicted with fairly high confidence ($r^2 = 0.69$) from degree days between April 1 and May 15. At the lower end of the interannual growth rate spectrum, the threshold was reached after 150 days; at the upper end, after 170 days. A relationship with lake volume in May was also tested and was suggestive but not statistically significant and it depends heavily on an outlying data point for 1992, without which there is no hint of a trend related to lake volume in May. A larger dataset might show a weak but significant relationship on the basis that a lower mean depth might lead to faster warming, but interannual variation in weather introduces considerable variation not related to lake depth.

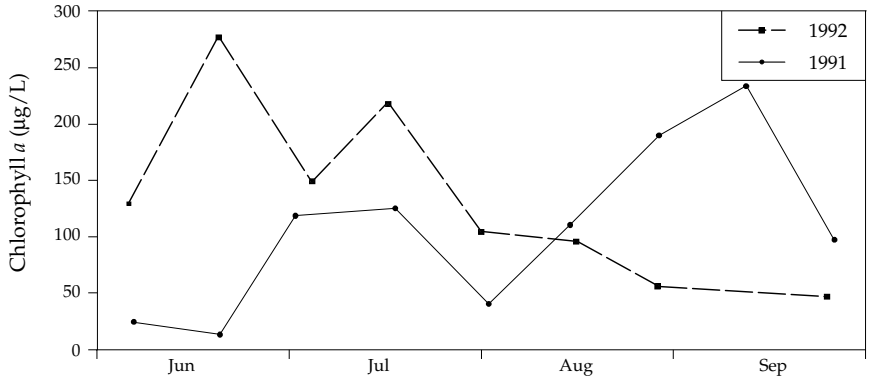


FIGURE 3-5 Change in chlorophyll *a* (lakewide averages, volume-weighted) over growing season for 2 consecutive years showing the potential interannual variability in development of chlorophyll maximums. Source: Redrawn from Welch and Burke 2001.

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Kann (1998) and Welch and Burke (2001) have placed considerable emphasis on the relationship between water temperature and the first occurrence of a threshold biomass of *Aphanizomenon* equal to 10 mg/L of wet mass in spring. The relationship is well supported by data, but it has virtually no application to the occurrence or timing of extreme water-quality conditions. The threshold of 10 mg/L of wet mass corresponds to chlorophyll *a* at about 20–30 μg/L, which is only about 10–20% of the maximum abundance of *Aphanizomenon* as it reaches its annual peak. Although temperature influences growth in early spring, it later loses its influence because temperature stabilizes and the full development of the bloom to harmful proportions depends on other factors, as acknowledged by Welch and Burke (2001). Thus, the relationship between temperature and growth rate of *Aphanizomenon* in early spring seems to be a dead end with respect to anticipating the timing of the ultimate biomass maximums or their magnitude.

Of direct interest in connection with extremes of water-quality degradation during summer are the mean and maximum biomasses for suspended algae (primarily *Aphanizomenon*) that the lake shows in a given year. As shown in Figure 3-6, neither peak biomass nor mean biomass during the growing season has any empirical relationship with water level in Upper Klamath Lake.

Welch and Burke have modeled the abundance of *Aphanizomenon* on the basis of light availability with the assumption that nutrients are available in sufficient quantities to produce very high biomass (which is demonstrably correct). Light availability is affected by mean depth. As a water column gets deeper, the mean light availability for individual cells circulating in the water column declines because cells spend a higher proportion of time at greater depth, where light is less available. The modeling led Welch and Burke to conclude that maximum algal biomass of *Aphanizomenon* in Upper Klamath Lake would be quite sensitive to mean depth of the lake (Welch and Burke 2001, p. 3-15). This conclusion is inconsistent, however, with measurements of algal biomass, which show no such relationship. Thus, the model predictions are contradicted by field observations, and the latter must be given greater weight.

Modeling of the type used by Welch and Burke is useful in directing research but often produces misleading predictions because modeling usually requires various assumptions. In the case of modeling related to light, for example, the estimation of light exposure for cells must assume uniform distribution of biomass throughout the water column at all times. Because *Aphanizomenon* is capable of buoyancy regulation, it may have a nonuniform vertical distribution during calm weather. Furthermore, although Upper Klamath Lake is not stratified throughout the growing season, as deeper lakes are, it is stratified for substantial intervals during which the

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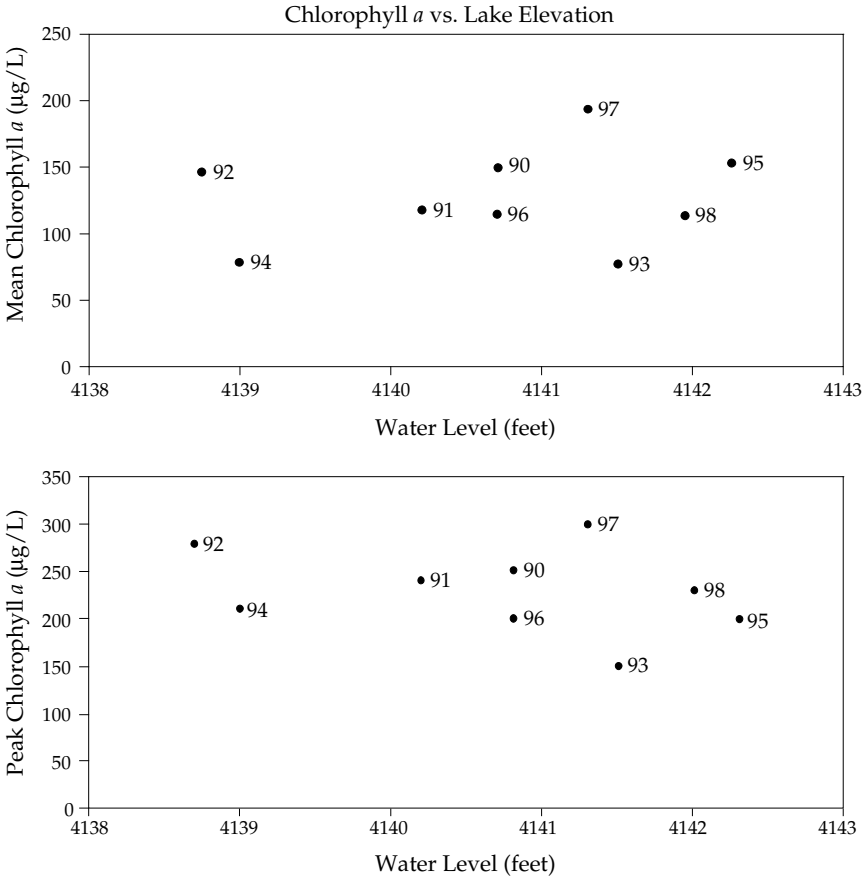


FIGURE 3-6 Relationship of mean chlorophyll (above) and peak chlorophyll (below) to water level in Upper Klamath Lake (median level for July and August). Source: Data from Welch and Burke 2001.

effective depth from the viewpoint of phytoplankton in the surface layer is less than the actual depth of the lake. Many other assumptions were necessary in modeling and could be a cause of divergence between model predictions and observations. At any rate, modeling cannot yet be used as a basis for predicting peak biomass of *Aphanizomenon* from water level in Upper Klamath Lake.

pH

Algal biomass, which typically is measured as chlorophyll concentration, is closely related to pH in Upper Klamath Lake (Kann 1998, Walker

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2001). This relationship is consistent with the expected rise in pH caused by high rates of photosynthesis in aquatic environments generally (Wetzel 2001). Thus, high algal abundance sustained by light and abundant nutrients is the proximate cause of high pH during the growing season in Upper Klamath Lake.

The photosynthetically induced high pH of Upper Klamath Lake has been used in formulating a hypothesis related to the control of internal phosphorus loading in Upper Klamath Lake (Boyd et al. 2001, Walker 2001). According to this hypothesis, designated here as the pH-internal loading hypothesis, internal loading occurs primarily under oxic conditions at the sediment-water interface and involves desorption of phosphorus from ferric hydroxide complexes at the sediment-water interface through the replacement of phosphate with hydroxyl ions at high pH. Thus, high pH is proposed as a direct cause of the phosphorus enrichment of Upper Klamath Lake through internal loading during the growing season. As explained above, however, the importance of other mechanisms of internal loading cannot be ruled out, especially because internal loading substantially increases phosphorus concentrations before the lake reaches its peaks of algal abundance that are the cause of peaks in pH.

If high pH is the main cause of internal phosphorus loading, which in turn supports extremes of algal biomass in Upper Klamath Lake, internal loading might be lower if the pH of the lake were lower. Thus, external loading might be connected causally to internal loading by way of pH; this hypothesis is the basis of some recommendations in the TMDL analysis of Upper Klamath Lake (Boyd et al. 2001). The hypothesis is, however, still highly speculative.

The pH of Upper Klamath Lake also may be directly significant to fish, which can be damaged or killed by high pH. For example, Saiki et al. (1999) showed that a mean 24- to 96-h LC_{50} for the two listed sucker species in both larval and juvenile stages was 10.3–10.7. Sublethal effects would be expected below this threshold for exposures of 1 day or longer and have been demonstrated in juvenile shortnose suckers at a pH of near 9.5 (Falter and Cech 1991). Any means of suppressing extreme pH could benefit the suckers, although the degree of potential benefit is not clear. Because pH does not peak during episodes of mass mortality of suckers, however, it seems unlikely that pH contributes to mass mortality (Saiki et al. 1999). Also, because peaks of pH are transitory because of 24-h cycling of pH, impairment of fish by high pH in Upper Klamath Lake is difficult to evaluate.

As mentioned above, the immediate cause of the highest pH values in Upper Klamath Lake is photosynthesis. Furthermore, the abundance of algae, as estimated from chlorophyll *a*, is strongly correlated with pH. Thus, suppression of algal abundance would lead to a suppression of pho-

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tosynthesis, which in turn would lead to a suppression of pH and, most important, elimination of the highest pH values. Kann and Smith (1999) suggested on the basis of a probabilistic analysis that a target chlorophyll *a* concentration of 100 μg/L would probably lead to a effective suppression of high pH.

The connection between pH and water level in Upper Klamath Lake has been of great interest because water level can be regulated to some degree. Welch and Burke (2001) argued on the basis of modeling that higher water levels would produce lower extremes of pH, which would potentially benefit the suckers. Their projection of pH with modeling was based on the presumption that chlorophyll *a* can be modeled in relation to water level. As mentioned above, however, observations of chlorophyll *a* in relation to water level are not as predicted by the model; there is no relationship between means or extremes of chlorophyll *a* and lake level based on monitoring during the 1990s. Thus, there is no reason to expect a relationship between pH and water level, given that pH is controlled by algal abundance. In fact, the monitoring data show no relationship between pH and water level (Figure 3-7; percentiles other than the one shown also fail to demonstrate a relationship between water level and pH). Even though they predict more favorable pH at higher lake levels, Welch and Burke (2001) acknowledge that there is no empirical relationship between pH and lake level as judged by information collected during the 1990s. The authors open the possibility of more complex relationships between lake level and pH. Any such relationship remains hypothetical, and the weight of current

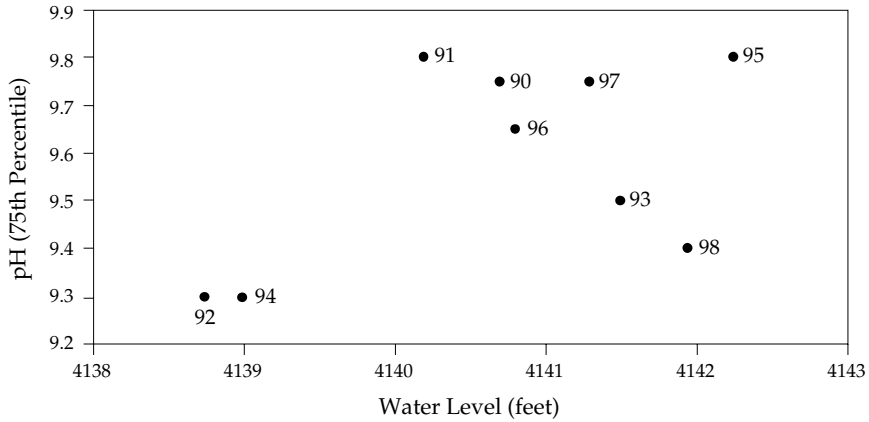


FIGURE 3-7 Relationship between water level (median, July and August) and pH in Upper Klamath Lake. The pH data are water-column maximum pH for 7 monitoring sites distributed across Upper Klamath Lake, shown as 75th percentile for all dates. Source: Data from Welch and Burke 2001.

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evidence does not support the argument that higher lake levels will mitigate problems associated with high pH.

One deficiency in the information on pH is lack of consideration of diel cycling in pH (a small amount of information is given by Martin 1997). In highly productive waters such as those of Upper Klamath Lake, pH changes extensively in a 24-h cycle; maximums occur in the afternoon hours, and minimums just before sunrise. The amplitude of pH cycles commonly exceeds 1 pH unit in fertile waters. Thus, evaluation of pH would be more complete if the pH cycle were taken into account.

Overall, pH is regulated by algae, and if the abundance of algae could be reduced, the extremes of pH could be moderated. It is likely that the abundance of algae has been increased by human actions either directly or indirectly, in which case pH under current conditions would be expected to peak substantially above the pH that was present before changes in land use in the basin. Potentially undesirable effects of high pH include direct damage to fish and amplification of internal loading, which is probably the largest source of phosphorus for Upper Klamath Lake. It is not yet clear how much harm high pH is causing suckers (especially in contrast with dissolved oxygen, for example), nor is it clear that internal loading of phosphorus, which can occur by a number of mechanisms, would be strongly suppressed by reduction in pH.

Ammonia

Ammonia has been proposed as a toxicant that potentially affects the endangered suckers of Upper Klamath Lake. Although ammonia is a plant nutrient with no adverse effects on organisms at very low concentrations, it is toxic at high concentrations. Toxicity typically has been associated with the unionized component of ammonia in solution. Thresholds of protection incorporated into various state regulations for warm-water aquatic life usually are in the vicinity of unionized ammonia (expressed as N) at 0.06 mg/L. Toxicity studies on the endangered suckers showed, however, that they are more tolerant of ammonia than many other species of fish (unionized ammonia LC_{50} for 24–96 h, 0.5–1.3 mg/L; Saiki et al. 1999).

Under oxic conditions, ammonia either is removed from the water column by autotrophs (which use it nutritionally) or is oxidized by nitrifying bacteria that convert it to nitrate. Thus, in the absence of a strong point source of ammonia, it is typical to have low concentrations of ammonia in inland waters that are oxic. In the absence of oxygen, however, ammonia produced by decomposition can accumulate, given that its conversion to nitrate or uptake by autotrophs does not occur under these conditions.

Upper Klamath Lake stabilizes in summer when wind speeds are low, as explained below in connection with the discussion of oxygen. At such

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times, ammonia accumulates in the lower water column as oxygen is depleted. Mixture of the ammonia into the entire water column could produce toxicity. Unionized ammonia seems a less likely cause of mass mortality of fish in Upper Klamath Lake than dissolved oxygen, however, because mass mortality continues after ammonia concentrations have declined (Perkins et al. 2000b), and because the suckers show relatively high tolerance to ammonia.

Dissolved Oxygen

Low concentrations of dissolved oxygen coincide with mass mortality of large suckers in Upper Klamath Lake. The suckers are relatively resistant to oxygen depletion (LC_{50} 1.1 to 2.2 mg/L; Saiki et al. 1999), but their tolerance limits are exceeded under some conditions in Upper Klamath Lake (Perkins et al. 2000b). Unlike extreme pH or high ammonia concentrations, low dissolved oxygen persists for days while mortality occurs. Thus, low dissolved oxygen appears to be the direct cause of mortality.

Most lakes of middle latitude are dimictic; that is, they mix completely in spring and fall but stratify stably during summer and are covered with ice continuously or intermittently in winter. Lakes that are exceptionally shallow in relation to their area, however, are polymictic; that is, they mix many times during the growing season. The shallowest lakes, which can mix convectively at night even in the absence of wind, are designated continuous polymictic lakes (Lewis 1983). Lakes that are too deep to be mixed entirely by free convection every night (about 2–3 m; MacIntyre and Melack 1984) but too shallow to sustain stratification throughout the growing season are intermediate in the sense that they develop and sustain stratification for intervals of calm weather, especially if there is no net heat loss, and mix completely when wind strength increases or substantial heat is lost; they are called discontinuous polymictic lakes. Upper Klamath Lake is a discontinuous polymictic lake, as shown by its episodes of stratification interrupted by extended intervals of full mixing. The dynamics of water-column mixing and stratification in Upper Klamath Lake are not well documented, however, because water-quality surveys have been separated by too much time to allow resolution of the alternation between mixing and stratification in the lake.

A discontinuous polymictic lake shows alternation of the two very different conditions associated with mixed and stratified water columns. While the water column is unstratified, the lake shows minimal vertical differentiation in oxygen or other water-quality variables. When the lake stratifies, however, depletion of oxygen begins in the lower part of the water column, where contact with atmospheric oxygen is lacking and there is not enough light for photosynthesis. Because Upper Klamath Lake is

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highly productive, its waters have high respiratory oxygen demand that quickly leads to the depletion of oxygen in the lower water column whenever the lake is stratified (e.g., Welch and Burke 2001, Horne 2002).

An empirical relationship has been shown between relative thermal resistance to mixing (RTR, an indicator of stability) and wind velocity during July and August for Upper Klamath Lake (Welch and Burke 2001). Thus, the expectation that intermittent stability is under the control of weather has been verified for Upper Klamath Lake. Further work on the dynamics of mixing would probably be useful for understanding changes in water quality in the lake. Future work should be based on stability calculations rather than RTR, however. Stability can be calculated from morphometric data on the lake, water level, and the vertical profile of density (Wetzel and Likens 2000). Stability depends on water depth and distribution of density with depth, both of which are more irregular in Upper Klamath Lake than would be ideal for use of RTR, which is a shortcut method of estimating stability that overlooks any changes in depth. The advantage of using true stability rather than RTR is that it may show more clearly relationships between stability and factors of interest to the analysis of mixing. The relationships already demonstrated are important, however.

Loss of stability after a period of high stability in Upper Klamath Lake is associated with low concentrations of dissolved oxygen and high concentrations of ammonia throughout the water column and with depression of algal abundances. To some extent, those changes can be understood simply as a byproduct of mass redistribution in the water column. For example, ammonia is expected to accumulate in deep water during stratification because it is a byproduct of decomposition and accumulates where oxygen is scarce or absent; it is distributed throughout the water column by destratification. Likewise, water that is depleted of oxygen near the bottom of the lake, when mixed with the upper portions of the water column, causes a decrease in oxygen concentrations in the entire water column until photosynthesis and reaeration processes at the surface combine to raise oxygen concentrations throughout the water column.

Some of the events that follow destratification in Upper Klamath Lake cannot be explained simply in terms of the redistribution of mass from a stratified water column. Concentrations of ammonia decline rather rapidly after destratification, as expected from the processes of nitrification (oxidation of ammonia to nitrate by bacteria) and autotrophic assimilation (uptake by algae). Low concentrations of dissolved oxygen, however, persist for many days rather than being offset by reaeration and photosynthesis, as might be expected. Furthermore, algal populations show substantial and prolonged decline. The prolonged decrease in oxygen appears to be the main cause of mass mortality of the endangered suckers during transition from a stratified to a fully mixed water column accompanied by the most

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severe decrease in dissolved oxygen (Perkins et al. 2000b). Therefore, it is important to understand why oxygen concentrations fail to recover.

The likely proximate cause of the extended decrease in oxygen concentrations after destratification is algal death. Stratification of the water column appears to produce conditions that are harmful to the algae. The mechanism of harm is still indeterminate. It could involve, for example, death of the algae that are trapped in the lower portion of the water column when stratification occurs; these algae would lack light and might be exposed to harmful chemical conditions as the lower water column becomes anoxic. Oxygen can be depleted quickly from the lower water column of Upper Klamath Lake, partly because the oxygen demand of sediments is very high (Wood 2001). One would expect that the buoyancy control of *Aphanizomenon* would allow the algae to escape these problems, but perhaps not. Alternatively, the occurrence of calm weather, which probably accompanies the development of stratification, could lead to extensive stranding of buoyant filaments of *Aphanizomenon* at the surface. This type of stranding is known to occur in dense populations of bluegreen algae. When population densities are high, the light climate is poor, and the vacuolate bluegreens often show buoyancy regulation as a means of maintaining the higher mean position in the water column, thus avoiding shading. When the water column is becalmed, however, this type of buoyancy regulation, which requires a relatively long period of adjustment, takes the filaments to the surface where they are exposed to excessive amounts of radiation (especially ultraviolet) and death results (Reynolds 1971, Horne 2002). These are merely speculations on mechanisms, however; additional research would be required to demonstrate which ones apply.

Regardless of the mechanism of algal death, it is clear that death of a substantial population of *Aphanizomenon* in Upper Klamath Lake would reduce the potential oxygen supply (by cutting off a portion of the photosynthetic capability of the water column) and would simultaneously generate a large amount of labile organic matter (as a result of the lysis of algal cells), which would raise the oxygen demand of the water column through the respiratory activities of bacteria whose growth would be stimulated by the presence of the organic matter (Figure 3-8). The extended nature of oxygen depletion suggests that it takes many days for the excess organic matter to be consumed, for the photosynthetic capacity of the lake to be regenerated, or both. In the meantime, substantial harm can occur to endangered suckers because oxygen concentrations remain low. An important practical question is whether the episodes of low dissolved oxygen throughout the water column are related to water level. Empirical evidence indicates that no such association exists, as shown Figure 3-8 (other locations and percentiles also lack a pattern). If stabilization of the water column is ultimately a danger to the fish through the induction of high algal mortality

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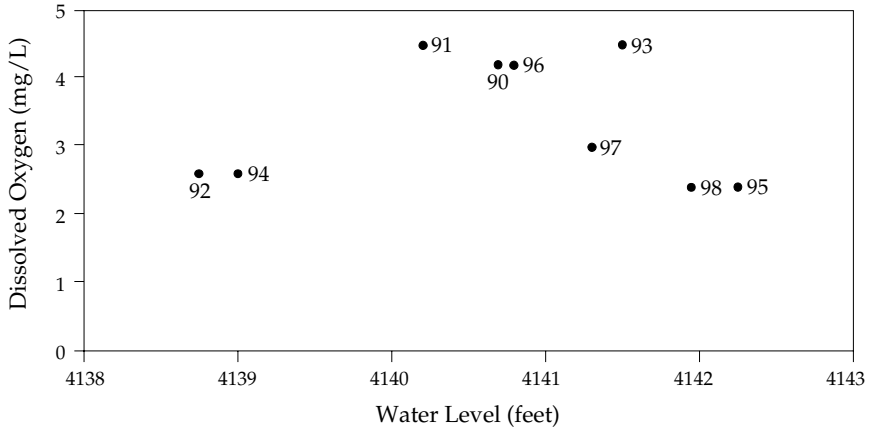


FIGURE 3-8 Relationship between water level (median, July and August) and dissolved oxygen in the water column of Upper Klamath Lake. Oxygen data are given as 75th percentile of minimums for all sampling dates in a given year at three sampling sites in the northern part of lake, which is considered to be especially important as habitat for large suckers. Source: Data from Welch and Burke 2001.

followed by loss of considerable oxygen from the entire water column, conditions leading to high stability would be least favorable to fish (Figure 3-9). Other factors being equal, deeper water columns are more stable, as acknowledged by Welch and Burke (2001); that is, one might expect higher water levels to produce greater mortality than lower water levels. However, given the complicating influence of numerous factors, including weather, associations between depth and extremes of oxygen concentrations may be too variable to detect. At any rate, there is no evidence based on oxygen that favors higher water levels over lower water levels as judged from information collected during the 1990s.

Highly productive lakes may show depletion of oxygen under ice during winter. Photosynthesis typically is weak in winter because of low irradiance and the effects of ice cover and snow on light transmission. Under winter conditions, even though respiration rates are suppressed by low temperature, dissolved oxygen can be completely depleted, and this can lead to the death of fish (winterkill). If all other factors are equal, a shallower lake is more likely to show winterkill than a deeper lake because a deeper lake has larger oxygen reserves and less respiration per unit volume than a shallower lake. Other factors are also important, however, including especially the duration of the period of ice cover and the presence of refugia, such as springs or tributaries, that move oxygen to selected locations where fish may find oxygen.

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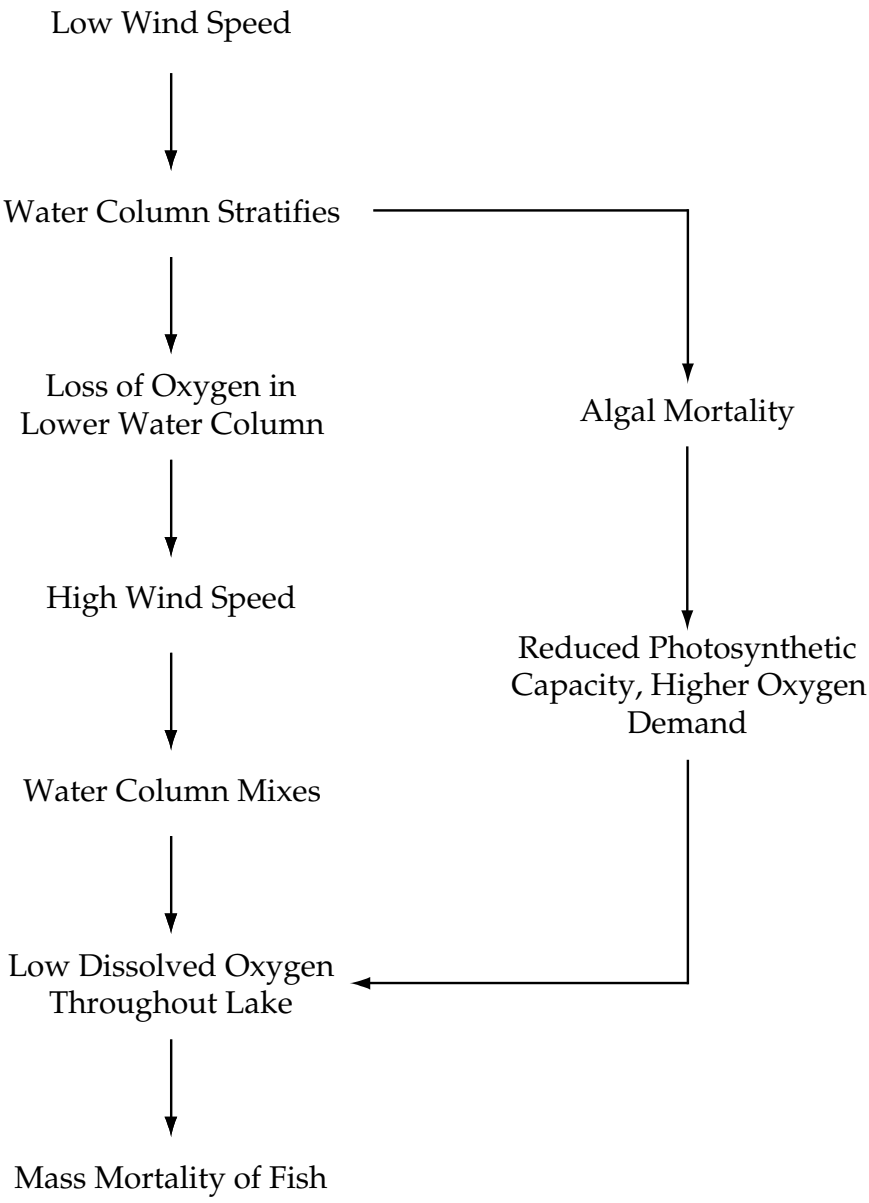


FIGURE 3-9 Probable cause of low dissolved oxygen throughout the water column of Upper Klamath Lake during the growing season leading to mass mortality of fish.

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Welch and Burke (2001) and USFWS (2002) have noted risk to the endangered suckers through increased potential for winterkill when the lake is severely drawn down, as it is in dry and critical dry years. No winter mortality has been observed, however, even though the period of observation includes 2 yr that have shown more severe drawdown than any other years in the last 40 yr of record. Sparse data on oxygen under ice do not indicate depletion (USFWS 2002), but much more information is needed. Analogies that Welch and Burke (2001) have shown with studies done elsewhere may be unreliable because of differences in the duration of ice cover and other factors that make comparisons problematic. On a hypothetical basis, winter fish kill seems more likely when the lake is drawn down than when it is not, but winter fish kill may not occur at all, in which case water level is not an issue within the operating ranges of the 1990s. Measurements of oxygen concentrations under ice cover would shed additional light on this issue.

Overview of Water Quality in Upper Klamath Lake

Poor water quality causes the mass mortality of the two endangered sucker species of Upper Klamath Lake and may also cause other, more subtle kinds of harm. The diagnosis and remediation of mechanisms leading to mass mortality or stress of fish require knowledge of the causal connections between human activity and poor water quality. Researchers working on both fish and water quality in the upper Klamath basin have worked out some causal connections (Table 3-2) but in other cases have not yet succeeded in establishing cause-effect relationships. There are two critical sets of causal connections related to water quality: (1) connection of human activity with high phytoplankton biomass and dominance of *Aphanizomenon* in Upper Klamath Lake, and (2) connection of high phytoplankton abundance with chemical conditions that could harm fish.

High phytoplankton biomass has, according to the hypothesis (external phosphorus-loading hypothesis) underlying the TMDL analysis of Boyd et al. (2001), occurred through augmentation of phosphorus loading of Upper Klamath Lake, mostly by nonpoint sources or through weakening of natural interception processes that occur in wetlands or riparian zones. There are, however, two major problems with this hypothesis (Figure 3-10). First, the anthropogenic augmentation of external loading is sufficient to account for only about 40% of the total load; the main factor accounting for very high phosphorus concentrations at present is internal loading rather than external loading. The pH-internal loading hypothesis proposes, however, a mechanism by which a 40% increase in external load could have produced a much larger increase in internal load. According to this line of thinking, the increase in external load raised the maximum algal abundances enough

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TABLE 3-2 Status of Various Hypotheses Related to Water Quality of Upper Klamath Lake

Hypothesis	Status
Algal abundance as measured by chlorophyll is positively related to total phosphorus in the water column	Well supported
Algal biomass as measured by chlorophyll is positively related to daytime pH	Well supported
Rate of early-spring development of biomass is positively related to rate of warming in the water column	Well supported
Rate of early-spring phytoplankton growth is inversely related to lake volume	Relationship weak or absent
Mean growing-season average algal biomass is inversely related to lake depth	Inconsistent with field data
Peak algal abundance is inversely related to lake depth	Inconsistent with field data
A large amount of phosphorus in the water column during the growing season originates in sediments (internal loading)	Well supported
pH is the main control on internal loading of phosphorus	Not resolved yet
Interception of anthropogenic phosphorus from the watershed will reduce algal abundance in the lake	Uncertain; unlikely
Lake water level is inversely related to pH	Inconsistent with field data

to increase the maximum pH during the growing season, which in turn greatly augmented internal loading by facilitating the desorption of phosphate from iron hydroxide floc on the sediment surface. It is also possible, however, that internal loading, which can occur by several mechanisms, always has been large enough to saturate algal demand, as suggested by the steady nature of internal loading beginning early in the growing season, before pH reaches its peak. A second weakness in the external phosphorus-loading hypothesis is that it fails to explain why *Aphanizomenon* has become dominant. Nutritional conditions seem to have been favorable for *Aphanizomenon* (or other nitrogen fixers) before land-use changes in the watershed because of an inherently low nitrogen:phosphorus ratio in the lake.

Because of the two major unresolved issues for the external phosphorus-loading hypothesis, alternate hypotheses are still worthy of consideration. One, shown in Figure 3-10, is based not on phosphorus enrichment, but rather on changes in the limnohumic acid content of the lake, which is likely to have been quite high in waters emanating from the extensive wetlands around Upper Klamath Lake. The hypothesis proposes that the basic cause of change in water quality of the lake is reduction in the supply of limnohumic acids to the lake, with a consequent increase in transparency or possibly even a decrease in inhibitory effects (toxicity of the acids to

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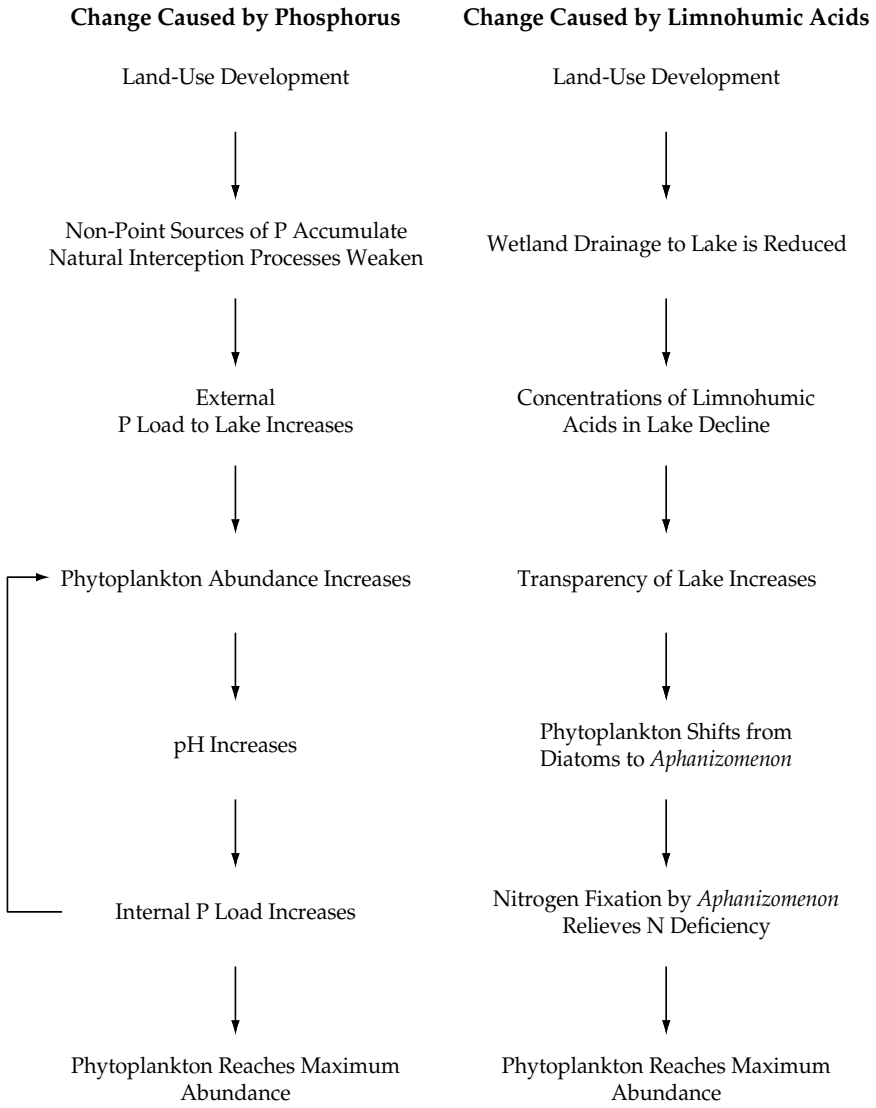


FIGURE 3-10 Two contrasting hypotheses that may explain connections between human activity and high abundances of phytoplankton in Upper Klamath Lake.

algae). Released from suppression by weak light availability or chemical inhibition, *Aphanizomenon* became more abundant in the lake. Unlike the diatoms that preceded it, *Aphanizomenon* was able to offset the low nitrogen:phosphorus ratio of the lake by nitrogen fixation, thus allowing

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algal growth for the first time to take full advantage of the abundant phosphorus supplies and produce the very high algal abundances that are now characteristic of the lake. The advantage of this hypothesis is that it accounts simultaneously for the change in community composition of phytoplankton and for an increase in biomass. The key factor causing major changes in the lake was, according to this hypothesis, drainage or hydrologic alteration of wetlands, rather than increase in external phosphorus loading.

Figure 3-11 shows causes leading from high algal abundance to water-quality conditions potentially harmful to fish. High abundance of phytoplankton produces high pH, which can be directly harmful to fish. Although the connection of phytoplankton abundance to high pH is well verified, the amount of harm to fish that it causes is still a matter of speculation. A second factor is episodic stratification of the water column, which leads to oxygen deficits in the bottom portion of the water column and appears to cause algal mortality. Mixing caused by windy weather brings oxygen-poor water to the surface, along with ammonia. The importance of ammonia in mass mortality is probably not great, but it could be harmful in more subtle ways to fish. Low oxygen that results from mixing probably is prolonged by algal death and probably is the main reason for mass mortality of fish.

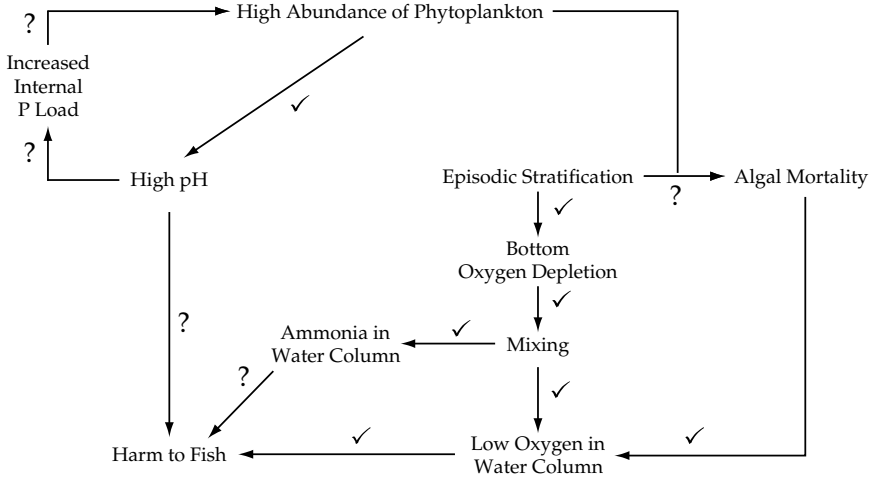


FIGURE 3-11 Potential (?) and demonstrated (√) causal connections between high abundance of phytoplankton and harm to fish through poor water-quality conditions.

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Potential for Improvement of Water Quality in Upper Klamath Lake

Two proposals have been made for actions that would improve the water quality of Upper Klamath Lake. Both presume, with substantial scientific support, that an improvement of water quality in Upper Klamath Lake will require suppression of algal abundance. The first proposal, which could be implemented immediately, is for maintenance of water levels in Upper Klamath Lake exceeding levels that have been characteristic of the recent historical past. The second proposal, which deals more with long-term improvement, is for reduction in the anthropogenic component of external phosphorus loading of Upper Klamath Lake.

Higher water levels have been proposed in recent biological opinions for operation of Upper Klamath Lake (USFWS 2001, 2002). USFWS makes a number of kinds of arguments for higher water levels, while noting that empirical evidence of a connection between lake level and water quality is "weak" (USFWS 2001, p. 51). One of the arguments is that higher water levels will improve water quality in Upper Klamath Lake. As shown by the preceding review of available evidence, there is no scientific support for the proposition that higher water levels correspond to better water quality in Upper Klamath Lake. For example, mean and maximum abundances of algae, which are the driving force behind poor water quality, show no indication of a relationship with water level. USFWS acknowledges that no relationship has yet been demonstrated, but it argues that a complex, multivariate relationship may exist but not yet be evident. For example, as noted by USFWS and others (Welch and Burke 2001), an effect of water level on water quality could be contingent on water-column stability, which in turn is under the influence of weather. Other multivariate relationships could be proposed that involve water level as one of several factors explaining the water-quality conditions in a given year. This line of argument leads to the conclusion that water-quality conditions may be explained in the future (after further study) by a suite of variables that include water level, but it also suggests that the influence of water level is too weak to be discerned without consideration of other variables.

The potential usefulness to management of a complex mechanism involving water level as a covariate would be low even if it could be demonstrated. Furthermore, the mode of influence of water level as one of a suite of variables affecting water quality would not necessarily work in the direction of water-quality improvement at higher water levels. For example, as indicated in the foregoing text, higher water level promotes water-column stability, which appears to be the principal means by which water-quality conditions for mass mortality develop in Upper Klamath Lake. All things considered, water level cannot now be managed with confidence for control of water quality.

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The second proposal, which is for long-term improvement of water quality through reduction in external phosphorus loading, has been favored by many and is the main recommendation related to water quality of Upper Klamath Lake in a recent TMDL analysis (Boyd et al. 2001). The proposal has three weaknesses: one related to the feasibility of intercepting substantial load, a second related to the internal-load effects of reducing external load, and a third involving the role of increased phosphorus loading in sustaining large algal populations under current conditions.

The TMDL proposal is for reduction of external phosphorus by about 40%. Because the current anthropogenic load is about 40% of the total, the proposal is to return the external phosphorus loading of Upper Klamath Lake to background conditions. Only about 1% of the anthropogenic loading is from point sources (wastewater treatment plants: Boyd et al. 2001). Interception of point-source loads is technically feasible, but interception of nonpoint-source loads, although approachable through best-management practices, is more problematic in that it would require major changes in agricultural practice and other types of land use. Even a reduction of 20% would be ambitious and potentially infeasible in view of the association between non-point sources and privately held lands.

Even a reduction of 40% in total external phosphorus loading would probably be ineffectual without suppression of internal phosphorus loading, given that internal phosphorus loading is very large for Upper Klamath Lake. The authors of the TMDL study have anticipated this problem. Invoking the pH-internal loading hypothesis as described above, they anticipate that a reduction in external loading will result in lower extremes of pH, which in turn will reduce internal loading, thus providing magnified benefits. This is a highly speculative proposition, however. Because soluble phosphorus is available in quantity even at the end of the growing season, it appears that internal loading is sufficient to supersaturate the needs of algae for phosphorus. Furthermore, a pH reduction, if it did occur, might or might not be sufficient to shut off internal loading related to high pH. Finally, high pH is only one mechanism by which phosphorus is mobilized from sediments; other mechanisms would remain as they are and could easily be sufficient to provide the internal loads necessary to generate the high phytoplankton biomass observed in the lake. Thus, reduction of external load as proposed in the TMDL document has results that are quite uncertain.

A third problem with the phosphorus-reduction strategy is that the high abundances of phytoplankton in Upper Klamath Lake may have not become established because of external phosphorus loading, but rather because of other changes in the lake. A drastic decrease in mobilization of limnohumic acid alteration of wetlands and hydrology, for example, fits historical observations more satisfactorily than a phosphorus-based hy-

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pothesis, given that Upper Klamath Lake apparently has always had the very low nitrogen:phosphorus ratios that set the stage for dominance by a nitrogen fixer, such as *Aphanizomenon*. The data suggest that other factors were holding back the nitrogen fixers and that human activity reversed or modified one of them, producing the current dominance of *Aphanizomenon*. *Aphanizomenon*, once established, could generate higher abundances than nonfixing algae because of its ability to offset nitrogen deficiency in the water. Thus, the key to improving water quality may be to suppress *Aphanizomenon*.

Restoration of limnohumic acids to the lake would be the most obvious way of restoring any beneficial effects that limnohumic acids might have had before land-use development of the upper Klamath basin watershed. Restoration of wetlands is under way and could increase transport of limnohumic acids to the lake. Although justified in large part by an attempt to intercept nutrients, these programs could have beneficial effects on limnohumic acid supply. One discouraging aspect of restoring limnohumic acid transport to the lake, however, is that many of the wetland sediments surrounding the lake that would have been perhaps the richest source of limnohumic acids have disappeared through oxidation after dewatering. Furthermore, restoration of limnohumic acid supply would require not just restoration of wetlands but also extensive rerouting of water through wetlands, with attendant loss of water through evapotranspiration. Nevertheless, this option is virtually unstudied and deserves more attention. It could be compatible with nutrient-removal strategies justified by improvements in water quality of streams.

Current proposals for improvement of water quality in Upper Klamath Lake, even if implemented fully, cannot be counted on to achieve the desired improvements in water quality. Thus, it would be unjustified to rely heavily on future improvements in the water quality of Upper Klamath Lake as a means of increasing the viability of the sucker populations.

Oxygenation as a Management Tool

The possibility that oxygenation of deep water could be used as a means of reducing mass mortality of endangered suckers in Upper Klamath Lake has been mentioned by USFWS in its biological opinion (2002; see also Martin 1997). An engineering study of the possibility is already available (Horne 2002). Because of the size of Upper Klamath Lake and the speed with which it can become anoxic toward the bottom of the water column during episodes of stratification, it is unlikely that oxygenation could be used in preventing low concentrations of dissolved oxygen from developing in the lower water column during stagnation or in restoring oxygen when the water column mixes at depressed oxygen concentrations.

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Even so, it is conceivable that oxygenation could be used in such a way as to provide specific refuge zones to which the endangered suckers would be attracted when they experience stress due to low dissolved oxygen. Of particular interest would be the adult suckers, which cluster in specific locations (USFWS 2002).

It is doubtful that the potential for aeration to reduce mass mortality of large suckers can be developed entirely from calculations and estimations. Pilot testing for proof of concept seems well justified for the near future. Potential success of this approach is uncertain, however, in that use of oxygenation specifically to create refugia in large lakes apparently does not appear in the literature on oxygenation.

CLEAR LAKE

Clear Lake was created in 1910 at the location of a smaller natural lake and associated marsh on the Lost River (Figure 3-12). One purpose for the creation of the reservoir was to allow storage of runoff for irrigation of lands below the dam. An additional purpose was to promote evaporative loss of water that otherwise would flow to Tule Lake and Lower Klamath Lake, which were intended for dewatering to allow agricultural development. In addition to high evaporative losses associated with its low mean depth, Clear Lake has extensive seepage losses.

Clear Lake is divided into east and west lobes that are separated by a ridge; the dam is on the east lobe. Willow Creek, a tributary of Clear Lake, is critical to the sucker populations, which appear to rely primarily or even exclusively on this tributary for spawning. The lands surrounding Clear Lake are not under intensive agricultural use. The area surrounding the reservoir consists primarily of Clear Lake National Wildlife Refuge, and the watershed above the lake is largely encompassed by the Modoc National Forest.

Although Clear Lake would store as much as 527,000 acre-ft at its maximum height, which corresponds to a lake area of 25,000 acres (USBR 2000a), its average area has been close to 21,000 acres, which corresponds to a storage of about 167,000 acre-ft and a mean depth of 8 ft (USBR 2002a, USBR 1994); it has never reached maximum storage. Average annual inflow is 117,000 acre-ft, which suggests a mean hydraulic residence time of 1–2 yr (computed from input and volume). Clear Lake is similar to Upper Klamath Lake in being shallow in relation to its area. It differs from Upper Klamath Lake in its considerably longer hydraulic residence time and its very low output of water relative to input. One other important feature, which has to do with water management, is the high interannual and interseasonal variation in storage volume of Clear Lake, which corresponds to great variations in area and mean depth (USBR 1994).

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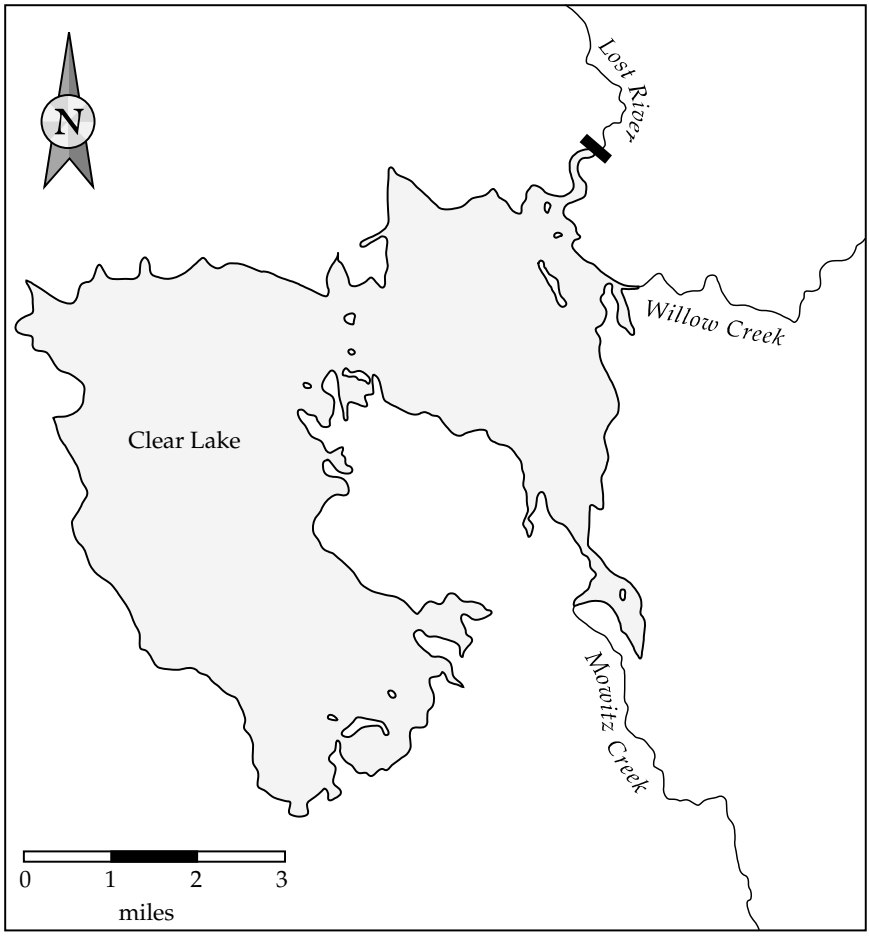


FIGURE 3-12 Map of Clear Lake.

Clear Lake contains both shortnose and Lost River suckers (USFWS 2002). Both species show evidence of stability and ecological success in Clear Lake, as indicated by diverse age structure and high abundance (USFWS 2002, USBR 1994; Chapter 5). Interannual variations in the welfare of the populations have been scrutinized, however, because of questions related to the maximum permissible drawdown of the reservoir in a dry year or in a succession of dry years. Monitoring of water quality and condition of fish in 1991–1995 provided a good opportunity to evaluate extreme drawdown because the water level in 1992 declined to its lowest point since the drought of the 1930s.

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Although water-quality records collected in 1991–1995 (USBR 1994, Hicks 2002) are useful, the breadth of information that is available for Clear Lake is much narrower than that of Upper Klamath Lake. Apparently, there has been no sampling for phytoplankton or for nutrients that would allow comparisons with Upper Klamath Lake. Observations suggest that Clear Lake has far lower population densities of phytoplankton than Upper Klamath Lake; there is no evidence of massive blooms of bluegreen algae, for example. Aquatic macrophytic vegetation like that found in Upper Klamath Lake is virtually absent from Clear Lake because of its wide range of water levels.

The water column of Clear Lake typically has a turbid appearance suggestive of fine inorganic particulate material that is continually suspended by wind-generated currents (USBR 1994). The transparency of the lake has been measured only sporadically. During 1992, when water levels were exceptionally low, Secchi depths ranged from 0.1 to 0.4 m, which indicated extremely low penetration of irradiance in the lake (M. Buettner, USBR, personal communication, 23 January 2003). In more typical years, transparency is low but not nearly at the extreme of 1992 (for example, June 1989, 0.4–1.5 m across 24 stations; M. Buettner, USBR, personal communication, 23 January 2003). Although Clear Lake is generally characterized as allowing less light penetration than Upper Klamath Lake, the scanty data on light penetration that are available suggest that the transparencies may fall within the same range for the two lakes (for example, see Kann 1998 for data on Upper Klamath Lake). Because transparency may be related to the welfare of sucker larvae through predation, which may be more pronounced in transparent waters, further study of this subject seems warranted.

In 1991–1995, recording sensors were used for measuring temperature, specific conductance, pH, and dissolved oxygen; vertical profiles also were taken for these variables. Although interpretation of the records is complicated by occasional malfunction of the sensors, which is characteristic of this type of data collection, the overall results are useful. The temperature record indicates that the lake is unstratified; if it does stratify, it does so only sporadically over the deepest water (near the dam). The pH varies seasonally but does not reach the extremes observed in Upper Klamath Lake, presumably because high rates of algal photosynthesis, the driving force behind extreme pH in Upper Klamath Lake, are not characteristic of Clear Lake (USBR 1994). The oxygen data indicate that the lake does not show episodes of strong oxygen depletion like those in Upper Klamath Lake. One incident of oxygen concentration as low as 1 mg/L near the dam apparently was associated with drainage of the east lobe of the reservoir during 1992 as the lake was drawn down to the extremes of that year. Monitoring under ice showed concentrations of oxygen near saturation,

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even during an interval of especially long ice cover during 1992, a year of very low water level (USBR 1994).

Mass mortality of suckers in Clear Lake is unknown. Loss of fish occurs through the dam but does not appear to be seriously decreasing the populations. The populations were studied for signs of stress during the dry year of 1992. Although mortality was not observed, there were several indicators of stress, including higher rates of parasitism and poor body condition. These indicators disappeared quickly as water levels climbed in 1993 at the end of the drought (USBR 1994). The indications of stress associated with water levels of 1992 have served as a basis of proposed thresholds of drawdown in Clear Lake (USFWS 2002).

The potential of Clear Lake to provide information about Upper Klamath Lake has not been well exploited. The agencies have invoked Clear Lake for comparative purposes in several instances, but the background information on the reservoir is not sufficiently broad and does not extend over sufficient intervals of time to allow good comparisons. Comparative population and environmental studies in the two lakes could open up new possibilities for diagnosing mechanisms that are adversely affecting endangered suckers in Upper Klamath Lake.

GERBER RESERVOIR

Gerber Reservoir was established on Miller Creek, a tributary of the Lost River, in 1925 (Figure 1-1). The lake can store as much as 94,000 acre-ft of water but often is substantially drawn down and shows considerable interannual and intraannual variability in volume, mean depth, and area (USBR 1994, 2002b). Nevertheless, characteristic depths of Gerber Reservoir probably are substantially greater than those of Upper Klamath Lake or Clear Lake. Statistics are not readily available, but the sampling record (USBR 2002b) suggests that in most years a substantial area of the lake would have water deeper than 15 ft. Extreme drawdown occurred in 1992, when the lake was reduced to less than 1% of its maximum volume (USBR 2002b). Even under those conditions, the water near the Gerber Reservoir dam was 15 ft deep.

As might be expected, given that it is smaller and deeper than Clear Lake or Upper Klamath Lake, Gerber Reservoir shows a tendency toward stability of thermal stratification, as indicated by loss of oxygen near the bottom during summer. Stability may be interrupted by mixing, and entrainment of water through the outlet may lead to a replacement of bottom waters, which could produce changes (oxygenation, warming) similar to those expected as a consequence of mixing.

Little information is available on the water quality of Gerber Reservoir. The lake appears to have less inorganic turbidity than Clear Lake, presum-

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ably because it is deeper and smaller. *Aphanizomenon flos-aquae* probably is present and apparently creates blooms but not to the same degree of Upper Klamath Lake (USFWS 2002). *Aphanizomenon* probably fares better in this reservoir than in Clear Lake because the latter has more suspended inorganic turbidity, which shades the water column.

Information on temperature, specific conductance, pH, and dissolved oxygen was collected for the first half of the 1990s by automated monitoring and occasional vertical profiles (USBR 2002b), as was the case for Clear Lake. The pH reaches higher extremes than in Clear Lake but is less extreme than in Upper Klamath Lake. This probably reflects a gradient of algal photosynthesis across the three lakes. Dissolved oxygen in Gerber Reservoir is substantially depleted in deep water both in summer and in winter, but without any obvious effect on fish. No episodes of mass mortality of the shortnose sucker, which occupies Gerber Reservoir, have been reported. During 1992, when drawdown of the lake was severe, the lake was aerated (USFWS 2002); sampling indicated that the fish had reached suboptimal body condition during the drought. Under other circumstances, the population appears to have been stable in that it has shown no indication of stress, has preserved a diversified age structure, and has been abundant. For reasons primarily having to do with water quality, the low water levels of 1992 serve as a guideline for setting thresholds to protect the fish from stress.

LOWER KLAMATH LAKE

Lower Klamath Lake has been reduced to a marshy remnant by dewatering. It has occasional connection to the Klamath River through which it appears to receive some recruitment of young suckers, but there is no adult population. Water quality apparently has not been studied in any systematic way. Development of an adult population is unlikely unless the depth of water can be increased, which would involve incursion of the boundaries of the lake onto lands that are used for agriculture. If the lake were deepened, water quality might be adequate for support of suckers.

TULE LAKE

Tule Lake historically was very large and capable of supporting, in conjunction with the Lost River, large populations of the shortnose and Lost River suckers (Chapter 5). It has been reduced to remnants as a means of allowing agricultural use of the surrounding lands. Water reaches Tule Lake from Upper Klamath Lake or from the Lost River drainage via irrigated lands or from Clear Lake or Gerber Reservoir. Water is removed

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from Tule Lake (now appropriately called Tule Lake Sumps) by Pump Station D (USBR 2000a).

There are two operational sumps at Tule Lake now: 1A and 1B. In the recent past, Sump 1B has been much less likely to hold adult suckers than Sump 1A; it is shallower and has shown a higher rate of sedimentation than Sump 1A. It also appears to have worse water quality than Sump 1A. Sump 1B is being manipulated by USFWS for increase of marshland in the Tule Lake basin.

Some water-quality information is available on Tule Lake through monitoring during the 1990s (USBR 2001a) and fish have been sampled (Chapters 5 and 6). It appears that the sucker population consists of a few hundred individuals, including shortnose and Lost River suckers, and that these favor specific portions of Sump 1A (the "doughnut hole" or a location in the northwest corner) that presumably provide more favorable conditions than the surrounding area. Monitoring of Sump 1A has not shown any incidence of strongly decreased oxygen concentrations or extremely high pH, as would be the case in Upper Klamath Lake (USBR 2001a). These adverse conditions may occur in Sump 1B, however. The fish of Tule Lake, although not very abundant, appear to be in excellent body condition, and this suggests they are not experiencing stress.

Suckers migrate from Tule Lake Sumps; migration terminates on the Lost River at the Anderson Rose Diversion Dam (USFWS 2002, Appendix C), in the vicinity of which spawning is known to occur. Water-quality conditions there for spawning appear to be acceptable (USBR 2001a). Larvae are produced but apparently are not passing into the subadult and adult stages.

From the water-quality perspective, it appears that the Tule Lake population is potentially closer to survival conditions than the Upper Klamath Lake population. An unresolved mystery, however, is the fate of larvae. It is not clear whether water quality prevents the larvae from maturing, or if other factors are responsible for their loss.

Sedimentation threatens the apparently good conditions for adults in Sump 1A. Without aggressive management, the favorable portion of Sump 1A may become progressively less favorable in the future.

RESERVOIRS OF THE MAIN STEM

There are five main-stem reservoirs (Table 3-1); because Copco 2 is extremely small, it generally does not receive independent consideration. The composite residence time of water in the main-stem reservoirs, which extend about 64 mi from Link River Dam to Iron Gate Dam, averages about 1 mo. At moderately low flow (for example, 1,000 cfs), hydraulic residence time is close to 2 mo; and at moderately high flow (such as 6,000

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cfs), it is close to 10 days. Thus, some of the processes that would make these lakes distinctive from each other and from their source waters are not expressed because of the relatively rapid movement of water through the system.

The main source of water for the main-stem reservoirs is Upper Klamath Lake, but it is not the only source. Agricultural returns and drainage water enter the system upstream of the Keno Dam (Figure 1-2) by way of the Klamath Strait Drain (about 400 cfs, summer) and the Lost River Channel (about 200–1,500 cfs, fall and winter). In addition, cold springs provide about 225 cfs all year at a point just below the J.C. Boyle Dam; and two tributaries, Spencer Creek and Shovel Creek, provide 30–300 cfs to J.C. Boyle Reservoir and Copco Reservoir. Fall Creek and Jenny Creek provide 60–600 cfs to Iron Gate Reservoir. During the wet months, sources other than the Link River, which brings water from Upper Klamath Lake, provide about one-third of the total flow reaching Iron Gate Dam; in midsummer, these sources may account for up to 50% of the total water reaching Iron Gate Dam (PacifiCorp 2000, Figure 2-7). Thus, source waters of diverse quality influence the quality of water in the reservoirs. The waters of Upper Klamath Lake often bring large amounts of algal biomass to the upper end of the system, along with large amounts of soluble and total phosphorus. When Upper Klamath Lake is experiencing senescence of its algal population, the entering waters also may have low concentrations of dissolved oxygen and an abundance of decomposing organic matter. Irrigation tailwater and other drainage would carry abundant nutrients and could carry organic matter but would probably lack substantial amounts of algae. Spring waters and tributary waters would be the coolest and cleanest of the water sources.

The reservoirs differ physically in several ways that are likely to influence water quality. Keno Reservoir and J.C. Boyle Reservoir are shallow and have the lowest hydraulic residence times. Physically, they resemble rivers more than lakes. In each, the water is pooled at the lower end and may run swiftly at the upper end, thus potentially benefiting from reaeration (gas exchange). The two lower reservoirs are much deeper and have hydraulic residence times that are short on an absolute scale but much longer than those of the two upper reservoirs.

None of the reservoirs has very deep withdrawal. Thus, for the two reservoirs that support stable stratification (Copco and Iron Gate), withdrawals reflect the characteristics mostly of epilimnetic (surface) water, although their withdrawal cone may extend a short distance into the hypolimnetic (deep) zone at times (Deas 2000). For example, the temperature of water leaving Iron Gate Dam during midsummer, when the hypolimnion has a temperature of about 6°C, reaches 22–23°C (PacifiCorp 2000, Figure 4-5; Deas 2000, Figure 6.5) because the powerhouse withdrawal is at about

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12 m depth when the lake is full. For Copco, withdrawal is at about 6 m when the lake is full. Thus, cold hypolimnetic water of the two deepest reservoirs tends to be much more static hydraulically than the upper water column during the stratification season, as would be the case in a natural lake of similar depth; the main withdrawal occurs by way of the epilimnion. A small withdrawal (about 50 cfs) for the Iron Gate Hatchery does occur from the hypolimnion at Iron Gate Reservoir, however.

The quality of water in the reservoirs and leaving the reservoir system has been studied many times by numerous parties dating back to the 1970s. PacifiCorp has sponsored a number of studies in conjunction with its Federal Energy Regulatory Commission (FERC) licensing and other regulatory requirements, and USBR has sponsored studies of water quality because of its oversight responsibilities for the Klamath Project. The city of Klamath Falls has also studied water quality, particularly in the upper end of the system, and the Oregon Department of Environmental Quality has studied and analyzed water quality from the viewpoint of fisheries. Other information is available from the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the North Coast Regional Water Quality Control Board. In its consultation document on FERC relicensing, PacifiCorp (2000) provides an overview of the monitoring programs.

Monitoring to date provides useful information but shows several deficiencies. Most of the monitoring has been limited to water-quality variables that can be measured with meters (temperature, pH, specific conductance, and dissolved oxygen). There is much less information on nutrients, total phytoplankton abundance, phytoplankton composition, total organic matter, and other important variables. Thus, interpretations are necessarily limited in scope. Also, there have been few efforts to synthesize and interpret the data, most of which exist merely as archives. Hanna and Campbell (2000) have modeled temperature and dissolved oxygen in the reservoirs. The temperature modeling is useful for planning, but the oxygen modeling fails to incorporate primary production, which could be important. Deas (2000) has done extensive modeling for Iron Gate Reservoir that is especially useful for temperature and dissolved oxygen. A full, system-level understanding of the reservoirs is not yet available, however.

During the cool months (October or November through May), all the lakes are isothermal and appear to mix with sufficient vigor to remain almost uniform chemically (see, for example, Figure 3-13). During the warm season, there may be substantial differences in temperature and water quality with depth. Keno Reservoir and J.C. Boyle Reservoir are not deep enough to sustain thermal stratification during summer. They may stabilize briefly, however, in which case oxygen may be depleted from deep water (see Figure 3-14), but such depletions probably are interrupted by episodes of mixing. Copco and Iron Gate reservoirs, in contrast, stratify

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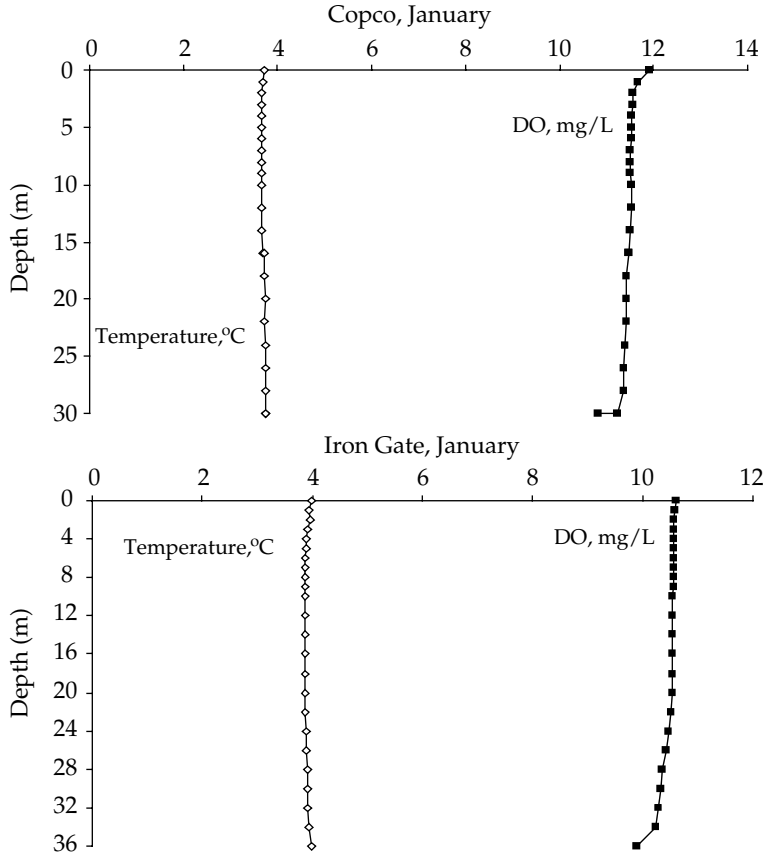


FIGURE 3-13 Water temperature and dissolved oxygen (DO) in Copco and Iron Gate Reservoirs, January 2000. Source: Data from USBR 2003.

stably on a seasonal basis. Thus, the water near the bottom of these two reservoirs can be classified as hypolimnetic and has a much lower temperature than that of the upper water column. As expected, oxygen is depleted in the hypolimnion of both lakes. Although the rate of oxygen depletion varies across years (Deas 2000), both reservoirs apparently have an anoxic hypolimnion for as much as 4 or 5 mo beginning in the last half of summer.

Periodic episodes of severe oxygen depletion may occur in the upper two reservoirs. One such event appears to have occurred in 2001, when the entire water column of Keno Reservoir became hypoxic or anoxic (Figure 3-15). It is not known how often such an event occurs. Because no mass mortality of fish in the reservoirs have been recorded, it is possible that the

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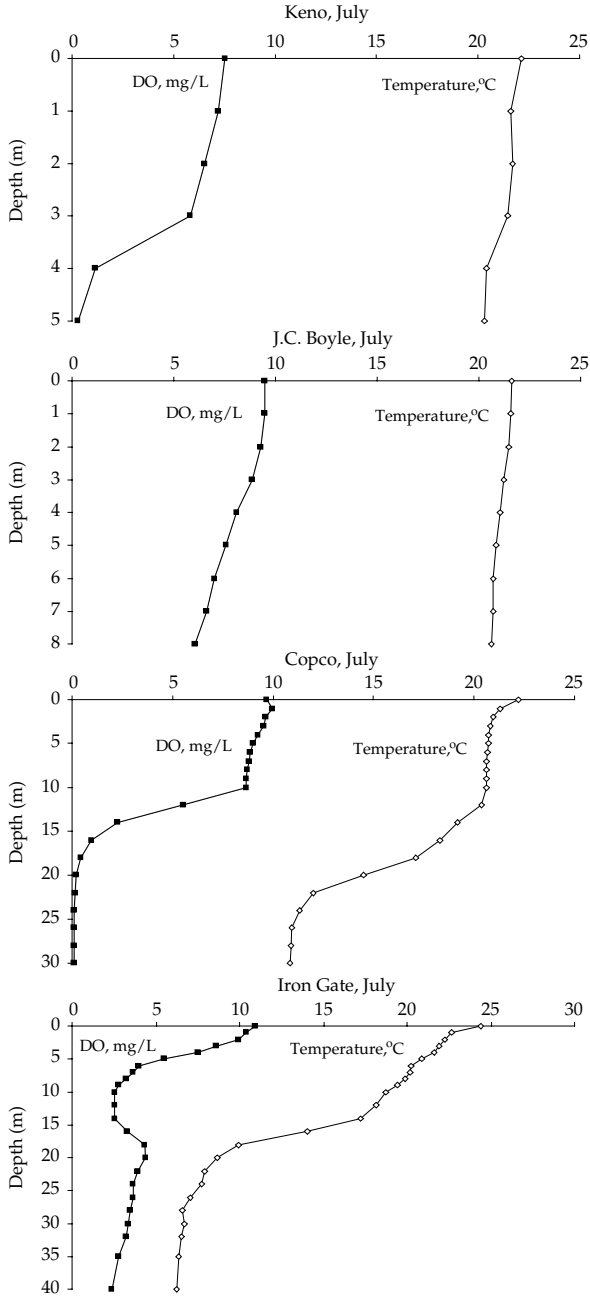


FIGURE 3-14 Water temperature and dissolved oxygen (DO) in all main-stem reservoirs, July 2000. Source: Data from USBR 2003.

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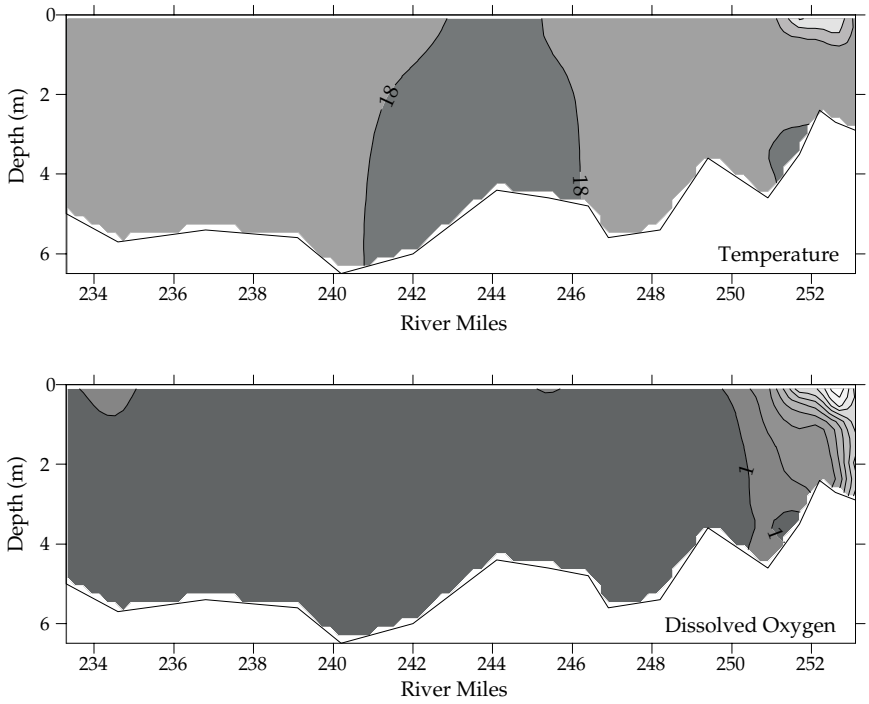


FIGURE 3-15 Longitudinal transect data on Keno Reservoir (Lake Ewauna), 13–14 August 2001. Isolines indicate temperature at 1°C intervals (top panel, increasing from 18°C) and dissolved oxygen at intervals of 1 mg/L (bottom panel, increasing from 1 mg/L). Darker tones indicate lower temperature or lower dissolved oxygen; the darkest zone on the bottom panel indicates concentrations of dissolved oxygen below 1 mg/L (i.e., without or almost without oxygen). Source: Data from USBR.

fish under these circumstances seek inflowing water of high oxygen concentration to sustain them until the episode dissipates.

Although the reservoirs receive abundant supplies of algae from Upper Klamath Lake, they do not appear to sustain such high rates of algal growth as Upper Klamath Lake, as indicated by comparisons of pH. Upper Klamath Lake shows extremes of pH extending above 10, but such extremes are not characteristic of the reservoirs. For example, monitoring of Copco, Iron Gate, and J.C. Boyle reservoirs in 1996–1998 by PacifiCorp showed the highest pH to be about 10.0, and even this was quite unusual (PacifiCorp 2000, Figure 4-10). More recent data are similar in this respect (Table 3-3).

Concentrations of phosphorus (means) tend to be about the same in the main-stem reservoirs as in Upper Klamath Lake. There is ample phos-

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TABLE 3-3 Summary of Grab-Sample Data for Surface Waters in the Main-Stem Reservoir System, 2001[a]

			Concentration, µg/L					
							Chlorophyll *a*	
Location		pH	NH_4^+–N	NO_3^-–N	SRP	Total P[b]	2001	2000
Keno (1 m)	Mean	7.50	1,080	80	160	390	62	—
	Max	8.82	1,220	90	240	730	—	—
J.C. Boyle (1 m)	Mean	7.31	190	1,120	250	260	50	5
	Max	7.86	260	1,760	290	450	—	20
Copco (1 m)	Mean	7.91	90	620	150	280	5	10
	Max	8.90	130	880	220	560	—	31
Iron Gate (1 m)	Mean	8.28	260	370	160	180	5	11
	Max	9.45	260	630	280	410	—	46
Below Iron	Mean	7.87	80	980	170	190	4	—
Gate (0.5 m)	Max	8.68	90	1,710	210	360	—	—

[a]N = 4 in most cases (monthly, June–September); N = 1 for chlorophyll in 2001 (July); additional chlorophyll data for 2000 (N = 6) are shown for three of the reservoirs. Chlorophyll shown at concentrations below about 20 µg/L is only a rough approximation because of limitations on analytical sensitivity.
[b]Total P less than SRP (soluble reactive P) for some dates.
Sources: USBR 2003; PacifiCorp, unpublished data, 2001.

phorus in available form for stimulation of phytoplankton growth, but it is not clear whether a net accumulation or a net loss of phytoplankton biomass occurs in the reservoirs because information on phytoplankton biomass shows some internal inconsistencies. Observations from the field suggest that substantial blooms of *Aphanizomenon* occur in both Copco and Iron Gate reservoirs (USFWS 2002). This would not be surprising, given the strong seeding of these reservoirs with *Aphanizomenon* from Upper Klamath Lake and the presence of large amounts of nutrients. Although the residence times for the two large reservoirs are not great enough to allow the establishment of large populations of algae starting from a very small inoculum, a large inoculum could double several times over the duration of residence in the two reservoirs and thus generate a bloom. Alternatively, a bloom could simply be transferred from Upper Klamath Lake. The difficulty with the observations, however, is that they are not confirmed by monitoring data in 2000 and 2001. For both of those years, analysis of chlorophyll *a* showed abundances of algae ranging from low to high but not extreme in the sense of Upper Klamath Lake (Table 3-3). There are several possible explanations. Field reports might be biased by appearance of some algae at the surface while underlying populations are not extraordinarily high. There could be something wrong

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with the chlorophyll analyses, or perhaps large blooms occur very seldom. These matters are unresolved.

One special concern with respect to coho salmon and other salmonids in the Klamath River main stem is the condition of water as it leaves Iron Gate Dam. Oxygen concentrations below Iron Gate Dam are seasonally below saturation but generally exceed 75% of saturation (Deas 2000), have a temperature that reflects surface waters in the lakes, and have lower concentrations of nutrients and algae than would be typical of Upper Klamath Lake. Because there is some question about the consistency of data on algae, however, no firm conclusions are possible about the export of *Aphanizomenon* to the main stem via Iron Gate Dam.

It appears that the upper two reservoirs have the poorest water quality, as judged from concentrations of nutrients and dissolved oxygen. The two lower reservoirs, although they develop anoxia in deep waters during summer, maintain better water quality than the upper two reservoirs in their surface waters. The major question of *Aphanizomenon* blooms in the system seems unresolved because of internal inconsistencies in the data. In general, the water-quality environment seems to be comparable with or slightly better than that of Upper Klamath Lake in the two upper reservoirs, which may have very low dissolved oxygen but do not seem to have the pH extremes that Upper Klamath Lake does. The two lower reservoirs appear to have better quality overall than the two upper reservoirs, although their deep waters are essentially uninhabitable for fish during the summer months because of their lack of oxygen. More synthetic work on the reservoirs is needed.

CONCLUSIONS

1. Water-quality conditions in Upper Klamath Lake are harmful to the endangered suckers. Mass mortality of large fish is caused by episodes of low dissolved oxygen throughout the water column. Very high pH and high concentrations of ammonia, although more transitory than the episodes of low dissolved oxygen, may be important agents of stress that affect the health and body condition of the fish.

2. Poor water quality in Upper Klamath Lake is caused by very high abundances of phytoplankton, which is dominated by *Aphanizomenon flos-aquae*, a nitrogen fixer. Suppression of the abundance of *Aphanizomenon* is essential to the improvement of water quality.

3. Very high abundance of *Aphanizomenon* in Upper Klamath Lake is almost certainly caused by human activities, but mechanisms are not clear. One hypothesis is that increased algal abundance has occurred because of an increase in phosphorus loading in the lake. An alternative hypothesis, which is more consistent with the shift in dominance to *Aphanizomenon*

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and with the naturally rich nutrient supply of phosphorus to the lake, is that loss of wetlands and hydrologic alterations have greatly reduced the supply of limnohumic acids to the lake. According to this untested hypothesis, loss of limnohumic acids greatly increased the transparency and may also have reduced inhibitory effects caused by the limnohumic acids. These changes allowed *Aphanizomenon* to replace diatoms as dominants in the phytoplankton. Total phytoplankton abundance then increased because of the ability of *Aphanizomenon* to offset nitrogen depletion by nitrogen fixation, which diatoms could not do.

4. Substantial evidence indicates that adverse water-quality conditions are not related to water level. Further study extended over many years may ultimately show multivariate relationships that involve water level. Control of water quality in Upper Klamath Lake by management of water level, within the range of lake levels observed during the 1990s, has no scientific basis at present.

5. Suppression of algal abundance in Upper Klamath Lake could involve drastic reduction in external phosphorus load or reintroduction of a substantial limnohumic acid supply, depending on the mechanism by which *Aphanizomenon* has become dominant. Both of these remedial actions, if undertaken on a scale sufficient to suppress the abundance of *Aphanizomenon,* could be achieved only over a period of many years and could prove to be entirely infeasible.

6. Because remediation of water quality in the near term seems very unlikely, recovery plans for the endangered suckers in the near term must take into account the potential for continued mass mortality of suckers.

7. Use of compressed air or oxygen to offset oxygen depletion near the bottom of Upper Klamath Lake has been suggested as a means of moderating mass mortality of adult suckers. Such a technique cannot be expected to offset oxygen depletion throughout the lake, but it has some potential to provide refuge zones. The endangered suckers may be particularly well suited for this type of treatment because the large suckers, which are susceptible to mass mortality, congregate in known locations.

8. Researchers have provided a great deal of useful information related to water quality of Upper Klamath Lake. Needs for additional information include studies designed to show the mechanism for *Aphanizomenon* death; physical studies, including continuous monitoring of temperature and oxygen and associated analytical and modeling work, that demonstrate more definitively the mechanisms that promote alternation of stratification and destratification during the growing season for the lake; studies of the effects of limnohumic acids on *Aphanizomenon* and of the former limnohumic acid supply to the lake; studies of diel pH cycling in the lake; and studies of water quality under ice.

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9. Clear Lake and Gerber Reservoir lack extremes of pH, oxygen depletion, and algal blooms that occur in Upper Klamath Lake. Better water quality, in combination with other favorable factors given in more detail in Chapters 5 and 6, appear to explain steady recruitment, diverse age structure, and good body condition of these populations. Deterioration of body condition of the listed suckers at a time of extreme drawdown provide a rationale for the lower allowable thresholds of water level in these lakes. The lakes and their tributary spawning areas have exceptional value for protection against loss of the two endangered sucker species. Additional studies of limnological variables (and those of fish populations) have special value for use in comparison with water quality and population characteristics of suckers in Upper Klamath Lake.

10. Tule Lake, which supports suckers in good body condition but does not show evidence of successful recruitment, may have water quality that would allow recovery of this subpopulation if problems involving spawning habitat and larval survival were resolved. Lower Klamath Lake, which now lacks adult suckers, might well support a sucker population if water levels were raised.

11. Of the four major main-stem reservoirs, Keno and J.C. Boyle appear to have the poorest water quality because they are shallow, have the strongest influence from Upper Klamath Lake, and show the least benefit of dilution by waters entering from other sources. Copco and Iron Gate reservoirs have better water quality but develop anoxia in hypolimnetic waters during summer. Water released to the Klamath main stem from Iron Gate Dam often is below 100% saturation with oxygen but seldom less than 75% of saturation and may be excessively warm in summer for salmonids because it is drawn mostly from the epilimnion. Algal populations in Iron Gate Reservoir appear not to reach the extremes that are typical of Upper Klamath Lake.

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4

Current and Historical Status of River and Stream Ecosystems

Aquatic ecosystems of the Klamath River basin have been extensively modified by human activities that have changed hydrology and channel morphology, increased fluxes of nutrients, increased erosion, introduced exotic species, and changed water temperatures. Efforts at restoration of declining native species need to recognize the unique characteristics of various portions of the basin in the current context of land use and human activities. This chapter considers the major streams and rivers of the Klamath basin and analyzes anthropogenic changes in conditions that affect especially the coho salmon and endangered suckers but also other fishes and aquatic life generally. Each section of this chapter considers either a specific section of the main-stem Klamath River or of its tributaries; locations are designated in river mi (RM) from the ocean.

TRIBUTARIES TO UPPER KLAMATH LAKE (RM 337-270)

Streams and rivers above Upper Klamath Lake are a source of nutrients to the lake and provide spawning and larval habitat for endangered suckers. The main sources of surface water for Upper Klamath Lake are the Williamson, Sprague, and Wood rivers (Kann and Walker 2001; Chapter 2). Groundwater and direct precipitation account for most of the balance of inflow.

For Upper Klamath Lake, external loading of phosphorus, a key nutrient that promotes algal blooms (Chapter 3), comes primarily from the Williamson, Sprague, and Wood drainages. Geologic features of this region

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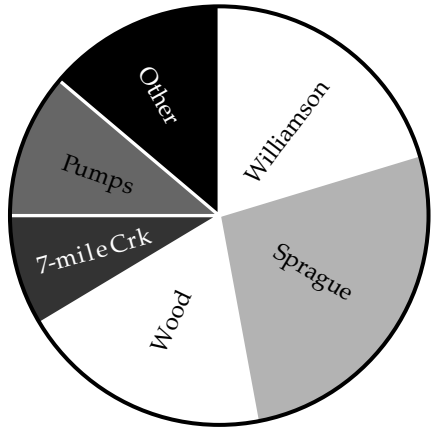


FIGURE 4-1 Relative external phosphorus loading from tributaries and other sources to Upper Klamath Lake. Source: Data from Kann and Walker 2001.

cause its streams and rivers to carry naturally high phosphorus loads (Chapter 3). Background concentrations of phosphorus, however, are augmented by human activity related to land use and river modifications. The Williamson and Sprague watersheds contribute 86 metric tons of phosphorus to Upper Klamath Lake per year (Kann and Walker 2001). The Williamson accounts for 21% of the total load, and the Sprague accounts for 27% (Figure 4-1).

Recent changes in hydrology may have affected total nutrient loading of Upper Klamath Lake. Annual runoff from the Williamson and Sprague drainages increased from the period 1922–1950 to the period 1951–1996 (Risley and Laenen 1999). The cause of the change is uncertain, but it is independent of climatic variability and probably is related to a combination of river channelization, reduction in area of wetlands, timber harvest, and other factors that reduce evapotranspiration in the watershed (Risley and Laenen 1999). Increased flows from the Williamson and Sprague drainages, coupled with current land-use practices, probably have increased phosphorus transport within the basin through greater erosion that leads to higher transport of suspended sediments, which carry phosphorus. Estimates of sedimentation rates from cores taken in Upper Klamath Lake support the hypothesis that transport of sediments from the watershed has increased in recent decades (Eilers et al. 2001).

Although its watershed is much smaller than that of the Williamson River, the Wood River is an important phosphorus source and has a high export of phosphorus per unit area of watershed (Figure 4-1). The balance

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of the phosphorus load to Upper Klamath Lake comes from Seven Mile Creek, agricultural pumps, and miscellaneous sources. Virtually all of this phosphorus is from nonpoint sources, including both natural and anthropogenic components.

Rivers and streams above Upper Klamath Lake support populations of cold-water fishes, including Klamath redband and bull trout (Chapter 5). During summer, temperatures can be undesirably high for these fishes in many stream reaches. For example, one threshold temperature that is used by government agencies to assess suitable rearing habitat for cold-water fishes is 17.8°C. The Williamson and especially the Sprague during late summer exceed this temperature (Boyd et al. 2001). In addition, concentrations of dissolved oxygen in the main stem of the Sprague River (mouth to junction of the North and South Forks) fall below Environmental Protection Agency water-quality targets (Boyd et al. 2002). Modeling indicates that restoration of riparian vegetation potentially could reduce temperatures in the Sprague through shading (Boyd et al. 2002), and also could have a beneficial effect on oxygen concentrations because water holds more dissolved oxygen at low temperatures than at high temperatures. In addition, shading could reduce the accumulation of algae and rooted aquatic plants on the sides and beds of tributaries. Plants produce oxygen through photosynthesis and thereby potentially increased concentrations of dissolved oxygen during the day, but nocturnal respiration and the degradation of accumulations of nonliving organic matter that they produce can cause oxygen depletion. Hence, temperature management via restoration of shading may help to alleviate a number of water-quality problems. Water-quality problems in the streams are less likely to affect endangered suckers than some of the other native fishes, however (Chapter 5).

Efforts are under way to restore wetlands associated with the Williamson, Wood, and Sprague rivers. The rationale for the projects is to restore wetland-river connections that promote such processes as nutrient trapping and sediment retention, to provide habitat for young fish, and to damp variations in river flow. Wetlands are sources of dissolved organic matter and tend to enrich water with complex humic compounds that may be related to changes in the composition of phytoplankton blooms observed in Upper Klamath Lake (Chapter 3).

THE LOST RIVER

The Lost River main stem (Figure 1-3) was an important spawning site for suckers and supported a major fishery, but few suckers use the river now (Chapter 5). Water that historically would have entered the Lost River from October to April is held back by Gerber and Clear Lake dams; summer flows are reduced by withdrawals and are dominated by irrigation

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tailwater. Free interchange of water and fish with the Klamath main stem is blocked in various ways. Not surprisingly, water quality of the Lost River is poor throughout the year, as indicated by low oxygen concentrations and high concentrations of suspended solids (Shively et al. 2000a, USFWS 2001), and physical habitat is greatly changed from its original state. The Lost River is now so degraded that restoration of conditions suitable for sucker spawning seems unlikely unless land-use or water-management practices change.

THE MAIN-STEM KLAMATH: IRON GATE DAM TO ORLEANS (RM 192-60)

Below Iron Gate Dam, the Klamath River runs unobstructed to the ocean. Alterations in flow and high temperatures make conditions in the main-stem Klamath less suitable than was the case historically for salmonids that use the river for spawning, rearing, and migration (Chapter 7). Four major tributaries (the Shasta, Scott, Salmon, and Trinity rivers) enter the Klamath main stem below Iron Gate Dam. These are considered in detail below.

The effect of management on the annual cycle of water flow has been the subject of considerable research on historical flows in the main stem. Before the creation of the Klamath Project and other modifications of flow, the Klamath River had a relatively smooth annual hydrograph with high flows in winter and spring that declined gradually during summer and recovered in fall. This pattern reflects the seasonal cycle of winter rainfall and spring rainfall and snowmelt in the basin (Risley and Laenen 1999). There is still an annual cycle, but its magnitude and seasonal dynamics have changed (Hardy and Addley 2001).

Figure 4-2 illustrates hydrologic change on the basis of a comparison of mean monthly flows for the periods 1905–1912 (pre-project) and 1961–1996 (post-project). Data on the earlier period are estimates based on measured discharges at the Keno gaging site extrapolated to discharges for the Iron Gate Dam site; data on the later period are based on direct measurements at the Iron Gate Dam (for methods, see USGS, Fort Collins, CO, unpublished material, 1995; Balance Hydrologics 1996; Hardy and Addley 2001). Flows over the period 1905–1912 have been adjusted to correct for the above-average precipitation that occurred then.

Post-project flows exhibit a shift in peak annual runoff from a mean maximum centered on April to a mean maximum centered on March (Figure 4-2). The later recession in spring flows extends to mean minimum flows lower than the historical minimums. Low-flow conditions during summer are more prolonged than they were before the project was built. The same analyses indicate that post-project flows during fall are slightly

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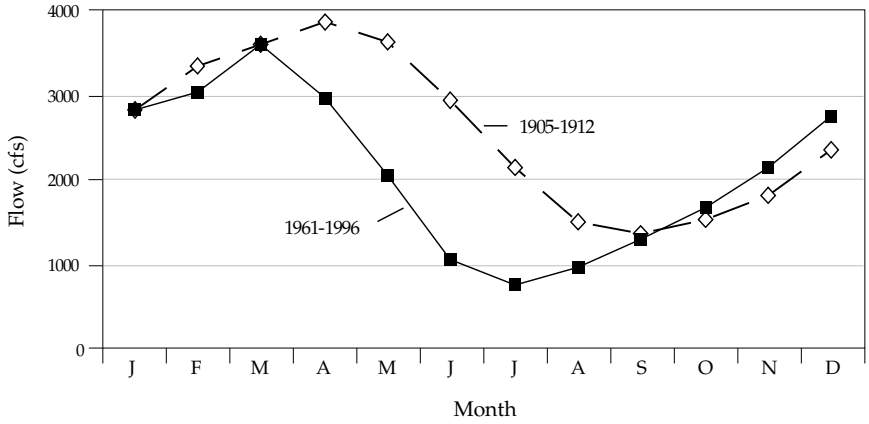


FIGURE 4-2 Mean monthly flows at Iron Gate Dam in 1961–1996 compared with reconstructed flows for 1905–1912. Source: Data from Hardy and Addley 2001.

higher than pre-project flows. The annual volume of flow from the upper Klamath basin is probably reduced. Estimated average annual runoff at the Iron Gate Dam site has declined by about 370,000 acre-ft since the construction of the Klamath Project (Balance Hydrologics 1996), as might be expected in view of the amount of water that is used for irrigation above Iron Gate Dam (Table 1-1). The magnitude of the change in water yield is a matter of dispute among groups concerned with water use in the upper basin. Nevertheless, there is no doubt that changes in seasonality of flow and at least some change in water yield have occurred since the full development of the Klamath Project.

As noted by the U.S. Geological Survey (USGS, Fort Collins, Colorado, unpublished material 1995) in its review of the hydrology of the Klamath River, the changes in flow below Iron Gate Dam are attributable to water-management practices in the upper and lower Klamath basin. The shift toward an earlier peak in annual runoff appears to be associated with increased flows in the Klamath River from the Lost River diversions and the loss of seasonal hydrologic buffering that originally was associated with overflow into Lower Klamath Lake and Tule Lake. The persistent low-flow conditions that occur in summer below Iron Gate Dam reflect irrigation demand in the Klamath Project and other parts of the upper Klamath basin and irrigation diversions on the Scott and Shasta rivers and other tributaries (discussion below).

Release of water from Iron Gate Dam has both direct and indirect effects on water temperature in the Klamath River. The magnitude of these effects depends on three principal factors: the temperature of the water as it

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is released from the dam, the volume of the release, and the meteorological conditions. The temperature of water released from Iron Gate Dam varies seasonally; a peak at about 22°C (+/– 2°C) occurs in August (Figure 4-3). In summer, the volume of flow exerts substantial control over the rate of daytime warming and nocturnal cooling. Low flows have long transit times and thus show greater change per unit distance. For example, a 500-cfs release takes 2.5 days to reach Seiad Valley, a distance of about 60 river mi, whereas a 1,000-cfs release moves the same distance in 2 days and a 3,000-

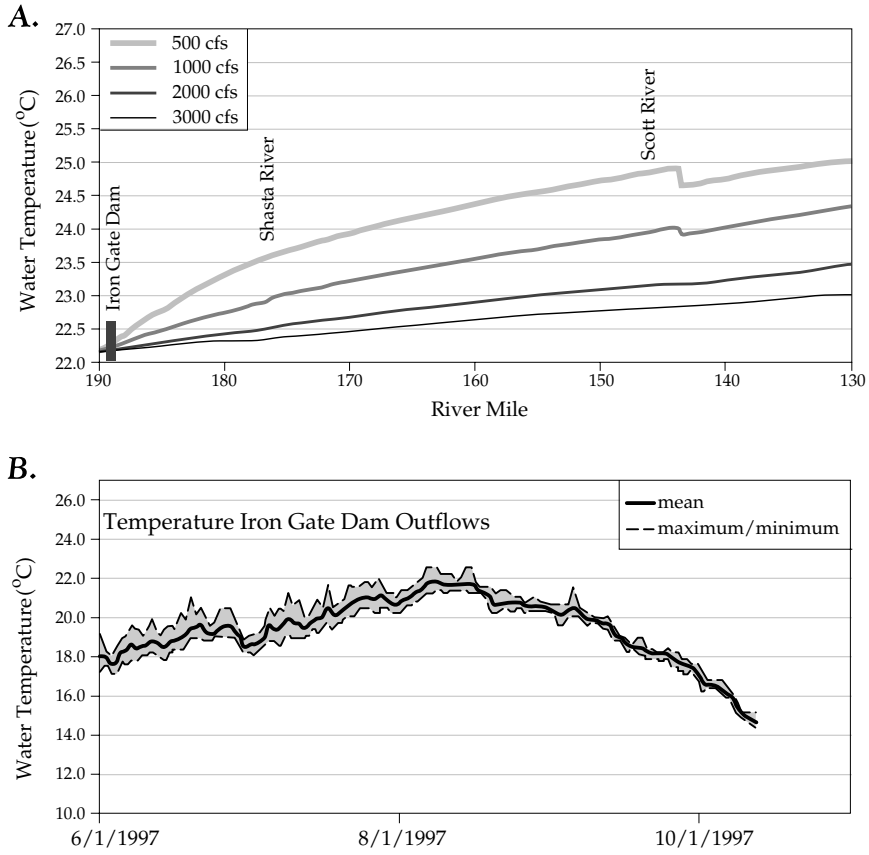


FIGURE 4-3 Simulated and measured temperature in the Klamath River below Iron Gate Dam. A) Simulated daily mean temperatures from Iron Gate Dam to Seiad Valley for flows of 500–3,000 cfs for conditions in August. B) Measured temperature of releases from Iron Gate Dam, June–October 1997. Note the minor diel change in temperature during the warmest summer releases. Source: Deas 2000. Reprinted with permission from the author; copyright 2000, University of California Press.

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cfs release does so in 1.25 days (Deas 2000). Warming and cooling per unit distance are reduced by short transit time and by greater depth. Higher flows extend the reach of river below Iron Gate Dam that supports lower mean water temperatures (Figure 4-4), but also may result in higher daily minimum temperatures over a portion of the reach below Iron Gate Dam (see below).

Increased releases from Iron Gate Dam may benefit coho salmon (Hardy and Addley 2001, NMFS 2001). The potential benefit from the releases is

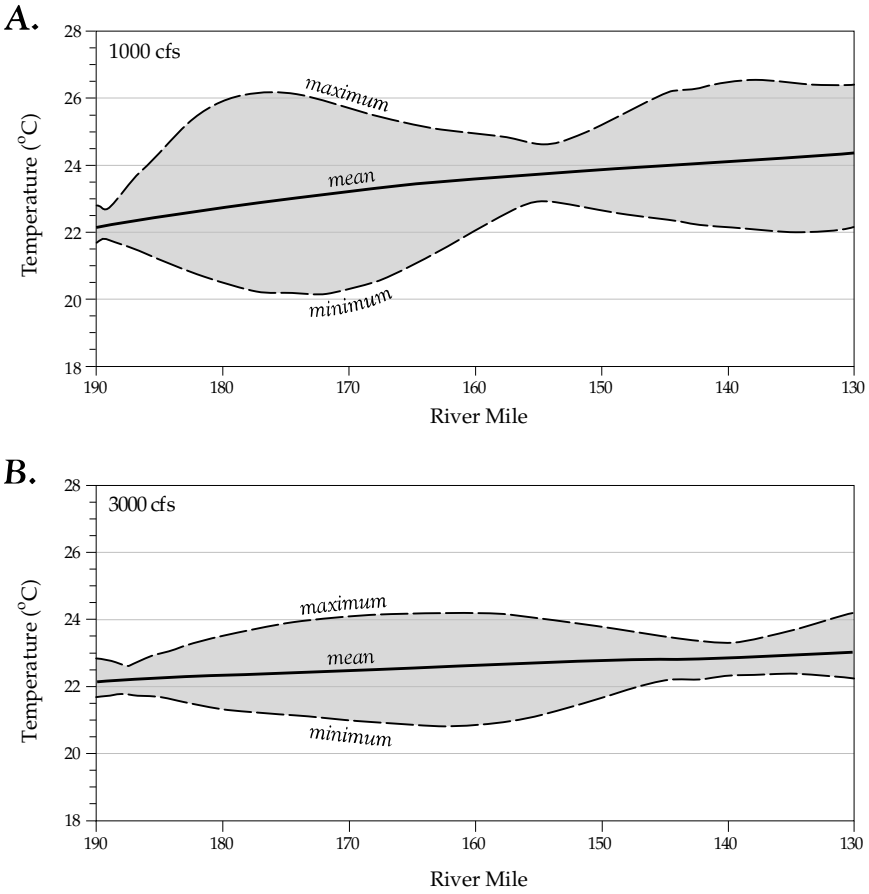


FIGURE 4-4 Simulated daily maximum, mean, and minimum water temperatures on the Klamath River from Iron Gate Dam to Seiad Valley for Iron Gate Dam releases of 1,000 cfs (A) and 3,000 cfs (B) under meteorological conditions of August 14, 1996. Source: Deas 2000. Reprinted with permission from the author; copyright 2000, University of California Press.

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confounded, however, by relationships between minimum, mean, and maximum temperatures. For example, water released from Iron Gate Dam in August has a mean temperature near 22°C, which is well above the acute tolerance threshold for coho (Chapters 7 and 8). Field-calibrated models developed by Deas (2000) and models presented by Hardy and Addley (2001) show a considerable increase in the daily mean water temperature with distance downstream for flows that are typical of August. As noted in Chapters 7 and 8, however, bioenergetics of salmonids depend not only on the mean temperature but also on the diel range of temperature; low minimum temperatures are especially important for coho salmon.

Simulations conducted by Deas (2000) provide insight into the thermal response of the Klamath River to increases in flow during late summer (Figure 4-4). Under moderate flow conditions in mid-August (1,000 cfs), with typical accretions from tributaries, maximum daily temperatures increase rapidly downstream of Iron Gate Dam to a peak of 26°C within 15 mi. Daily minimum temperatures caused by nocturnal cooling reach a minimum of 20°C within about the same distance. By the time this water reaches Seiad Valley (RM 130), maximums are greater than 26°C, and minimums are 22°C; the average gain from Iron Gate Dam is 2°C. Tripling the flow from Iron Gate Dam (Figure 4-4B) provides modest reduction in mean and maximum daily temperatures, particularly in the first 20 mi of the river downstream from the dam. The increased volume of water and shorter transit time, however, reduce the effect of nocturnal cooling in the reach between Iron Gate Dam and Seiad, and raise minimum temperatures for about two-thirds of the reach. Although increased flows reduce mean and maximum temperatures, the increase in minimum temperatures may adversely affect fish that are at their limits of thermal tolerance (Chapters 7 and 8).

Two additional complications arise from increased releases from Iron Gate Dam. First, during low-flow conditions, tributaries can influence main-stem temperatures. Temperatures in the Klamath River at 1,000 cfs are affected substantially by the Scott River and minimally by the Shasta River. Modification of flow and temperature regimes in these tributaries through better water management could improve main-stem temperatures. Increase in flow to 3,000 cfs, however, eliminates any thermal benefit from the tributaries (Deas 2000).

In regulated rivers such as the Klamath, there often is a node of minimum diel temperature variation about 1 day's travel time from a dam (Lowney 2000) and an antinode of maximum variation at half this distance. The muted minimums and maximums of the thermal node reflect a single diel cycle of roughly equal heating and cooling during 1 day's travel time. Conversely, the large variation in temperatures at the antinode reflects only half a diel heating or cooling cycle. Reduction in maximum temperature is one of the benefits of the thermal nodes. These nodes, how-

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ever, also exhibit greatly increased minimum temperatures. In the Klamath River under flow and meteorological conditions typical of August, the highest minimum daily temperatures will occur at the node and may be points of greatest thermal stress for salmonids. Increases in flow will cause the node to shift downstream because of decreased transit times (Figure 4-4), thus increasing the amount of river that is subjected to increased temperature minimums.

The main-stem Klamath—like the lakes, reservoirs, and rivers of the upper basin—has concentrations of nitrogen and phosphorus that are quite high relative to many aquatic systems (Campbell 2001; Figure 4-5); they indicate eutrophic conditions. In addition, much of the nitrogen and phosphorus is readily available for plant uptake (for example, the forms nitrate and soluble reactive phosphorus). As a consequence of high nutrient concentrations, the river has the potential to support high rates of primary production. Even when nutrient concentrations are high, however, blooms of phytoplankton, such as those in Upper Klamath Lake, do not occur in streams or rivers of moderate to high velocity because flow limits the accumulation of suspended algae. Conditions may be favorable in the main stem for the growth of phytoplankton during low flow, when the water is moving slowly, and growth of attached algae and aquatic vascular plants also can be stimulated by nutrients. Stimulation of any kind of plant growth can affect oxygen concentrations.

During summer, oxygen concentrations in the Klamath River often fall below 7 mg/L and, for brief periods, below 5.5 mg/L (Campbell 2001). For

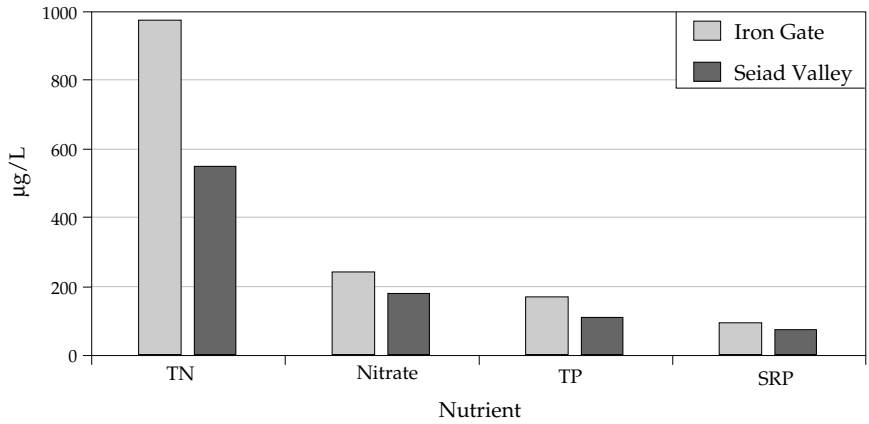


FIGURE 4-5 Mean annual concentrations of total nitrogen (TN) and total phosphorus (TP), nitrate (NO_3^- expressed as N), and soluble reactive phosphorus (SRP) at two stations on the Klamath River. Source: Data from Campbell 2001.

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example, average concentrations were below 7 mg/L on 36 days at the Seiad Valley monitoring station in 1998. More severe and extended periods of low oxygen concentrations occur at Iron Gate Dam because of degradable organic matter (such as dead phytoplankton) originating in reservoirs. Low oxygen concentrations, especially below 5.5 mg/L, are unfavorable to salmonids (Chapter 7).

THE SHASTA RIVER (RM 177)

Flow of the Shasta River is dominated by discharge from numerous cool-water springs and not by surface runoff. The stable, cool flows and high fertility of the Shasta historically created a highly productive, thermally optimal habitat for salmonids.

The Shasta River maintains about 35 mi of fall-run Chinook habitat, 38 mi of coho habitat, and 55 mi of steelhead habitat (West et al. 1990). The amount of habitat has not declined since 1955 but is substantially smaller than the original amount. Use of remaining habitat is contingent on flow and water quality, both of which may be inadequate in dry years. Mean annual runoff from the Shasta River is 136,000 acre-ft, which is less than 1% of the runoff of the Klamath River at Orleans. Runoff within the basin peaks during winter, when daily flow is near 200 cfs (Figure 4-6).

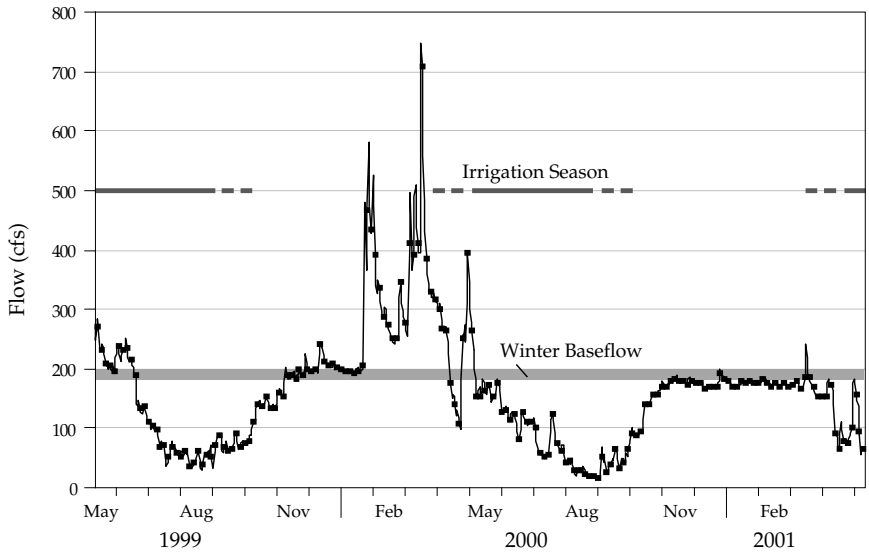


FIGURE 4-6 Annual hydrograph for the lower Shasta River (at Yreka, California), from May 1999 to May 2001. Note base-flow recovery during fall and sustained base flow throughout the winter of 2001.

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Peaks are associated with rain at times when there are no irrigation diversions (note that peaks did not occur in 2001, a year of drought). Flow declines rapidly with the onset of irrigation in late March. Flow minimums typically averaging less than 30 cfs occur during summer. Flow increases rapidly in the fall when irrigation ends. Winter base-flow conditions typically are 180–200 cfs, regardless of precipitation.

The hydrology of the Shasta River is affected by surface-water diversions, alluvial pumping, and the Dwinnell Dam (Figure 4-7). Historically, springs and seeps dominated the hydrograph of the Shasta River. Mack (1960) reported that one small tributary, Big Springs (Figure 4-7), supplied a consistent 103 cfs to the Shasta River before water development. Flow from the springs and numerous small accretions in the reach above them would have supplied flows close to or exceeding today's bankfull condition, even during summer months. Flows of that magnitude would have had very short transit times (less than 1 day to the Klamath River), thus maintaining cool water throughout summer for the entire river. Consistency of flow and cool summer water were the principal reasons that the Shasta River was historically highly productive of salmonids. During summer, the Shasta River may also have cooled the main-stem Klamath near the confluence of the Shasta and the main stem.

Since 1932, surface-water resources in the Shasta valley have been under statutory adjudication (Decree 7035). Three of the four major irrigation districts have a cumulative appropriative right to divert more than 110 cfs from the Shasta River from April 1 to October 1 (Gwynne 1993). Dwinnell Dam is used by the fourth major irrigation district to store winter flows of the Shasta River and Parks Creek. Dwinnell Dam, constructed in 1928, has a capacity of 50,000 acre-ft. The California Department of Water Resources Watermaster Service has been apportioning water within the basin since 1934. Riparian water rights below Dwinnell Dam are not adjudicated and are not regulated by the watermaster, and the 1932 adjudication did not address groundwater, which is critical for support of base flow.

Seven major diversion dams and numerous smaller dams or weirs are on the Shasta River and its tributaries below Dwinnell Dam (Figure 4-7). When the diversions are in operation, they substantially and rapidly reduce flows in the main stem (Figure 4-6). During the drought of 1992, flows in the Shasta dropped from 105 cfs on March 31 to 21 cfs by April 5. The numerous diversions on the Little Shasta River now routinely lead to complete dewatering of its channel in late summer. Although surface diversions play an important role in causing the low flows of the Shasta, there is little quantitative information on the relative role of each diversion, and records either have not been kept or are not available from the watermaster service that apportions flows.

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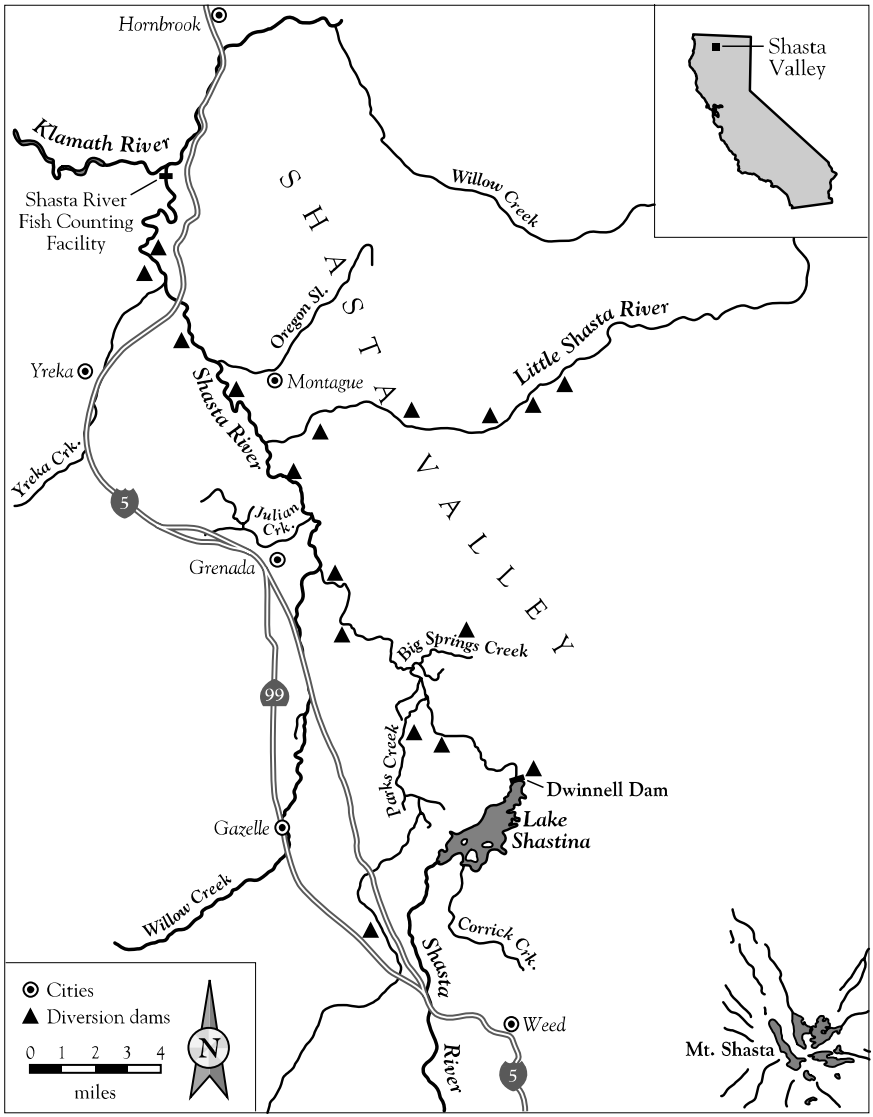


FIGURE 4-7 Map depicting substantial water diversions from the Shasta River below Dwinnell Dam. Note that the Shasta River flows north and drains into the Klamath River. Source: Modified from Gwynne 1993.

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Dwinnell Dam affects the hydropattern of the Shasta River. Peak winter flows associated with large precipitation events have been strongly suppressed. Absence of flushing flows reduces sediment transport and reduces the availability of spawning gravels downstream of the dam (Ricker 1997). With the exception of above-average water years, when Lake Shastina is full, no flow is released from Dwinnell Dam except for small amounts to specific water users downstream. Water in Parks Creek is diverted into Lake Shastina, thus decreasing winter flows in the creek. In addition, seepage losses from Lake Shastina are large; they exceed the total amount of water supplied to irrigators (Dong et al. 1974).

Groundwater is not part of the adjudication of water rights in the Shasta basin, and little is known about its influence on surface flows. The exceptionally high specific capacity of the aquifers and the large recharge area make groundwater one of the most important and resilient resources in the valley. Well records of the California Department of Water Resources (CDWR) indicate a great increase in the number of irrigation wells in the valley since the 1970s. The shift toward groundwater production from use of surface diversions may have had a measurable effect on surface flows and may have exacerbated low-flow conditions. For example, the Big Springs Irrigation District ceased using surface diversions and switched to groundwater wells in the 1980s to meet its water needs; these highly productive wells may have contributed to the reported dewatering of the springs that historically fed Big Springs Creek.

Recent surveys have shown that channel conditions in the main stem of the Shasta River and its most important tributary, Parks Creek, generally are poor and may limit salmonid production. Replicate habitat surveys summarized by Ricker (1997) and Jong (1997) focus on Chinook spawning gravels and indicate that the percentage of fines in gravels is high throughout the main stem and Parks Creek. The fines, which are detrimental to egg survival and emergence of fry, are associated with accelerated erosion and lack of flushing flows that maintain and recruit coarse gravels.

In some reaches, particularly in the lower canyon and the reach below the Dwinnell Dam, limited recruitment of coarse gravels is contributing to a decline in abundance of spawning gravels (Buer 1981). The causes of the decline in gravels include gravel trapping by Dwinnell Dam and other diversions, bank-stabilization efforts, and historical gravel mining in the channel.

Loss of vegetation in the riparian corridor poses a widespread and important threat to salmonid habitat. In the lowermost reach of the Shasta River, the loss is explained principally by mining. In the valley above the lower Shasta, grazing has been responsible for most of the loss. Where intense unfenced grazing has occurred, trampling and removal of vegetation have commonly led to accelerated bank erosion, loss of shading, re-

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duced accumulation of local woody debris, loss of pool habitat to sedimentation, loss of channel complexity and cover, and degradation of water quality. Riparian fencing programs and construction of stock-water access points are under way in the Shasta valley, but efforts to date are modest (Kier Associates 1999).

The Shasta River contains seven major diversion dams and multiple smaller dams or weirs (Figure 4-7). Dwinnell Dam eliminated access to about 22% of habitat historically available to salmon and steelhead in the watershed (Wales 1951). The reach between Big Springs and Dwinnell Dam, which has the potential to support a range of salmonids, receives minimal flows from the dam.

Although Dwinnell Dam is the most important diversion structure on the Shasta River, numerous other diversions have an important but unquantified effect. Many of the structures create low-water migration barriers and during summer create water-quality problems by acting as thermal and nutrient traps. Unscreened diversions have been identified as a serious problem for salmonid spawners, outmigrants, and juveniles (Chesney 2000).

Surface diversions and groundwater withdrawals have eliminated or substantially degraded flows on the Shasta River and its tributaries. The alterations are most evident during late spring through early fall, when increasing air temperatures and low flow coincide with poor water quality. The low flows also reduce habitat for salmonids and increase the adverse effects of diversion structures on migration.

Substantial reduction of flows by water withdrawal and the associated poor water quality probably are principal causes of decline in salmonid production in the Shasta watershed. The 1932 adjudication of surface waters in the basin, as currently administered, is insufficient to supply the quantity and quality of water necessary to sustain salmonid populations in the basin.

A major bottleneck for salmonid production in the Shasta River watershed is high water temperature (Figure 4-8). Daily minimum temperatures in the lower main stem in summer are typically greater than 20°C, and daily maximums often exceeding 25°C. Salmonids, especially coho salmon, rarely persist under such conditions. McCullough (1999) found that salmonids are typically absent from waters in which daily maximum temperatures regularly exceed 22–24°C for extended periods, although bioenergetic considerations or presence of thermal refugia may push distribution limits into slightly warmer water (see Chapter 7). Growth and survival are usually highest when temperatures stay within an optimal temperature range; this range differs among species and life-history stages, but for juvenile salmonids in the Klamath system, optimal temperatures are 12–18°C (Moyle 2002); bioenergetic considerations also alter optimal temperatures for growth and survival (McCullough 1999). The Shasta River becomes

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progressively cooler as elevation and flows increase, but temperatures remain largely suboptimal for salmonids for most of its length from late June through early September (Figure 4-8). Higher temperatures also are associated with reduced amounts of dissolved oxygen (DO) in the water. DO concentrations below saturation are apparently uncommon in the Shasta River, but where they occur, they coincide with high temperatures and low flows (Campbell 1995, Gwynne 1993). The causes of high temperatures include chronic low flow due to agricultural diversions, lack of riparian shading, and addition of warm irrigation tailwater. Temperature simulations for the Shasta River conducted by Abbott (2002) demonstrate the importance of flow (Figure 4-9) and riparian vegetation to river temperatures. Low flows with long transit times typical of those now occurring in the summer on the Shasta River cause rapid equilibration of water with air

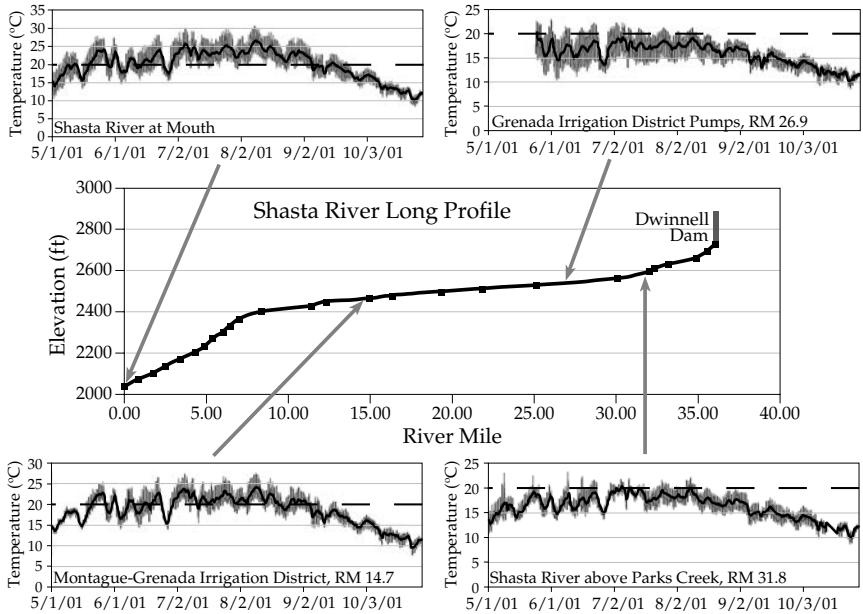


FIGURE 4-8 Temperature (thin line) and daily average temperature (wide line) within the Shasta River below Dwinnell Dam during the summer of 2001. The dashed line at 20°C is for comparison between plots. Note that the generally cool, spring-fed upper reaches of the river have temperatures suitable for salmon. Low flow, warm tailwater return flows, and lack of riparian cover on the lower main stem lead to high temperatures unsuitable for salmonids. Source: Abbott 2002. Reprinted with permission from the author; copyright 2002, University of California Press.

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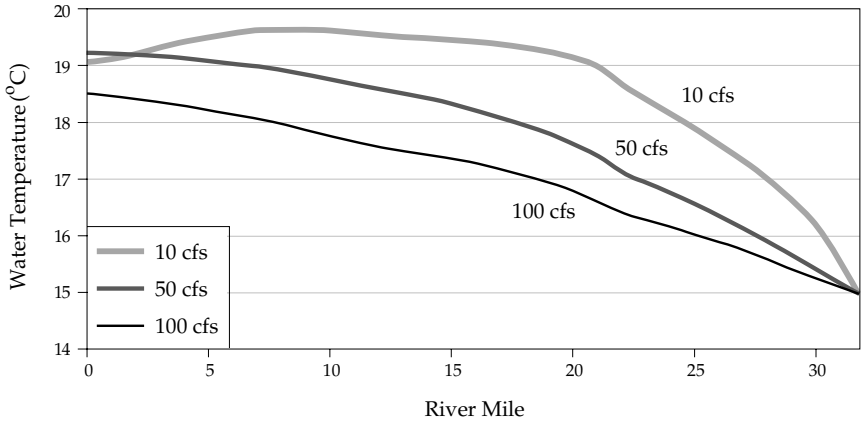


FIGURE 4-9 Simulation of daily mean water temperatures in the Shasta River at three flows for August 2001 conditions. Simulations assume no significant shading. Source: Abbott 2002. Reprinted with permission from the author; copyright 2002, University of California Press.

temperatures, which produces water temperatures exceeding acute and chronic thresholds for salmonids well above the mouth of the river. Small increases in flow could reduce transit time substantially and thus increase the area of the river that maintains tolerable temperatures. Increases in riparian vegetation also could help to sustain lower water temperatures. Unlike other large tributaries, the Shasta River has a relatively narrow channel that could be strongly affected by riparian shading. Simulations of the effect of mature riparian forests for weather conditions of August 2001, and in drought conditions, showed lowering of daily mean water temperature at the mouth of the river from 21.4°C to 17.1°C and lowering of average maximum temperatures from 31.2°C to 24.2°C (Abbott 2002).

THE SCOTT RIVER (RM 143)

The watershed of the Scott River historically has provided important spawning and rearing habitat for coho salmon and, on the basis of records of spawning runs as recent as winter 2001–2002 (USFWS 2002), remains one of the most important tributary watersheds for coho in the lower Klamath basin.

The hydrology and water budget of the Scott River watershed are poorly documented. One USGS gage at Fort Jones provides the longest continuous record of flows (1942–2002). The gage is 16 mi upstream of the Klamath River and does not take into account accretions from the tributar-

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ies to the Scott River Canyon. Mean annual runoff within the basin is 489,800 acre-ft (range 54,200–1,083,000 acre-ft). Flows within the tributaries are poorly documented.

The hydrograph of the Scott River, like that of the Salmon River, shows two seasonal pulses (Figure 4-10) that are unaffected by any large impoundments. The winter pulse is caused by high precipitation from mid-December through early March and is highly important geomorphically because it accounts for most of the annual sediment transport (Sommerstram et al. 1990, Mount 1995). The second pulse is caused by the spring snowmelt, which begins in late March and in wet years continues through June (Figure 4-10).

From late June through November, flows in the Scott River and its tributaries are low (Figure 4-10). During average to dry years, the tributaries with large alluvial fans are disconnected from the Scott River except through subsurface flow (Mack 1958, CSWRCB 1975). The loss of flow is caused by high seepage in the alluvial fans and diversions for irrigation. Along the main stem of the Scott River, surface flow ceases in several reaches during August and September of average and dry years. Discontinuous flow occurs into the fall. During average and wet years, continuity of

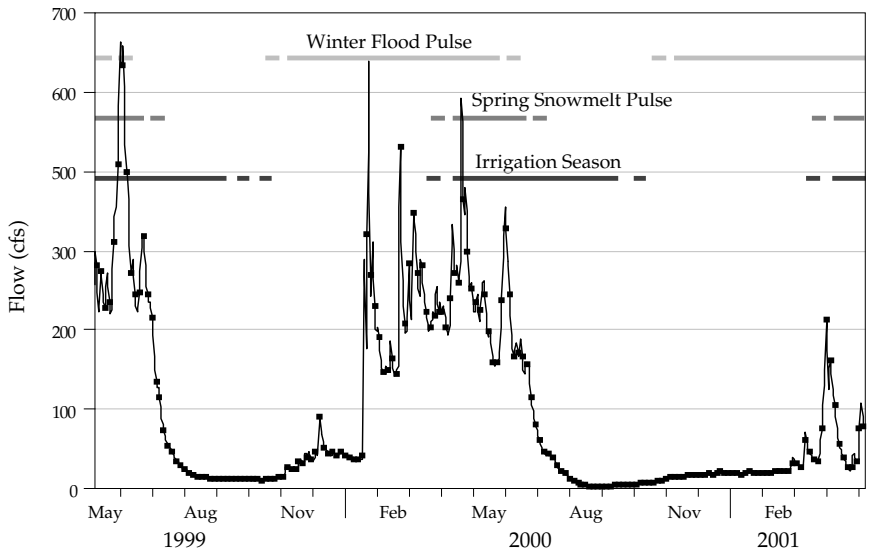


FIGURE 4-10 Annual hydrograph of Scott River at Fort Jones, California, May 1999 through May 2001. Note the significant decline in flows at the start of the irrigation season and weak recovery of flows during the dry winter of 2000–2001.

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flow is restored between late October and early November as evapotranspiration declines and irrigation decreases. During dry years, low-flow conditions persist until substantial rainfall occurs. Unlike the Shasta River, the Scott River shows lack of significant recovery of base flow during late fall and winter in years of low rainfall, indicating lack of resiliency in the groundwater reservoirs.

Because low base flow during summer and early fall is a natural element of the Scott River hydropattern, dry conditions in some reaches of the river may have occurred at some times before water management. Water management has decreased fall flows and has increased the frequency and duration of negligible flow.

The main groundwater source for irrigation and domestic water use in the Scott valley is the extensive alluvium under the river (Mack 1958, CDWR 1965). High rates of recharge to the valley aquifer, whose volume exceeds 400,000 acre-ft, are a byproduct of the fan heads of west-side tributaries, which receive seepage through the river bed; direct recharge from seepage of precipitation; infiltration losses from irrigation ditches; and deep percolation of irrigation water.

Groundwater levels in the valley aquifer reflect drawdown during the irrigation season and recharge during the wet season. The combination of high specific capacity of the shallow alluvial aquifers of the basin and high hydraulic gradients produces rapid seasonal changes in groundwater levels. Where subsurface water-bearing sediments are hydraulically connected in the Scott Valley, groundwater pumping can cause serious losses in channel flow (Mack 1958, CSWRCB 1975). Thus, pumping may be an important contributor to low-flow and no-flow conditions. There has been no comprehensive analysis of the water budget of the Scott River.

The Scott River and most of its tributaries are adjudicated under California water law. Adjudication and enforcement play key roles in the water budget of the Scott River. The Scott Valley Irrigation District initiated adjudication proceedings by petition to the California State Water Resources Control Board (CSWRCB) in 1970. Investigations cited above revealed the hydraulic connections between shallow groundwater and surface flows, indicating that adjudication should include both surface-flow rights and pumping rights adjacent to the river. At the time, this type of adjudication was not allowed under California statutes. Special legislation was developed for the innovative adjudication of the Scott River. Most of the shallow groundwater in the valley probably is linked to the surface flows. Recognizing this, the CSWRCB staff arbitrarily chose an adjudicated zone extending about 1,000 ft from the main-stem channel of the Scott River (CSWRCB 1975).

In 1980, the Siskiyou County courts decreed the Scott River adjudication, recognizing 680 diversions capable of diverting up to 894 cfs from the

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river and its tributaries above the USGS gage at Fort Jones (CH2M HILL 1985). Adjudications had been completed earlier on Shackleford and Mill creeks and on French Creek. Since 1989, the Scott River and its tributaries French, Kidder, Shackleford, and Mill creeks have been considered fully appropriated by CSWRCB.

The CDWR has provided a watermaster service to minimize litigation over water rights. Although a watermaster oversees 102 decreed water rights on several tributaries in the basin, no watermaster service has been requested for the main stem.

During the adjudication process, the state and federal governments both failed to negotiate successfully for water that would favor robust populations of fish. There are now no adjudicated rights for fish upstream of the USGS gage in Fort Jones. Below the Fort Jones gage, the U.S. Forest Service (USFS) was allotted flow of 30 cfs during August and September, 40 cfs during October, and 200 cfs from November through March to protect fish. With no watermaster service, USFS, a junior appropriator, commonly does not receive its adjudicated flows during late summer and fall.

Assessments of limiting factors for coho salmon have been summarized by Siskiyou County Resource Conservation District (Scott River Watershed CRMP Council 1997, West et al. 1990) and are given in Chapter 8. The limiting factors can be grouped into two classes: those associated with tributary flows and conditions, and those associated with the main stem of the Scott River.

Tributaries that drain the west side of the watershed and the East and South Forks of the Scott have substantial habitat for coho and other salmonids. Juvenile salmon occupy the uppermost reaches of the tributaries, where they benefit from the consistently low water temperatures and perennial flows (West et al. 1990). West-side tributary reaches that are above the major diversions maintain high water quality and favorable temperatures throughout the year, including August and early September (SRCD 2001). Maximum weekly average temperatures range from 15 to 17°C, and diel fluctuations are less than 3°C.

The principal limiting factor in the upper tributary reaches is excessive sediment derived from logging, particularly in tributaries with granitic soils (CH2M HILL 1985, Lewis 1992). Highly erodible decomposed granite has led to a serious loss in volume and number of pools in tributaries and associated degradation of spawning and rearing habitat. Logging over the past 50 yr has taken place on a mix of USFS land and land held by a few large private timber companies. Historical logging practices have been poor, particularly on private land, and have left a legacy of degraded hillslope and stream conditions.

Within the lower reaches of the west side, where tributaries contain surface diversions or large alluvial fans, low or negligible flow may be a

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limiting factor for coho and other salmonids. The loss of base flow in these tributaries may have occurred historically during dry years, particularly where there were large alluvial fans. Diversions and groundwater withdrawal, however, probably have increased the frequency and length of dry conditions, particularly in Etna, Patterson, Kidder, Mill, and Shackleford creeks (Mack 1958). The dewatering of these tributaries eliminates potential rearing habitat for coho and causes loss of connectivity and reduction of base flow in the main stem. Dry conditions in these creeks can persist into fall, thus blocking tributary access for spawning coho, steelhead, and Chinook.

West et al. (1990) documented 128 mi of potential spawning and rearing habitat for coho in the Scott River, mostly on the main stem. Degradation of habitat, however, is considerable; less than 30% is rated good to fair (SRCD 2001). California Department of Fish and Game (1999) rated the holdover of adults before spawning as fair, spawning habitat as fair, and juvenile rearing habitat as poor. The decline in salmonid habitat conditions on the main stem of the Scott is caused by channel alterations, low flow, and poor water quality.

The main-stem channel of the Scott River has been extensively altered over the last 150 yr by placer and hydraulic mining, logging, grazing in the riparian corridor, unscreened irrigation and stockwater diversions, elimination of wetlands, and flood-management or bank-stabilization efforts. These activities have cumulatively degraded salmonid habitat on most reaches of the main stem above the canyon. The most important limitations appear to arise from loss of optimal channel complexity and depth, loss of riparian vegetation, and unscreened diversions. There are 153 registered diversions in the Scott Valley, of which 127 are listed as active by SRCD. Fish screens have been installed on 65 of these diversions; another 38 are funded but not yet built (SRCD 2001).

Seasonal low flows are consistently recognized as one of the most important limiting factors for all salmonids that use the main stem of the Scott River (CH2M HILL 1985, West et al. 1990, SRCD 2001). Low flows and dry conditions contribute to the decline in spawning and rearing habitat in the river and exacerbate poor water quality during summer and early fall. During years when seasonal rains arrive late, low-flow conditions can persist into the fall, and limit access of salmon to spawning sites in tributary streams.

Low-flow and dry conditions are a natural aspect of the main-stem Scott in dry years, but the adjudication of the Scott River and its tributaries offers little protection for stream flow and related temperature requirements of salmonids in the watershed even during normal years. The adjudicated water rights are sufficient to allow removal of all flow from the river during the summer and early fall. The shift from surface diversions, which

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are naturally self-limiting, to groundwater wells, has exacerbated the apparent overappropriation of water in the watershed. That problem is compounded by a limited watermaster service in the basin and insufficient records, so it is not known whether diverters are adhering to their appropriative rights. The net result is that limited management and overappropriated water have seriously affected flows in the river.

The frequency and duration of low-flow conditions has increased since the 1970s (summary in Drake et al. 2000); the most important effects occur in September (Figure 4-11A), as confirmed by analysis of double-mass

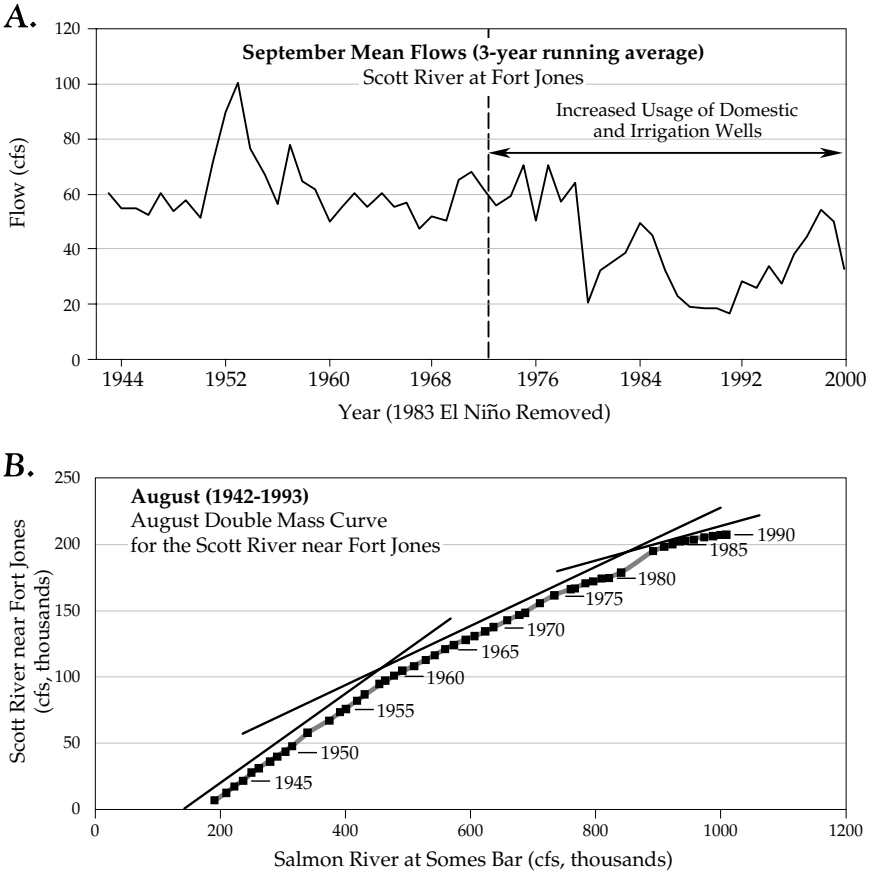


FIGURE 4-11 Declines in late summer and early fall flows on the Scott River. A) 3-yr running average of September mean flows, 1942–2002. Note the shift in low-flow conditions in late 1970s. B) Double-mass curve of August flow volumes on the Scott vs the Salmon River showing decline in August volume in the Scott relative to the Salmon during last 50 yr. Source: Bartholow 1995.

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curves that compare runoff between the Scott River and the nearby Salmon River, which is not subject to diversion (Figure 4-11B). The decline in late summer and fall runoff is a considerable challenge to restoration of salmonid holding, spawning, and rearing conditions in the Scott River. In the absence of credible information and hydrologic models, there has been widespread speculation about the causes of declining flows in the Scott River. For example, Drake et al. (2000) postulated that the principal cause of declining late summer and fall flows in the Scott River is climate change. Drake et al. analyzed the relationship between precipitation in the Scott River watershed and fall runoff. Their work demonstrated a modest statistical correlation between declining precipitation in April at two snowpillows (snow-accumulation sensors) in the western edge of the watershed and declining runoff in September. On the basis of that correlation, Drake et al. (2000) ascribed the fall runoff shifts to declines in the water content of the April snowpack caused by climate change. They concluded that changes in land-use practices and water use were not responsible for declining flows.

The analysis by Drake et al. correlated fall flows only to two snow gages that showed declines in April snowpack. Five other gages in the basin showed no long-term changes in precipitation. As Power (2001) noted, the two stations that Drake et al. used are also invalid for comparative purposes because encroachment of forest vegetation has progressively reduced the catch of the snowpillows since their installation. Thus, it remains likely that the decline in fall flows can be attributed to changes in land cover and water-management practices in the watershed.

Cropping patterns in the Scott River valley have changed during the last 50 years (Figure 4-12A). In 1953, there were 15,000 acres of irrigated agriculture and 15,000 acres of natural subirrigation in the Scott valley (Mack 1958). Land surveys (CDWR 1965; CDWR, Red Bluff, CA, unpublished material, 1993) show that the amount of irrigated land has not changed substantially since 1953, but land use has. Grain declined from 7,000 acres in 1953 to 2,000 acres in 1991; alfalfa increased by 40% from 10,000 acres to more than 14,000 acres. Alfalfa has evapotranspiration rates that are several times greater than those of grain. Increased cultivation of alfalfa, including a tendency to seek four cuttings per year (SRCD records) rather than the traditional three, may have caused a decline in fall flows.

The change in cropping patterns is mirrored by a shift from surface diversions to irrigation wells (Figure 4-12B). CDWR records of well drilling in the Scott valley indicate a large increase in irrigation and domestic wells during the 1970s and 1990s. During the 1950s, there were about 60 domestic wells and six irrigation wells in the valley. During the 1970s, more than 300 domestic wells and 100 irrigation wells were drilled in the valley. That shift from surface diversions to wells increased the amount and reliability of water for irrigation. Because of the high specific capacity of shallow aqui-

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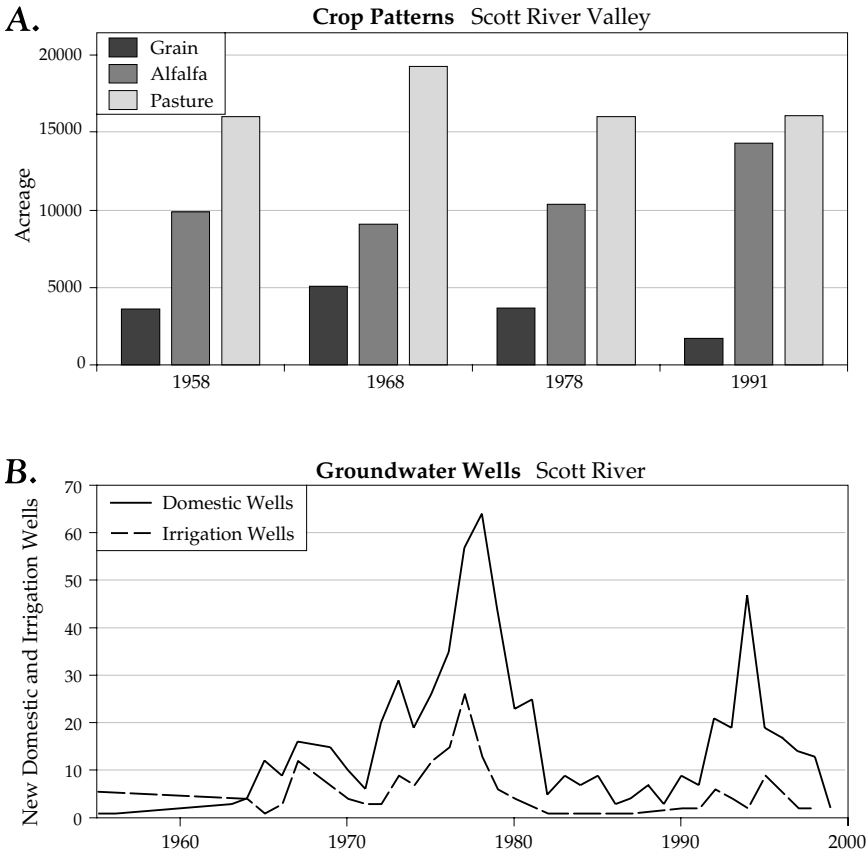


FIGURE 4-12 Changes in cropping and water wells in the Scott Valley. A) Increase in alfalfa production from 1958 to 1991. Sources: citations in text. B) New domestic and irrigation wells recorded in the Scott Valley from 1954 to 1999, showing increase in well-drilling activity in the 1970s. Source: Data from CDWR records, provided by K. Maurer.

fers in the Scott basin, pumping also decreased the contribution of shallow groundwater to base flow in the Scott River.

Water temperatures of the Scott River in July through September exceed thresholds for chronic and acute stress of coho and other salmonids (Figure 4-13). Ambient air temperature is the primary control on maximum weekly average temperature (MWAT)—warmest 7-day period for 1995–2000—of the main stem during summer and early fall (SRCD 2001).

MWAT increases downstream along the main stem of the Scott River because of the long hydraulic residence time of summer flow (Figure 4-13). Local cooling of main-stem temperatures is associated with augmentation

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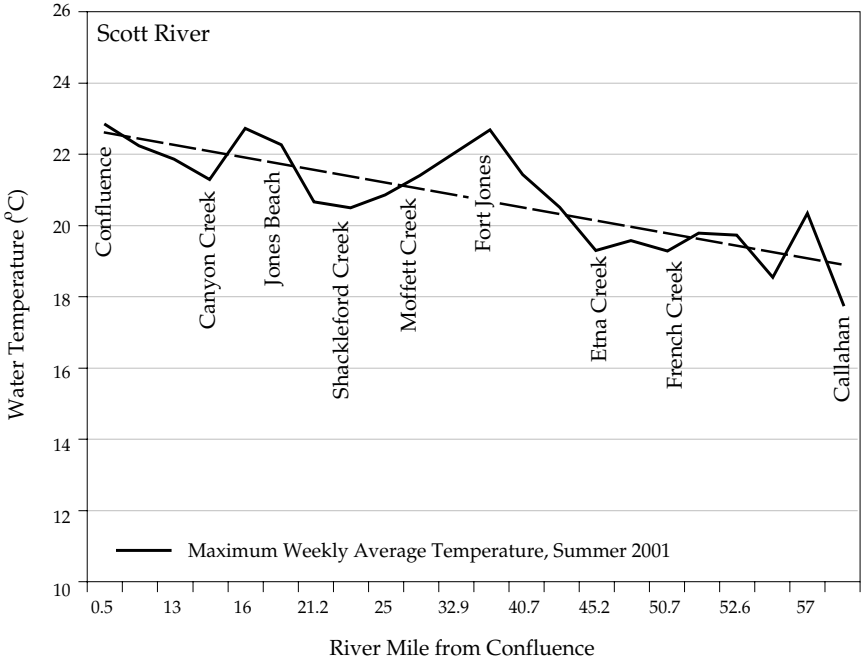


FIGURE 4-13 Plot of downstream changes in maximum weekly average water temperature on the main stem of the Scott River during summer. Note the irregular pattern of change in temperature, presumably associated with accretions from groundwater and the effects of irrigation return flows. Source: Modified from SRCD 2001.

of baseflow by shallow groundwater. Local warming of the Scott is associated with reaches of the river where water loss and tailwater return flows occur, but the current monitoring program is not capable of resolving heat flux.

Dissolved oxygen of the Scott River has been monitored sporadically. Dissolved-oxygen data are available from 1967 to 1979 at Ft. Jones (Earthinfo, Inc. 1995) and from 1961 to 1967 and 1984 (CDWR 1986). The lowest concentrations of oxygen occur during late August and early September, when flows are low and temperatures are high. The data suggest that problems with low concentrations of dissolved oxygen, if any, are limited temporally and spatially.

Extensive, locally driven efforts are under way in the Scott Valley to address the decline in water quality, and in salmonid spawning and rearing habitat. These efforts are led by the SRCD and the local Watershed Council, with cooperation from state and federal agencies, and have been well funded through aggressive grant acquisitions. Only a handful of these ef-

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forts have monitoring programs that allow assessment of their effectiveness, and there appears to be no independent review of the restoration and monitoring programs. More importantly, these efforts have yet to address comprehensively water budgets and water uses, including the contribution of groundwater to surface flows and water quality. Until a comprehensive water budget is developed, significant progress at restoring coho and other salmonids is unlikely to occur.

THE SALMON RIVER (RM 62)

Within the lower Klamath watershed, the Salmon River remains the most pristine tributary; it has a natural, unregulated hydrograph, no significant diversions, and limited agricultural activity. Although it is not well documented, runs of all the remaining anadromous fishes in the Klamath watershed (Chapter 7, Table 7-1) occur in the Salmon River (Moyle et al. 1995, Moyle 2002).

The Salmon River's unique characteristics stem from its mountainous terrain and public ownership of land. At 750 mi^2, the Salmon River is the smallest of the four major tributary watersheds in the Klamath basin. Even so, the annual runoff from the Salmon is twice that of the Scott and 10 times as great as that of the Shasta River. High runoff reflects the steep slopes and high annual precipitation (50 in) of the watershed. Runoff in the basin is dominated by a winter pulse associated with high rainfall and a spring snowmelt pulse from April through June (Figure 4-14). During summer and late fall, low-flow conditions predominate, particularly in smaller tributaries. Unlike the Scott and Shasta, the Salmon River watershed is almost entirely federally owned (Chapter 2).

The Salmon River watershed supports about 140 mi of fall-run Chinook spawning and rearing habitat and 100 mi of coho and steelhead habitat (CDFG 1979a). Logging roads, road crossings, and frequent fires in the basin appear to contribute to high sediment yields. Historical and continuing placer mining has reduced riparian cover and disturbed spawning and holding sites in the basin as well. Increased water temperatures have been noted in the Salmon River during late-summer low-flow periods, but their cause is unclear; they may be natural or may be in part a byproduct of logging and fires. The high summer temperatures may also be in part a function of the orientation of the watershed and naturally low base flow during late summer (Kier Associates 1998).

THE TRINITY RIVER (RM 43)

The Trinity River has the largest tributary watershed in the lower Klamath basin (2,900 mi^2). The watershed extends up to 9,000 ft in the

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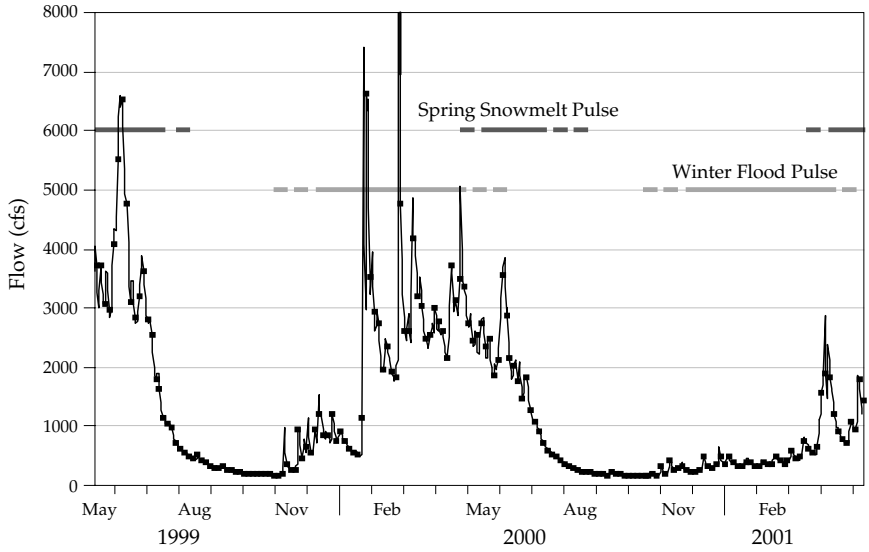


FIGURE 4-14 Annual hydrograph of the Salmon River at Somes Bar, California, May 1999–May 2001.

Trinity Alps and the Coast Ranges and flows more than 127 mi to its confluence with the Klamath at 230 ft asl, 43 mi above the Klamath River mouth (Figure 4-15). It is the largest contributor of tributary flow to the main-stem Klamath. Prior to construction of the Trinity River Diversion (TRD), the Trinity River accounted for close to one-third of the average total runoff from the Klamath watershed (based on USGS gaging records)—more than twice the runoff from the entire upper basin.

Hydrologically, the Trinity watershed is broadly similar to the Scott and Salmon watersheds. Prior to construction of the Trinity River Diversion (TRD) project in 1963 (discussed below), runoff averaged close to 4.5 MAF annually. The bulk of this runoff was concentrated into two seasonal pulses (Figure 4-16)—winter floods associated with mixed rain-snow events that typically occur between mid-December and mid-March, and a spring snowmelt pulse that begins in late March–early April and, depending upon snowpack conditions, ceases in July. The summer and fall are dominated by baseflow conditions. Historically, late summer and early fall flows on the Trinity were quite low, indicating limited natural baseflow support. During years of below-average moisture, tributaries to the Trinity commonly dry up.

Precipitation patterns and associated runoff vary considerably throughout the Trinity watershed. Precipitation averages 57 in. annually, but approaches nearly 85 in. in the Hoopa Mountains and the Trinity Alps. In the

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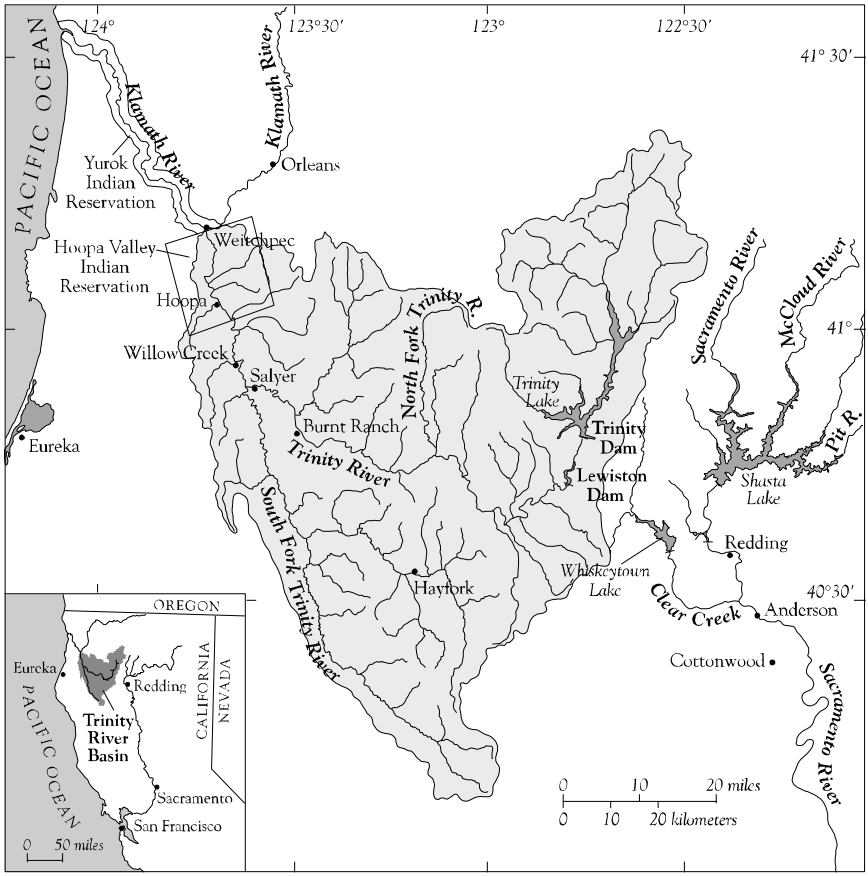


FIGURE 4-15 Index map of the Trinity River watershed. Source: Modified from USFWS/HVT 1999.

high-altitude, northeastern portions of the watershed, the annual hydrograph is dominated by snowmelt runoff during the spring and early summer. In contrast, the lower-elevation watersheds, such as the South Fork and North Fork, are dominated by winter rainfall flood pulses.

As noted in Chapter 2, the tectonic, geologic, and climatic setting of the Trinity River has amplified the influence of land-use activities on fish. Highly unstable rock types, which are associated with the Coast Range Geologic Province on the west and the Klamath Mountains Geologic Province on the east, coupled with high rates of uplift, lead to naturally high erosion rates (Mount 1995). Like the western portions of the Scott watershed, the eastern portions of the Trinity watershed contain deeply weath-

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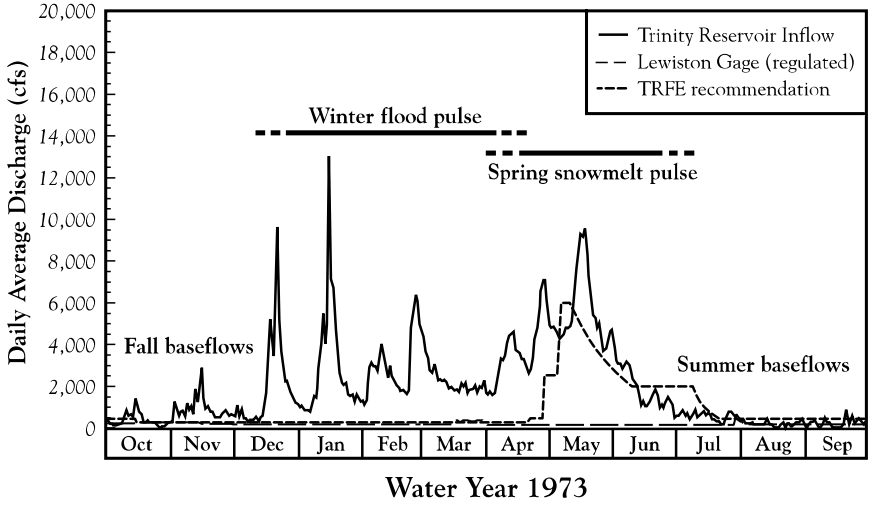


FIGURE 4-16 Example of regulated (dotted line, current recommended outflow) and unimpaired (solid line, inflow to Trinity Diversion Project) flows on the Upper Trinity River for water year 1973, a normal water year (40–60% exceedance probability for annual flow volume). Source: Modified from USFWS/HVT 1999.

ered granitic rocks that yield highly erodible soils dominated by decomposed granite. In both the eastern and western portions of the watershed, highly unstable metamorphic rock units are associated with numerous and widespread slope failures. Landslides play a dominant role in hillslope evolution on the South Fork Trinity and in canyon reaches of the main stem.

Approximately 80% of the Trinity watershed is federally owned and is managed by USBR and USFS. The remainder is a mix of private ownership and lands within the Hoopa Valley and Yurok Indian reservations. Land-use practices on public and private land within the Trinity watershed have played a central role in the precipitous decline of salmon runs in the latter half of the 20th century.

As with most tributary watersheds of the Klamath system, logging, mining, and grazing have reduced the quantity and quality of salmon habitat in the Trinity watershed. The greatest effects have occurred in the South Fork of the Trinity and on the main stem below Lewiston Dam and above the confluence of the main stem with the North Fork.

The South Fork is the largest tributary of the Trinity River, and was historically a significant producer of Chinook and coho salmon and steelhead trout (Pacific Watershed Associates 1994). The South Fork and its

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main tributary, Hayfork Creek, comprise 31% of the Trinity watershed and 6% of the total Klamath watershed. The South Fork, which is undammed, is the largest unregulated watershed in California. Currently, more than 56 mi of the river are protected under the California Wild and Scenic Rivers Act.

The South Fork has high background sedimentation rates, but intense logging in the 1960s on highly unstable soils, coupled with a large storm in 1964, produced sedimentation rates significantly above background levels. Adverse effects of sediment on aquatic life caused EPA to require a total maximum daily load (TMDL) study for sediment in the South Fork (EPA 1998). Loss of riparian cover and deep pools also appears to have affected water temperature.

Most regional and national attention has been focused on the main stem of the Trinity River. Mining, logging, and grazing practices within this portion of the watershed contributed high volumes of sediment to the main stem and degraded habitat prior to creation of the TRD (EPA 2001). Logging on sensitive soils produced high loads of fine sediment in the mainstem Trinity. Prior to TRD operations, however, seasonal high flows associated with the winter and spring flood pulses appear to have maintained habitat of reasonable quality, thus preventing a significant decline in steelhead and salmon (McBain and Trush 1997).

In 1955 Congress authorized construction of the TRD project to divert water from the upper Trinity River into the Sacramento River as part of the Central Valley Project (CVP). The primary beneficiaries of these diversions are farms of the San Joaquin Valley serviced by the Westlands Water District. The TRD consists of two dams: the Trinity Dam, which has an impoundment capacity of 2.4 MAF, and Lewiston Dam, which impounds Lewiston Reservoir and provides the diversion for the CVP.

The closure of Lewiston Dam in 1963 led to loss of access to spawning sites and degradation of habitat. Located at Trinity RM 112, Lewiston Dam currently blocks access to more than 109 mi of potential spawning habitat in the upper watershed (USFWS 1994). Additionally, the Trinity and Lewiston Dams trap all coarse sediment that would normally be supplied by the upper watershed.

When completed, the TRD diverted more than 88% of the annual runoff from the upper watershed to the CVP. After 1979, these diversions were decreased to 70% of the annual runoff. The magnitude of the diversions and associated flow release schedules eliminated winter and spring flood pulses in the main stem of the Trinity (Figure 4-16). The effects of these manipulations are most acute between Lewiston Dam and the North Fork Trinity (RM 112-72). Below the North Fork, tributary flow and sediment supply reduce the adverse effects of upstream water management (USFWS/HVT 1999).

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Changes in hydrology on the Trinity River, loss of sources of coarse sediment, and continued influx of fine sediment from hillslope erosion have created significant changes in habitat conditions downstream of the TRD. Channel response to changes in flow regime included reductions in cross section, reduction in lateral migration, establishment of riparian vegetation on channel berms, loss of backwater habitat, and loss of spawning gravel. The new channels have been static, reduced in size, and deficient in suitable habitat.

In 1981 the Secretary of the Interior authorized a Trinity River Flow Evaluation (TRFE) study of ways to restore the fishery resources of the Trinity River (USFWS/HVT 1999). The final TRFE report recommends releases from TRD based on five water-yr types: extremely wet, wet, normal, dry, and critically dry. The hydrographs consistent with these recommendations still allow for delivery of water to the CVP, but shape the hydrographs so that they support the life-history needs of salmonids, including reintroducing disturbance to control establishment and growth of riparian vegetation, coarse sediment transport to establish pools and riffles and to clean spawning gravels, and sufficient flows to reduce water temperatures for rearing. The TRFE also contained an adaptive management approach that calls for assessment of the effect of changes in flow regime and adjustments as necessary to improve the success of the program.

The TRFE and the associated federal environmental impact statement (EIS) and environmental impact report (EIR) were the product of multiple years of collaborative effort on the part of agencies and stakeholder groups. This program was subjected to rigorous external peer review, which led to numerous, substantive revisions in proposed remediation measures. The TRFE was used in the Department of the Interior's Record of Decision (ROD; Trinity River Mainstem Fishery Restoration, USFWS 2000). A lawsuit filed by the Westlands Water District in 2001 contended, however, that the underlying studies did not adequately address the economic impacts of the CVP water on users and electricity consumers, and failed to account for the effects of changes in flow on ecosystems of the Sacramento-San Joaquin Delta. In 2001, U.S. District Court Judge Oliver Wanger ruled against the Department of the Interior (DOI) and ordered it to complete a supplemental EIS, which is still in preparation. Consequently, the recommended TRFE flow releases have not occurred. In response to the lower Klamath fish kill of September 2002, the presiding judge was asked by the Hoopa Valley Tribe to allow some operational flexibility in order to help avoid fish kills in September 2003. The judge allowed 50,000 acre-ft to be set aside for emergency increases in flow to reduce the chances of a fish kill. In August 2003, the Trinity Management Council requested that DOI allow a sustained flow release in September 2003 due to low-flow conditions and

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predictions of a large salmon run. As of September 2003, these modifications in flow were under way.

Given the size of the Trinity River watershed and its large amount of runoff, the operations of the TRD must affect the quality of habitat in the lowermost Klamath River and its estuary. There is little published information, however, on the effects of the Trinity on the lowermost Klamath and the estuary. Information provided here is principally derived from an analysis of USGS gaging data (1951–2002) from the Trinity and the Klamath, and from the Trinity River Flow Evaluation study (USFWS/HVT 1999).

Following construction of the TRD, the contribution of the Trinity to the total flow of the Klamath River declined from 32% to approximately 26% (Figure 4-17). This decline is not equally distributed throughout the year. The largest effect of the TRD occurs in the spring, during filling of the Trinity Reservoir. Prior to construction of the TRD, snowmelt runoff from the Trinity provided approximately 290,000 acre-ft, or approximately one-third of the inflow to the estuary, to the Klamath River in June. Following construction of the TRD, the average contribution of the Trinity in June declined to 160,000 acre-ft; during this same period, inflow to the Klamath estuary declined by approximately 200,000 acre-ft per yr.

During the late summer and early fall the Trinity, prior to construction of the TRD, contributed a relatively small amount to the total flow of the Klamath River (less than 15% in September). In the period following con-

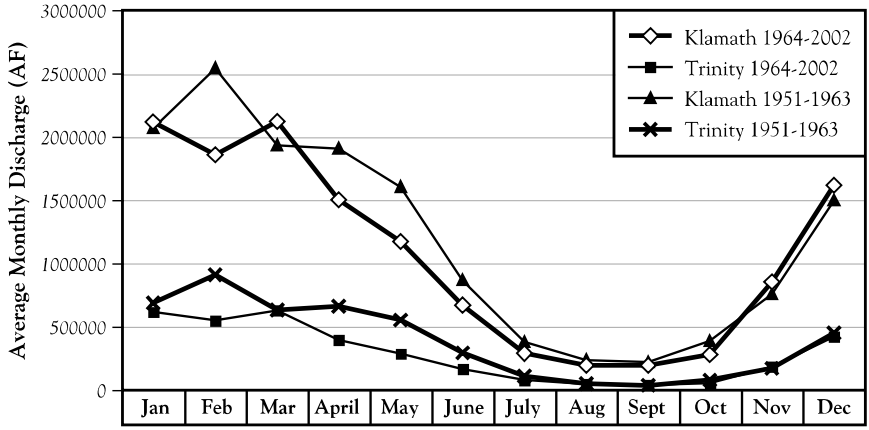


FIGURE 4-17 Average monthly discharge of the Klamath River at Klamath (USGS 11530500) and the Trinity River at Hoopa (USGS 11530000) for the period 1951–2002. The Trinity River Diversion project was constructed in 1963. Note the reduction in spring flows associated with operation of the TRD.

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struction of the TRD, there was a decline of 11% in average September flow of the Klamath main stem above the Trinity. Because of minimum flow requirements for the TRD, however, average flows from the Trinity increased during this period, partially offsetting the declines in flow from Iron Gate Dam and boosting the Trinity's relative contribution to 20%.

Spring and early summer water temperatures are of concern in the lower Klamath and Trinity due to their effect on outmigrating steelhead and salmon smolts. Field and modeling studies conducted in 1992–1994 at the confluence of the Klamath and Trinity demonstrate the relative importance of flow to water temperatures (Appendix L in USFWS/HVT 1999). Although temperature differences between the Klamath and the Trinity River can be considerable (up to 5°C or more), temperature regimes usually are quite similar at the confluence because of the long distances of travel (> 100 mi) for water released from both Iron Gate Dam and Lewiston Dam, and the broadly similar release schedules of the two reservoirs. Differences between the two rivers become pronounced only when there are large disparities in flow volumes. For example, when the Trinity flow releases are very large (by a factor of 2 to 3) compared to flow within the Klamath main stem, the Trinity cools the Klamath because its waters reach the confluence more quickly than at low flow.

The Trinity River Mainstem Fishery Restoration program (USFWS 2000) is, by necessity, focused principally on restoring spawning and rearing habitat within the main-stem Trinity River. Thus, from the viewpoint of coho recovery, the EIS process cannot be expected to result in the improvements of tributary habitat that coho require. Also, the program does not appear to have invested significant effort in evaluating its beneficial effects on the lower Klamath and its estuary. With the exception of the participation of the Hoopa Valley and Yurok Tribes, there also appears to be only minimal effort to coordinate management of the Trinity watershed with efforts to manage the rest of the Klamath watershed. The proposed flow release schedule contained within the 2001 ROD, which is currently held up in litigation, may, however, provide substantial benefit downstream of the Trinity, thereby increasing the welfare of salmon and steelhead throughout the Klamath watershed.

MINOR TRIBUTARIES TO THE LOWER KLAMATH MAIN STEM (RM 192-0)

Many small tributaries enter the main-stem Klamath between Iron Gate Dam and the mouth of the river. They drain mountainous, largely forested watersheds, but most are creeks affected to some degree by logging, past mining, grazing, and agriculture. In many of the tributaries along the stream corridors, water withdrawal leads to reductions in summer base flows.

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Water quality has not been extensively studied, but the tributaries may be particularly important in providing cold-water habitats for salmonids (Chapter 7). Of these creeks, 47 are known to have coho populations (NMFS 2002), but little is known about the specific conditions of these populations in relation to habitat and changing conditions in the basin.

In the more mountainous sections of the basin, slopes are steep, soils are unstable, and streams are affected by erosion that is exacerbated by roads and disturbance in the riparian zone. Large floods that have occurred about once per decade also have led to erosion, debris jams, and aggradation of sediments where tributaries enter the Klamath. In some cases, the bars, which consist of aggraded sediments, block flow during low-flow conditions, thus preventing fish passage, but many of the blockages have been removed in recent years (Anglin 1994).

MAIN-STEM KLAMATH TO THE PACIFIC (RM 60-0)

Over its final 60 mi the Klamath flows first southwest from Orleans to Weitchipee, where the fourth major tributary, the Trinity River, enters at RM 43. The Klamath then flows northwest to the ocean. The estuarine portion of the Klamath River is relatively short in relation to the watershed. Because intrusion of salt water varies seasonally, the length of the estuary is variable. The greatest intrusions occur at low flow, but brackish water (15–30 ppt) extends only a few mi upriver even at low flow (Wallace and Collins 1997). Tidal amplitudes in the estuary vary up to 2 m.

Flows in the lowermost Klamath are driven by a seasonally varying mixture of main-stem flow and accretions of water from tributaries. For example, water reaching the river via the Iron Gate Dam contributes less than 20% of the flow at Orleans in May and June (1962–1991). The other 80% of the flow is derived primarily from tributaries. The percentage of flow that comes from Iron Gate Dam increases over the summer. In September, over 60% of the flow originates from Iron Gate Dam (Hydrosphere Data Products, Inc. 1993). As noted above, the Trinity River and operations of the TRD exert substantial influence over hydrologic conditions of the lower Klamath and its estuary. Changes in release, even under the new ROD, have led to declines in late winter through early summer flows at the mouth of the Klamath. Fall flows, on the other hand, are augmented by increased flows from the Trinity.

Although alteration of hydrographs in a number of headwaters and tributaries has been quite substantial (e.g., Lost River, Shasta River), the overall effect of water development on total annual flow of the downstream reaches of the Klamath River is surprisingly small. Runoff from the upper Klamath basin has been reduced from approximately 1.8 million acre-ft to 1.5 million acre-ft in a year of average moisture (USGS 1995, Hardy and

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Addley 2001, Balance Hydrologics 1996), and irrigation has depleted the mean annual flow at Orleans (above the Trinity), where the flow is approximately 6 million acre-ft, by less than 10%. There has been a noticeable shift in the timing of runoff, however. Peak annual runoff occurs in March instead of April and the flows of late spring and early summer tend to be lower than they were historically. In late summer, water temperatures at Orleans exceed 15°C typically from June into September (Figure 4-18). River temperatures in excess of 20°C occur on most dates in July and August and in many years, high temperatures extend into fall. For example, temperatures over 18°C have been observed in late October. Temperatures in the Klamath may have always been high (over 15°C) in summer and fall, but it is likely that the loss of cold water from tributaries has resulted in a net increase in temperatures over the annual cycle, particularly during summer under either normal or low-flow conditions.

Even though hydrologic change in the lowermost Klamath main stem seems too small to have caused large changes in the estuary, significant impairment of the estuary could have occurred through warming of the river water and through increased organic loading caused by eutrophication and alteration of flow regimes in headwaters. The estuary could show adverse chemical conditions as a result of these changes, and coho in the estuary thus could be affected. The extent of these changes and their potential effect on coho have not been well documented, however. Information on water quality of the lowermost Klamath River is sparse.

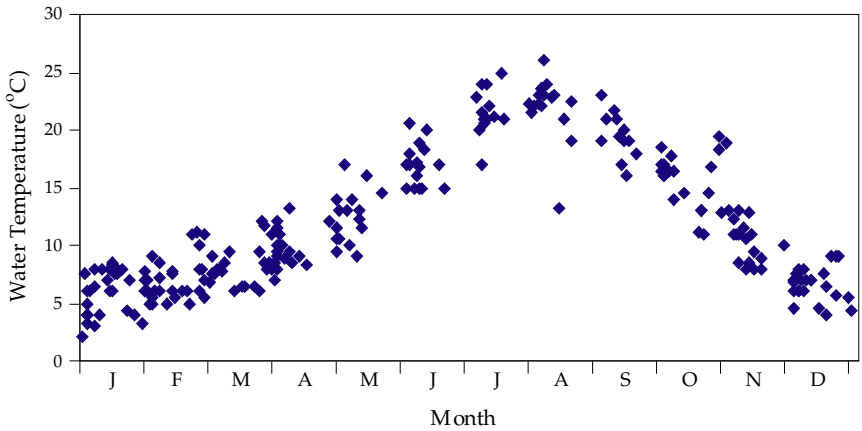


FIGURE 4-18 Water temperature (instantaneous daytime values) of the Klamath River at Orleans based on observations at USGS station 18010209, 1957–1980, plotted on a single annual time span.

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CONCLUSIONS

Most flowing waters of the Klamath basin show substantial environmental degradation involving loss of coarse gravels, excessive suspended sediment, impaired channel morphology, loss of woody riparian vegetation, major alteration of natural hydrographic features, and excessive warmth. These changes affect not only the main stems of the Klamath River and major tributaries, but also small tributaries where salmon are or could be present. While to some extent historical, degradation continues through a variety of water-management and land-use practices including irrigation, grazing, mining, and timber management. Documentation is poor for some locations, and especially so for small tributaries.

In the upper basin, the tributaries that drain into Upper Klamath Lake are poorly understood except in regard to nutrient transport. Knowledge of basic hydrology and water use is sparse, as are conditions relevant to spawning of listed suckers and refugia for sucker fry. Topics of special interest include substrate and channel quality, sediment load, and status of riparian vegetation. In the lower basin, research has documented extensive modifications of riparian habitats, especially along the Scott and Shasta rivers. Adverse changes in stream-channel structure, sediment transport, flow, and temperature are commonplace even on federal lands.

Nutrients, dissolved oxygen, temperature, flows, and physical habitat of the main stem of the Klamath River have been extensively studied. Still, additional research that would clarify the interactions between hydrology and temperature, especially as affected by water-management strategies, is needed. Considerable research on this topic is in progress, but field investigations have focused primarily on the river between Iron Gate Dam and Orleans. Conditions in the lowermost reaches of the Klamath River, including the estuary, have received less attention but are important to salmonids, as shown by the mass mortality of salmonids in 2002 (Chapter 7).

The Klamath system as a whole is nutrient-rich and productive. High concentrations of phosphorus, a key nutrient, are typical of Klamath waters because of natural sources. Anthropogenic sources may be important in some cases as well. Water-quality conditions, except temperature, are within satisfactory bounds in most cases for flowing waters. The greatest impairments involve physical features, including temperature for salmonids.

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5

Fishes of the Upper Klamath Basin

The upper Klamath basin is an ancient, isolated, and unusual environment for fish. Most, or possibly all, of the native species that live in the upper basin are endemic to it. The distinctiveness of the upper basin and its fishes has been recognized since the first ichthyologists explored it in the late 19th century (Cope 1879, Gilbert 1898), but the application of new kinds of genetic analysis to the fishes is revealing even more diversity and complexity than was previously known (e.g., Docker et al. 1999, Tranah 2001).

Since the shortnose and Lost River suckers were listed as endangered species in 1988, a great deal of attention has been paid to their biology, especially in Upper Klamath Lake, whereas the rest of the species and the rest of the basin have received comparatively little attention. The other endemic fishes, some of which may be considered for listing in the future, interact with the endangered suckers and thus complicate management practices intended to benefit them. In addition, nonnative fishes, which are abundant in the basin, affect the endangered suckers. Overall, the upper basin's land and water should be managed through an ecosystem-based approach with all native fishes in mind under the assumption that management favoring native fishes is likely to have positive effects on other ecosystem components. Failure to do this is likely to result in listing of additional species as threatened or endangered. The purposes of this chapter are to describe the factors that led to the high endemism of fishes in the upper Klamath basin and to its invasion by nonnative fishes, to give a brief summary of the biology and welfare of each of the native fishes with special

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attention to the listed suckers, an overview of the nonnative fishes, and to identify gaps in knowledge about all the fishes.

NATIVE FISHES

The fishes of the upper Klamath basin originated when a large river draining the western interior of North America flowed through the Klamath region on its way to the ocean (Minckley et al. 1986, Moyle 2002). Uplift and erosion have since caused the water in the region to flow at different times into the Great Basin to the east, into the Columbia River via the Snake River to the northwest, into the Sacramento River via the Pit River to the south, and into the lower Klamath River to the west. As the connections to large drainage basins shifted back and forth, fishes from each of the basins entered the upper Klamath basin (Minckley et al. 1986, Moyle 2002). Species that persisted through periods of change, which included drought and volcanism, evolved into the endemic fauna of the upper Klamath basin (Table 5-1). These fishes are adapted to the shallow lakes, meandering rivers, and climatic extremes of the upper Klamath basin. The closest relatives of modern fishes of the upper Klamath basin are now found in the Great Basin, Columbia River, Pit River, and lower Klamath River.

The present connection of the upper Klamath basin to the lower Klamath basin probably is fairly recent (Pleistocene, less than 1.8 million years BP), but the connection formed and was blocked more than once. Connection of the upper and lower basins led to colonization of the upper basin by anadromous Chinook salmon, steelhead, and Pacific lampreys. Repeated isolation of anadromous fishes, which occurred when the connection between the two parts of the Klamath basin was broken, left behind resident populations that now differ from parent stocks (such as redband trout and Klamath River lamprey).

The lower basin contains mainly fast-flowing, cool-water rivers and streams that are ideally suited for anadromous fishes but inhospitable to fishes of the upper basin, which are adapted to lakes or warmer streams and rivers of lower gradient. Thus, the two basins have remarkably different fishes. The absence of major physical barriers to movement of fish before installation of dams explains the former use of the upper basin by anadromous fishes and the apparent occasional entry into the upper basin of the Klamath smallscale sucker, which is abundant in the lower basin.

Only five families of fishes—Petromyzontidae, Cyprinidae, Catostomidae, Salmonidae, and Cottidae—are native to the upper basin, and the species in these families have many unusual adaptations to the environment of the basin. The lampreys and suckers of the upper basin show some interbreeding (hybridization) among species.

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TABLE 5-1 Native Fishes of the Upper Klamath Basin

Species	Adult Habitat[a]	Status[b]	Comments
Pacific lamprey, *Lampetra tridentata*	R, L	C?	Same species as in lower river but land-locked and probably distinct
Klamath River lamprey, *L. similis*	R	C	Also in lower river
Miller Lake lamprey, *L. milleri*	R, L, W	U	Once thought extinct
Pit-Klamath brook lamprey, *L. lethophaga*	W, C	C?	Shared with Pit River
Klamath tui chub, *Siphatales bicolor bicolor*	L, R, W	A	Abundant and widespread
Blue chub, *Gila coerulea*	R, W	C	Special concern species in California
Klamath speckled dace, *Rhinichthys osculus klamathensis*	W, C, R, L	C?	May be more than one form
Shortnose sucker, *Chasmistes brevirostris*	L, R	L	Listed as endangered
Lost River sucker, *Deltistes luxatus*	R, L	L	Listed as endangered
Klamath largescale sucker, *Catostomus snyderi*	R, L, W	C?	May be more than one form; declining?
Klamath smallscale sucker, *C. rimiculus*	R, W, C	R	Common in lower basin
Klamath redband trout, *Oncorhynchus mykiss* subsp.	R, L	C?	Fishery; may be more than one form: lake and stream
Coastal steelhead, *O. mykiss irideus*	R, C	E	Anadromous, common in lower basin
Chinook salmon, *O. tshawytscha*	R	E	Anadromous, common in lower basin
Bull trout, *Salvelinus confluentus*	C	L	Threatened species
Upper Klamath marbled sculpin, *Cottus klamathensis klamathensis*	C, W, R	C	Widespread in basin
Klamath Lake sculpin, *Cottus princeps*	L, R	A	Abundant in Upper Klamath Lake
Slender sculpin, *Cottus tenuis*	L, R	R	Gone from much of former range

[a]Adult habitat: L, lakes; R, river; W, warm-water creeks; C, cold-water creeks.
[b]Status in upper basin: A, abundant; C, common; E, extirpated; L, listed under federal Endangered Species Act; R, rare; U, unknown.

Petromyzontidae: Lampreys

The lampreys of the upper Klamath basin are all derived from anadromous Pacific lampreys that became land-locked, perhaps multiple times

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over millions of years. Their evolution and ecology are poorly understood. Four species are recognized (Docker et al. 1999, Lorion et al. 2000, Moyle 2002), but additional species may be uncovered as genetic studies proceed. There are two basic life cycles among lampreys: one with predatory adults and one with nonpredatory adults. Both types spend the first 3–7 yr of their lives living in mud and sand as eyeless, wormlike larvae (ammocoetes) that feed on algae and organic matter. The ammocoetes metamorphose into silvery, eyed adults. Adults of the predatory forms attach to other fish with their sucking-disc mouths, through which they remove blood and body fluids. Typically the prey survives the attack of a predatory lamprey, but the attack may impair growth and survival (Moyle 2002). Predatory lampreys engage for about a year in this feeding behavior, which enables them to grow to produce a larger number of gametes than do nonpredatory lampreys. The adults of the nonpredatory form do not feed; they live only long enough to reproduce (Moyle 2002).

The Pacific lamprey is regarded as a land-locked version of the predatory anadromous species, but the form native to the upper Klamath basin probably should be a separate taxon. Nothing is known about its ecological differences from the slightly smaller (14–27 cm) Klamath River lamprey. The Klamath River lamprey is a nonmigratory predatory species that is widespread in the upper and lower basins. Little is known about its biology except that it preys on native suckers and cyprinids, especially in reservoirs (Moyle 2002). The Miller Lake lamprey is the smallest (less than 15 cm) predatory lamprey known anywhere in the world; it occurs mainly in the Sycan and Williamson rivers, where resident prey species are abundant (Lorion et al. 2000). The Miller Lake lamprey is closely related to the nonpredatory Pit-Klamath brook lamprey, which is abundant and widespread in small streams in the upper Klamath and Pit River basins. Because of the long (about 1 million years) separation of the Pit and Klamath basins, genetic studies will probably show that the two populations belong in different taxa. The exact distribution of the four species in the watershed is not known, because most collections are of ammocoetes, which are difficult to identify in the field.

Cyprinidae: Minnows

The Klamath tui chub is widespread in the interior basins of the western United States and is divided into a number of subspecies (Moyle 2002). Some, including the Klamath tui chub, may eventually be recognized at the species level. Tui chubs are chunky, omnivorous minnows that can become large (about 30 cm) and have high longevity (20–35 yr), especially in large lakes. In the Klamath basin, they are the most abundant and widely distrib-

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uted native fish. They occur in streams, rivers, reservoirs, and lakes (Simon and Markle 1997a,b; Buettner and Scoppettone 1991) and in a wide array of habitats (Bond et al. 1988). They are tolerant of high temperature (over 30°C), low dissolved oxygen (below 1 mg/L), and high pH (10–11; Falter and Cech 1991, Castleberry and Cech 1992, Moyle 2002). Despite those tolerances, they typically are among the most abundant species in fish kills of Upper Klamath Lake (Perkins et al. 2000b), although counts of dead chubs usually do not distinguish tui chubs from blue chubs. In the last 30 years, the tui chub has declined in abundance in the Lost River, where it has changed from a dominant member to a minor component of the fish fauna (Shively et al. 2000a).

In contrast with tui chub, the blue chub is confined largely to the Klamath basin and a few adjacent basins into which it may have been introduced (Moyle 2002). It is especially abundant in lakes, reservoirs, and other warm, still habitats (Bond et al. 1988, Buettner and Scoppettone 1991). It may be the most abundant native fish in Upper Klamath Lake, although it may also be in decline there, along with most other native fishes (Simon and Markle 1997b, Moyle 2002). It clearly is in decline elsewhere in the upper Klamath basin. For example, Contreras (1973) found that the blue chub was the most abundant species in the upper part of the Lost River but that the tui chub was the most abundant in the lower half of the river. More recent sampling indicates that both species have been largely replaced by fathead minnows, brown bullheads, and other nonnative species that tolerate poor water quality (Shively et al. 2000a). Not much is known about the biology of the blue chub except that it is omnivorous, schools, and reaches a length of about 25 cm. It is somewhat less tolerant of high temperatures and low dissolved oxygen than the tui chub (Castleberry and Cech 1992) and is common in fish kills of Upper Klamath Lake (Perkins et al. 2000b).

The speckled dace is even more widespread than the tui chub in western North America and probably consists of a complex of species (Moyle 2002). Dace from both the upper and lower Klamath basins are recognized as just one subspecies, but the two forms probably are distinct, and the upper basin probably supports more than one taxon (M. E. Pfrender, Utah State University, personal communication, 2002). The speckled dace is common in the upper basin but is most abundant in cool streams associated with rocks and gravel (Buettner and Scoppettone 1991, Bond et al. 1988). Even so, Castleberry and Cech (1992) found that it could withstand high temperatures (28–34°C) and low concentrations of dissolved oxygen (1–3 mg/L). The status of the speckled dace in the basin is not known, because collections are biased toward the larger fishes. It apparently has become very uncommon in the Lost River, however (Shively et al. 2000b).

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Catostomidae: Suckers

The four species of suckers in the Klamath basin (Table 5-1) have an interesting and long evolutionary history (Moyle 2002) and probably once were the most abundant fishes, in terms of biomass, in the lakes and large rivers. The listed shortnose sucker and Lost River sucker, which have been the focus of most fish studies in the upper basin, will be treated in the last part of this chapter. The Klamath smallscale sucker is rare (or perhaps absent since the construction of Copco Dam) in the upper basin, although it is found in upper Jenny Creek, a tributary to Copco Reservoir. It is abundant in the lower basin (see Chapter 7). The Klamath largescale sucker is resident in the upper basin. All four species show some evidence of hybridization with each other (Tranah 2001).

The Klamath largescale sucker, which becomes large (about 50 cm) and has a long lifespan (31 yr or more), as do the shortnose and Lost River suckers, is one of the least understood fish in the basin (Moyle 2002). It appears to be mainly a resident of large rivers, although a small population exists in Upper Klamath Lake, and it is rare or absent in the Lost River (Koch et al. 1975, Buettner and Scoppettone 1991, Shively et al. 2000a). It apparently is common and widely distributed in the Williamson, Sprague, and Wood rivers (Reiser et al. 2001). In Upper Klamath Lake, the Klamath largescale sucker is found mainly near inflowing streams; this suggests a low tolerance for lake conditions, but it has been found at temperatures near 32°C in environments of dissolved oxygen at 1 mg/L and pH over 10 (Moyle 2002). Lake populations of largescale suckers migrate for spawning in March and April; peak spawning activity occurs a month or so earlier than that of shortnose and Lost River suckers. Radio-tagged fish have migrated as far as 128 km upstream, presumably to find gravel for spawning (Reiser et al. 2001). The Klamath largescale sucker hybridizes with the shortnose and Lost River suckers. Genetic studies by Tranah (2001) suggest that the largescale suckers in the Sprague River belong to a different taxon from other largescale suckers in the basin.

The status of the Klamath largescale sucker is poorly understood. The lake populations probably are similar to those of the shortnose and Lost River suckers in having declined in abundance. The status of stream populations is not known, although they are assumed to be widespread and abundant (Reiser et al. 2001).

Salmonidae: Salmon and Trout

The bull trout is a predatory char that is widely distributed in the northwestern United States but is considered a relict species in the Klamath basin. It apparently entered the Klamath basin when it was connected to the

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Snake River but then became isolated. Genetic evidence reflects isolation and suggests that the bull trout of the upper Klamath basin could be assigned to a distinct taxon or evolutionarily significant unit (Ratliff and Howell 1992). The bull trout is known from only 10 creeks in the upper Klamath basin—four tributaries to the Sprague River, four to the Sycan River, and two to Upper Klamath Lake (Ratliff and Howell 1992, Buchanan et al. 1997)—although it has been extirpated or is at risk of extirpation in most of these creeks. An important characteristic of streams containing bull trout is high water quality; temperatures do not exceed 18°C in these streams (Moyle 2002). The bull trout tends to disappear from streams with degraded water quality even if the streams can support other kinds of trout. The bull trout also declines when the brook trout invades its habitat. Hybridization between the bull trout and the brook trout has taken place in some Klamath basin streams (Markle 1992). Threats to the existence of the bull trout are not peculiar to the Klamath basin; they occur throughout its range. Thus, the bull trout of the upper Klamath basin was listed by the U.S. Fish and Wildlife Service (USFWS) in 1998 as threatened.

The bull trout, like the endangered suckers of the upper basin, demands special attention in the future. Unlike the suckers, however, the bull trout is spatially separated from the Klamath Project and most other water management because its distribution is restricted primarily to headwaters that are remote from Upper Klamath Lake or the lower reaches of tributaries that are so important to suckers. At present a good deal of attention is being given to the welfare of bull trout, but much work remains to be done.

The redband trout is a resident rainbow trout whose ancestors entered the upper Klamath basin when it was connected to the Columbia Basin via the Snake River (Behnke 1992). Coastal rainbow trout (steelhead) later entered the upper basin, but the redband trout derived from the Columbia Basin maintained its identity and is recognizable by its morphology and color. Behnke (1992) indicates that there are two types of redband trout in the basin: a small form resident in isolated streams and the form present in Upper Klamath Lake; he suggests that the lake form is so distinctive (for example, it has large numbers of gill rakers, an adaptation to life in lakes) that it deserves subspecies designation (as *O. m. newberrii*). The Oregon Department of Fish and Wildlife (ODFW), however, regards all redband trout in the interior basins of Oregon as belonging to one taxon, even though it states that the Klamath Lake redband trout is "unique in terms of life history, meristics, disease resistance, and allozyme variation" (Bowers et al. 1999). The various stream populations in the basin also show genetic evidence of isolation from one another (Reiser et al. 2001). Regardless of taxonomic position, these fish have persisted because of their ability to thrive in lake and stream conditions that would be lethal to most salmonids.

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Behnke (1992) wrote of observations he made on Upper Klamath Lake in September 1990 (p. 181): "In clear-water sections influenced by spring flows, hundreds of large, robust trout from about 1 to 5 kg could be readily observed. In shallow (2 m) Pelican Bay, in the midst of a bloom [of bluegreen algae] (I estimated a Secchi disk clarity of about 40 cm), I caught a magnificent trout of 640 mm and 2.3 kg." This is consistent with continuing reports of a strong summer fishery for trout, especially in Pelican Bay (e.g., Hoglund 2003). Water temperatures in Upper Klamath Lake in summer are 20–25°C, occasionally spiking to 27°C, and dissolved oxygen may drop below 4 mg/L for several days (Perkins et al. 2000b). Springs and the mouths of streams in Pelican Bay, which apparently have higher water quality than the lake, may serve as refuges for the trout, especially during episodes of very poor water quality in the lake. Trout have been reported in the lake's summer fish kills, but the only example of mass mortality was in 1997, when about 100 large trout were found dead (Perkins et al. 2000b).

The lake population of redband trout is adfluvial; it migrates up into the Wood, Williamson, and Sprague rivers for spawning during spring. The rivers also support resident populations of these trout, as does the river below Upper Klamath Lake, mostly above Boyle Dam (Bowers et al. 1999). Isolated populations, which are genetically distinct from the Klamath Lake and river populations, exist in the upper Williamson and Sprague rivers and in Jenny Creek, which flows into Iron Gate Reservoir (Bowers et al. 1999).

Hatchery rainbow trout (coastal stock) in the past have been stocked in Klamath basin streams, and some interbreeding with native redband trout was noted. Stocking now is limited to Spring Creek, which flows into the lower Williamson River. The hatchery fish apparently have poor survival because they are not resistant to endemic disease and are not adapted to high pH (Bowers et al. 1999).

Redband trout are doing surprisingly well in the Klamath basin, considering all the changes that have taken place. The fishery for the lake and river populations is an important recreational resource. The populations of small streams are vulnerable, however, to habitat degradation by roads, grazing, and other activities. The lake and river populations will need protection from adverse water quality and nonnative species and probably would benefit from improved habitat in the rivers and improved access to upstream habitat (Bowers et al. 1999).

Cottidae: Sculpins

The sculpins are a poorly studied group in the Klamath basin despite the presence of at least three endemic species (Klamath Lake sculpin, slender sculpin, and Upper Klamath marbled sculpin). There may be additional taxa in the watershed as well (Bentivoglio 1998).

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The Klamath Lake sculpin apparently is the most abundant sculpin in Upper Klamath Lake. It is caught in large numbers in the lake with bottom trawls (D. Markle, Oregon State University, personal communication, 2001) and in smaller numbers with beach seines and trap nets (Simon and Markle 1997b). The abundance of this sculpin is estimated to be in the millions (Simon et al. 1996). It is present only in Upper Klamath and Agency lakes and in springs and creeks that flow into the west side of Upper Klamath Lake (Bentivoglio 1998). The present distribution coincides with the known historical distribution of the species. Little is known about its environmental requirements, but it lives mainly in offshore areas with bottoms of sand and silt and appears to be able to withstand widely varied lake conditions. No Klamath Lake sculpins have been reported in the fish kills of Upper Klamath Lake, but dead fish of this species would not float and so would be easy to overlook. The apparent ability of the Klamath Lake sculpin to live in conditions of poor water quality (especially low dissolved oxygen) is similar to that of prickly sculpin (*Cottus asper*) in Clear Lake of central California which, like Upper Klamath Lake, is subject to massive blooms of cyanobacteria (Moyle 2002).

The slender sculpin apparently once was common in the Williamson, Sprague, Sycan, and Lost rivers and in Upper Klamath Lake (Bentivoglio 1998). Bentivoglio (1998) collected sculpins throughout the upper basin in 1995–1996, however, and found slender sculpins only in the lower Williamson River and a few in Upper Klamath Lake. Simon and Markle (1997b) also recorded small numbers in Upper Klamath Lake. Little is known about the ecology of this fish, although it seems to require coarse substrates and high water quality; it is especially characteristic of cold springs. Its closest relative is the rough sculpin (*C. asperimmus*) of the Fall River in California (Robins and Miller 1957), which requires cold, spring-fed streams (Moyle 2002). It is fairly long-lived for a sculpin (7 yr) but is small (rarely longer than 75 mm; Bentivoglio 1998). Overall, the slender sculpin appears to have disappeared from much of its native range and is uncommon in most areas where it is found today.

The Upper Klamath marbled sculpin is the most widely distributed sculpin in the Klamath basin (A. Bentivoglio, USFWS, personal communication, 2002). It is found in most streams and rivers in the basin in a wide range of conditions, including summer temperatures over 20°C (Bond et al. 1988). It is most abundant among coarse substrates in the larger streams where water velocities are moderate to low (Bond et al. 1988). In the Lost River basin, it is known mainly from riffles in Willow and Boles Creeks (Koch et al. 1975) but has become scarce in recent years (Shively et al. 2000a). It is largely absent from the reservoirs in the basin, at least in California (data in Buettner and Scoppettone 1991), but is fairly common in Upper Klamath Lake (Simon et al. 1996, Simon and Markle 1997b). It

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occurs mostly on soft bottoms in the lake and apparently enters the water column to feed at night (Markle et al. 1996). It has been recorded in at least one of the fish kills of Upper Klamath Lake (Perkins et al. 2000b). The marbled sculpin, like most stream sculpins, generally hides under or among rocks, where it feeds on benthic invertebrates (Moyle 2002). Females glue their eggs to the bottoms of rocks and logs where developing embryos are tended by males until they hatch. The larvae are benthic and do not move far from their natal site. They become mature in their second summer and live 4–5 yr (Moyle 2002). The details of their ecology and life history in the upper Klamath basin have not been described.

NONNATIVE FISHES

In the last century, the upper Klamath basin has been invaded by 17 nonnative species (Table 5-2), 15 of which were introduced for sport fishing or for bait. Most of the 17 are not particularly common in the basin, but some are abundant and widespread (or are spreading), and their effects on native fishes are poorly understood. One of the most recent invaders is the fathead minnow, which is now one of the most abundant fishes in Upper Klamath and Agency lakes (Simon and Markle 1997a). The Sacramento perch, which was introduced into Clear Lake in the 1960s, has the potential to become very abundant in other lakes of the basin (Moyle 2002). Other introduced species—especially yellow perch, brown bullhead, and pumpkinseed—are locally abundant, especially in reservoirs and sloughs or ponds (Buettner and Scoppettone 1991, Simon and Markle 1997b). Brook trout, brown trout, and nonnative strains of rainbow trout are common in cold-water streams and have replaced native redband trout and bull trout in many areas. One concern is that future changes in water quality in the basin may promote further expansion of nonnative species.

The fathead minnow, which is native to eastern North America, appeared in the Klamath basin in the early 1970s, perhaps as a result of release of fish used in bioassay work (Simon and Markle 1997a). By 1983, it was common in Upper Klamath Lake and by the early 1990s it had spread to the Lost River system (Simon and Markle 1997a, Shively et al. 2000a). It was collected in the lower Klamath River in 2002 (M. Belchik, unpublished memo). Fathead minnows often are the most abundant species at sampling sites. Their effects on other fishes are not well understood, although declines in catches of tui chub and blue chub have been associated with their ascendance.

The Sacramento perch is native to central California, where it has largely disappeared from its native habitats. It survives mainly when introduced into alkaline waters outside its native range (Moyle 2002). It was introduced by the California Department of Fish and Game into Clear Lake in the 1960s and spread throughout the Lost River and into the Klamath

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TABLE 5-2 Nonnative Fishes of the Upper Klamath Basin

Species	Adult Habitat[a]	Status[b]	Comments
Goldfish, *Carassius auratus*	L, R, P	U	Locally common
Golden shiner, *Notemigonus chrysoleucas*	L, R, P	R	Bait fish
Fathead minnow, *Pimephales promelas*	L, P	A	Probably still spreading
Brown bullhead, *Ameiurus nebulosus*	P, L, W	A	Widespread
Black bullhead, *A. melas*	P, L	U	Localized populations
Channel catfish, *Ictalurus punctatus*	L, R	?	May not be established
Kokanee, *Oncorhynchus nerka*	L	U?	Localized populations?
Rainbow trout, *O. mykiss*	L, R, C	C	Widely planted, hatchery strains
Brown trout, *Salmo trutta*	C, R	C	—
Brook trout, *Salvelinus fontinalis*	C	U	Localized in headwaters
Sacramento perch, *Archoplites interruptus*	L, P, R, W	C	Spreading
White crappie, *Pomoxis annularis*	L, R	U	Abundant in a few reservoirs
Black crappie, *P. nigromaculatus*	L, P	U	Recorded in Lost River
Green sunfish, *Lepomis cyanellus*	P, W	C	Widespread in reservoirs
Bluegill, *L. macrochirus*	P, W	U	Locally abundant
Pumpkinseed, *L. gibbosus*	L, R, P	C	Widespread
Largemouth bass, *Micropterus salmoides*	P, L, R	C	Common in reservoirs
Yellow perch, *Perca flavescens*	L, R, P	A	Abundant in large reservoirs

[a]Habitats are listed in order of importance for each species: C, cold-water streams; L, lakes; P, ponds and reservoirs; R, rivers; W, warm-water streams.
[b]Status in upper basin: A, abundant; C, common; R, rare; U, uncommon.

River downstream to Iron Gate Reservoir (Buettner and Scoppettone 1991). It is not particularly abundant in most areas where it is present. It has not yet established itself in Upper Klamath Lake. If it does colonize Upper Klamath Lake, it will probably become abundant there, as it has in other shallow lakes (Moyle 2002). It feeds primarily on insect larvae (especially midges), but adults can be piscivorous (Moyle 2002).

ENDANGERED SUCKERS OF THE KLAMATH BASIN

All four native sucker species of the Klamath basin are endemic. The endangered Lost River sucker and shortnose sucker are part of a species

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group of suckers that are large, long-lived, late-maturing, and live in lakes but spawn primarily in streams; collectively, they are commonly referred to as lake suckers. Lake suckers populated much of the Snake River, Great Basin, and Lahontan Basin region (Miller and Smith 1981, Scoppettone and Vinyard 1991). Present-day species in the genus *Chasmistes* include not only the shortnose sucker (*C. brevirostris)* but also the cui-ui (*C. cujus*) of Pyramid Lake, Nevada; the June sucker (*C. liorus*); and a species that recently became extinct, the Snake River sucker (*C. muriei*) of Wyoming. Lost River suckers and shortnose suckers (Figure 5-1) are closely related to the more speciose and widely distributed sucker genus *Catostomus*; some recent taxonomic treatments place Lost River suckers in this genus (e.g., Moyle 2002).

The lake suckers differ from most other suckers in having terminal or subterminal mouths that open more forward than down, an apparent adaptation for feeding on zooplankton (small swimming animals) rather than suctioning food from the substrate (Scoppettone and Vinyard 1991). Zooplanktivory can also be linked to the affinity of these suckers for lakes, which typically have greater abundances of zooplankton than do flowing waters.

Historically, Lost River suckers and shortnose suckers occurred in the Lost River and upper Klamath River and their tributaries, especially Tule

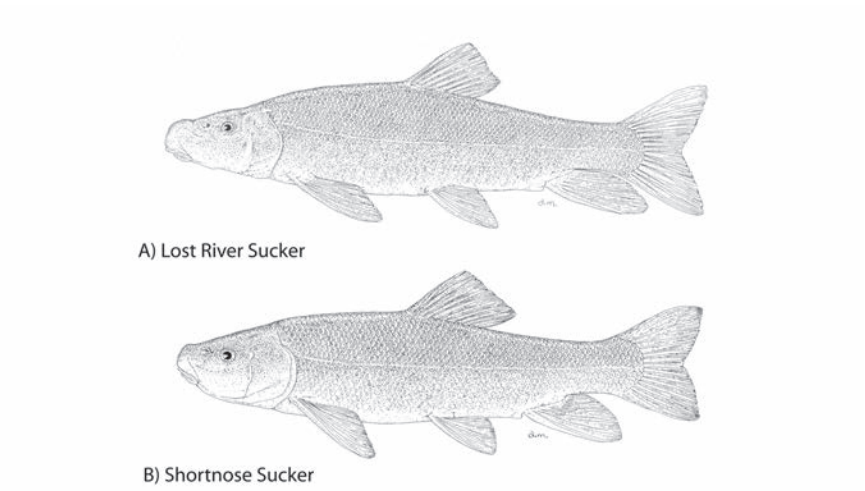


FIGURE 5-1 Endangered suckers of the Klamath River basin. (A) A Lost River sucker from Clear Lake; (B) a shortnose sucker from Clear Lake. Source: Moyle 2002, pp. 199, 203. Drawings by A. Marciochi. Reprinted with permission; copyright 2002, University of California Press.

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Lake, Upper Klamath Lake, Lower Klamath Lake, Sheepy Lake, and their tributaries (Moyle 2002; USFWS 2002, Appendix D). Their current distribution (Table 5-3; Figures 5-1 and 5-2) reflects a combination of local extirpations and redistribution through water management. Suckers no longer occur in Lower Klamath Lake or Sheepy Lake, which were extensively drained in the 1920s; the populations in Tule Lake apparently do not reproduce successfully. Juveniles of Lost River and shortnose suckers have been found in much of the Lost River, but they probably originate in Miller Creek (Shively et al. 2000a). An additional population, probably consisting of shortnose suckers, was extirpated from nearby Lake of the Woods, Oregon, in 1952 when government agencies poisoned the lake to remove potential competition with trout (53 Fed. Reg. 27130 [1988]). The endangered suckers also are found in the main-stem reservoirs of the Klamath irrigation project (Chapter 3; Figure 1-4), but these populations appear to be nonreproducing (Desjardins and Markle 2000, USFWS 2002). Reproducing populations exist in Clear Lake and perhaps the Lost River. Shortnose suckers also have a reproducing population in Gerber Reservoir (Moyle 2002, USFWS 2002).

Accounts of sucker distribution often are complicated by difficulties in distinguishing species, especially when the fish are young. Lost River suckers and shortnose suckers are partly distinguished from Klamath largescale suckers and Klamath smallscale suckers by greater maximum size. The Lost River sucker can be 26–40 in. long, the shortnose sucker no longer than 21 in., the Klamath largescale sucker no longer than 18 in., and the Klamath smallscale sucker, a poorly studied species, at least 18 in. The Lost River sucker differs from the shortnose sucker and the Klamath largescale sucker with respect to some anatomical features of the head, mouth, lips, gill rakers, and body shape (Cunningham et al. 2002); it can generally be distinguished by its longer head and narrower, smaller mouth (see Figure 5-1).

The life histories of Lost River suckers and shortnose suckers are in some ways similar to those of anadromous salmon. Salmon spawn in freshwater and live most of their lives at sea before returning to their natal (birth) rivers to spawn and die. Similarly, the adults of the endangered suckers commonly ascend from lakes to rivers to spawn, the eggs hatch in gravel, and the larvae float or swim downstream to lakes, where they grow and mature before returning to rivers or springs to spawn. Unlike salmon, lake suckers spawn repeatedly. It is not known which individuals return consistently to their natal rivers to spawn, but at least 50% do return at least one time to a river in which they have previously spawned (Cunningham et al. 2002). There are many exceptions to these generalizations. For example, some individuals or subpopulations spawn in lakes, whereas others live their entire lives in rivers or streams. The repeated spawning of the

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TABLE 5-3 Current and Former Distribution of Adult Lost River Suckers and Shortnose Suckers in the Klamath Basin

Habitats[a]	Map Code	Lost River Suckers	Shortnose Suckers	Reference
Upper Klamath Lake		+	+	Moyle 2002
Peripheral Springs				
Boulder Springs	1	Spawn	Spawn	Hayes et al. 2002
Cinder Flats	2	Spawn	Spawn	Hayes et al. 2002
Ouxy Springs	3	Spawn	Spawn	Hayes et al. 2002
Silver Bldg. Springs	4	Spawn	Spawn	Hayes et al. 2002
Sucker Springs	5	Spawn	Spawn	Hayes et al. 2002
Harriman Springs	6	Spawn*	–	59 Fed. Reg. 61744 [1994]
Barkley Springs	7	Spawn*	–	59 Fed. Reg. 61744 [1994]
Tributaries				
Wood River	8	Spawn*[b]	Spawn	Markle and Simon 1994
Lower Williamson River	9	Spawn	Spawn	Cunningham et al. 2002
Upper Williamson River	10	0[b]	0	
Sprague and Sycan	11	Spawn	Spawn	Janney et al. 2002
Lake of the Woods, OR	12	0	+*[c]	Moyle 2002
Lower Klamath Lake, CA	13	+*	+*	Scoppettone and Vinyard 1991
Clear Lake, CA[d]	14	+	+[e]	59 Fed. Reg. 61744 [1994], USFWS 2002
Willow Creek	15	Spawn	Spawn	Moyle 2002
Boles Creek	16	Spawn	Spawn	Moyle 2002
Gerber Reservoir	17	0	+[e]	59 Fed. Reg. 61744 [1994]
Sheepy Lake	18	+*	+*	Moyle 2002
Sheepy Creek	19	Spawn*	–	Moyle 2002
Tule Lake	20	(+)	(+)	USFWS 2002
Lost River	21	Spawn[f]	Spawn	59 Fed. Reg. 61744 [1994]
J.C. Boyle Reservoir	22	(+)	(+)	53 Fed. Reg. 27130 [1988]
Copco Reservoir	23	(+)	(+)[g]	Scoppettone 1988, Scoppettone and Vinyard 1991
Iron Gate Reservoir	24	(+)	(+)	Moyle 2002
Klamath River	25	(+)	(+)	59 Fed. Reg. 61744 [1994]

[a]Tributary streams and springs are listed under lakes into which they flow.
[b]R. S. Shively, U. S. Geological Survey, Klamath Falls, Oregon, personal communication, 2002.
[c]An extirpated population of *Chasmistes* in Lake of the Woods, Oregon, originally referred to as *C. stomias* (Andreasen 1975), may have been another population of shortnose suckers (Moyle 2002).
[d]Drainage for Clear Lake includes numerous small reservoirs and tributary streams that contain both species (USFWS 2002, Appendix D).
[e]Shortnose suckers in Clear Lake and Gerber Reservoir may have been confused with Klamath largescale suckers or with shortnose suckers and Klamath largescale sucker hybrids (D. F. Markle, Oregon State University, personal communication 2002), although genetic information indicates that hybridization is rare (D. Buth, University of California at Los Angeles, and T. Dowling, Arizona State University, personal communications, July, 2002).
[f]Larvae in Lost River apparently do not survive (Moyle 2002).
[g]Shortnose suckers in Copco Reservoir may have hybridized with Klamath smallscale suckers (Scoppettone and Vinyard 1991).
Abbreviations: +, currently present; +*, previously present; (+), small population, probably nonbreeding; Spawn, current or previous spawning; Spawn*, spawning inferred from fish in spawning condition; 0, not known ever to occur; –, lack of information.

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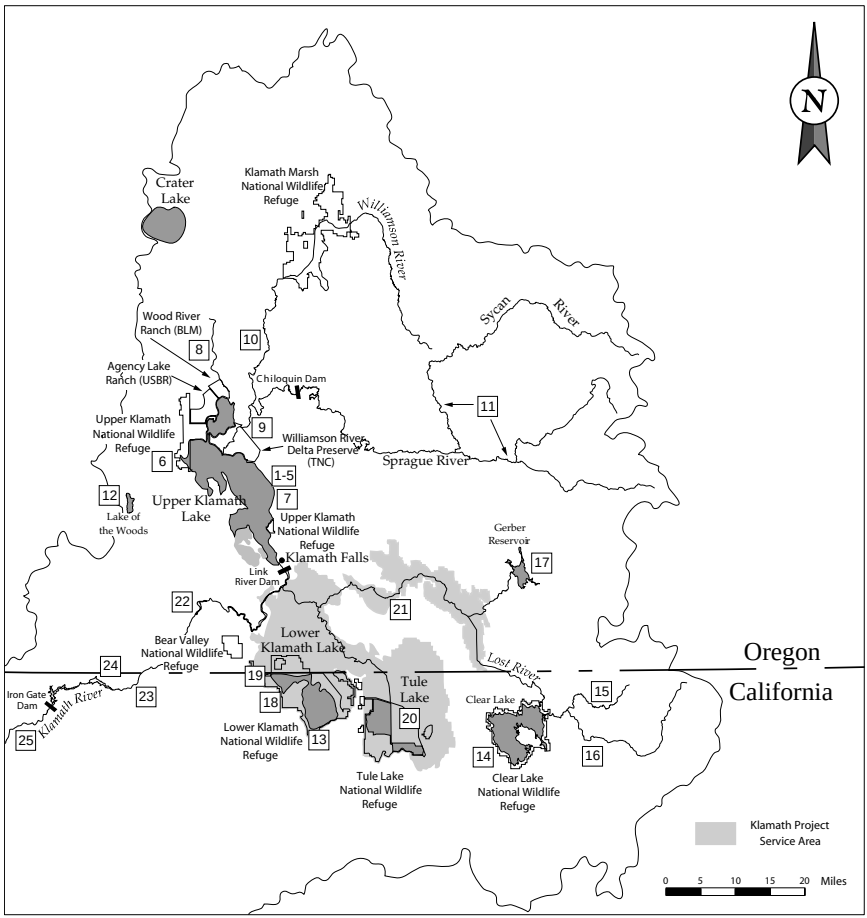


FIGURE 5-2 Locations of current and past populations of Lost River suckers and shortnose suckers. Numbers indicate current or former locations of suckers; light gray shows the area of the Klamath Project; dark gray shows standing water. See Table 5-3 for additional information.

endangered suckers, combined with their exceptional longevity, allows individual adults to contribute to multiple year classes. Successful year classes are crucial to survival of both species, as explained below.

The requirements of the two species of endangered suckers are best understood in the context of their life-history stages, as described below. Unless a species-specific difference is indicated, the description of any given life-history feature is assumed to apply to both species. The quantity and quality of information on the species have increased substantially since the fishes were listed as endangered in 1988.

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Spawning

Spawning occurs in tributary streams, in springs caused by upwelling of groundwater in lakes, and around springs in rivers. The suckers may migrate as little as 2–4 mi up a stream from a lake (for example, up Willow Creek from Clear Lake), or over 20 mi (for example, up Boles Creek from Clear Lake and up the Sprague River to RM 74 from Upper Klamath Lake; R. S. Shively, U. S. Geological Survey, Klamath Falls, Oregon, personal communication, 2002). Upstream migrations commence when snowmelt leads to increases in river discharge—from early February through early April for Lost River suckers and from late February to late May for shortnose suckers (Moyle 2002). Spawning can occur at temperatures of 5.5–19°C (Moyle 2002). For example, migrations of Lost River suckers up the Williamson River in 2001 were concentrated in April and May and showed a peak in mid-April. Spawning of shortnose suckers peaked in mid-May 2001 (Cunningham et al. 2002). In any given year, some temporal separation of spawning among species may occur. Klamath largescale suckers migrate first and are followed by Lost River suckers and then shortnose suckers (Coleman et al. 1988, cited in Scoppettone and Vinyard 1991), although migrations of the three may overlap (USGS 2002).

Shortnose suckers were numerically dominant in the lower Williamson River in 2001, but Lost River suckers outnumbered shortnose suckers by more than 10 to 1 at Chiloquin Dam, about 9 mi farther upstream (Cunningham et al. 2002, Janney et al. 2002). Thus, the Lost River suckers may be more likely than shortnose suckers to migrate upriver to spawn, or perhaps the two species react differently to dams. In 2001, 30 shortnose suckers were collected at lakeshore sites, compared to 900 found in the Williamson River, whereas Lost River suckers were five times more abundant at spawning sites in the lake than in the Williamson River system (Hayes et al. 2002, Cunningham et al. 2002). This suggests that spawning by shortnose suckers in Upper Klamath Lake is relatively rare at present. Shortnose suckers that do spawn in the lake use the same spawning sites as Lost River suckers. In flowing water, the suckers spawn in riffles or runs with moderate current (less than 3.3 ft/s) over cobble or gravel bottoms at depths of 0.7–6.6 ft (Scoppettone and Vinyard 1991, Perkins and Scoppettone 1996, Markle and Cooperman 2002). Gravel appears to be preferred; patches of gravel added to a spawning area will be used if flow and depth are appropriate (Golden 1969, Scoppettone and Vinyard 1991, Moyle 2002). Spawning in the upper Sprague River appears to be concentrated around springs (L. Dunsmoor, cited in USFWS 2002). Spawning behavior is similar to that of other suckers in that one female spawns with several males and the fertilized eggs, which are 2.5–3.2 mm in diameter, drop into spaces in the gravel.

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Sampling at six known spawning sites along the eastern shoreline of Upper Klamath Lake (Sucker Springs, Silver Building Springs, Ouxy Springs, Boulder Springs, Cinder Flats, and Modoc Point) indicates that Lost River suckers spawning in the lake are slightly larger than those ascending the Williamson River (lake fish were 150–200 mm longer: Hayes et al. 2002, $p < 0.05$). Nearly 80% of the fish captured at lake spawning sites occurred at three of the six sites (Sucker Springs, Silver Building Springs, and Ouxy Springs). As is common among spawning suckers, males outnumber females at spawning sites. Sex ratios at nonspawning sites in Upper Klamath Lake indicate a predominance of females; males tend to remain at spawning sites, whereas females do not (Coen et al. 2002).

Lake spawning occurs in 0.5–3.7 ft of water; 95% of successful spawnings occur in water deeper than 1.0 ft, and about 35% occurs at 1–2 ft (Klamath Tribes, in USFWS 2002). Spawning aggregations were present from mid-March to early May. Peak abundances at all sites occurred during the first 2 wk of April, and a second peak occurred at Sucker Springs, the most heavily used site, in late April. The relative spawning condition (prespawn, ripe, postspawn) of fish captured in Upper Klamath Lake from February to June 2001 suggests that some eastern regions near spawning sites, such as Modoc Point and Goose Bay, are staging areas for spawning and that some western bays are used more heavily after spawning (Coen et al. 2002). The temporal sequence of capture of the sexes during the spawning season also suggests that males move to staging and spawning areas ahead of females.

Evidence from Hayes et al. (2002) is consistent with earlier conclusions by Perkins et al. (2000b) that river spawners and lake spawners constitute subpopulations of Lost River suckers in Upper Klamath Lake, but does not prove complete segregation of populations. Of 201 Lost River suckers tagged during previous years and recaptured at springs in the lake in 2001, with some recaptures separated by as much as three yr, 198 (98.5%) were captured both times at eastern shore spawning sites. The other three fish had been tagged in the Williamson River. Also, 76% of the fish recaptured at the Chiloquin Dam fish ladder in 2001 had been tagged originally at the ladder in previous years, and 20% of the fish had been tagged at other sites on the Williamson River (Janney et al. 2002). About half the Lost River suckers caught in Upper Klamath Lake were from sites other than those where they were tagged, either for within-year or between-year recaptures; this indicates that lake-spawning fish do not restrict their breeding activities to a single lacustrine spawning site. Ten shortnose suckers captured in 2001 were recaptures from previous years; all had originally been captured at shoreline sites. Movement between lake sites was apparent, as with the Lost River sucker.

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Female Lost River suckers contain 44,000–236,000 eggs, and female shortnose suckers contain 18,000–72,000 eggs. Larger females bear more eggs, as is typical of most fishes (USFWS 2002). It is unknown whether individuals of either species spawn more than once each year or whether individuals spawn every year. Recapture data on lake spawners (Perkins et al. 2000b, Hayes et al. 2002) suggest that some Lost River suckers spawn every year. Cui-ui (*Chasmistes cujus*) are known to spawn several hundred times over a period of 3–5 days (Scoppettone and Vinyard 1991); Lost River suckers and shortnose suckers might behave similarly. Coen et al. (2002) found that 75% of male but only 40% of female Lost River suckers and 69% of male but only 46% of female shortnose suckers captured in February–June 2001 were in spawning condition (see also Coen and Shively 2001). These observations suggest that a large portion of the adult population of both species is not in spawning condition during any given spawning season. Observations of tagged fish frequenting more than one lake spawning site in a year suggest multiple spawning events for individual fish. Frequency of spawning is relevant to the populations' potential for recovery.

Larvae

Embryos remain in the gravel for 2–3 wk (USFWS 2002). The subsequent larval stage lasts for about 40–50 days (Markle and Cooperman 2002). Stream-spawned larvae emerge ("swim up") from the gravel and immediately move downstream, mostly at night, in late March to early June, depending on spawning date (Moyle 2002). The abundance of larvae peaked in the Williamson River system 21 days after the peak in spawning (Coleman et al. 1988, cited in Scoppettone and Vinyard 1991). Larvae spawned in the Williamson River system pass to Upper Klamath Lake in as little as a day. More than 99% of larvae enter the lake before the caudal fin has formed and well before the yolk sac is absorbed, after which the fish must feed (Cooperman and Markle 2000). How these movement rates are related to location of spawning (lower Williamson River or Sprague River below or above Chiloquin Dam) and how different they would be if more fish spawned above the dam are unknown. Larval mortality in the Williamson River is around 93% per day (L. Dunsmoor, personal communication, in Markle and Cooperman 2002). Mortality in fishes with planktonic larvae is in general very high (Houde 1987, 1997).

Larval habitat is best described as shallow, nearshore, and vegetated in both rivers and lakes (Figure 5-3) except in Clear Lake and Gerber Reservoir, which lack vegetation (Klamath Tribe 1991, Markle and Simon 1994, Reiser et al. 2001). Larvae are most abundant in the northeastern portion of Upper Klamath Lake, including the Williamson River estuary and the lower Williamson River (Markle and Cooperman 2002). In Upper Klamath

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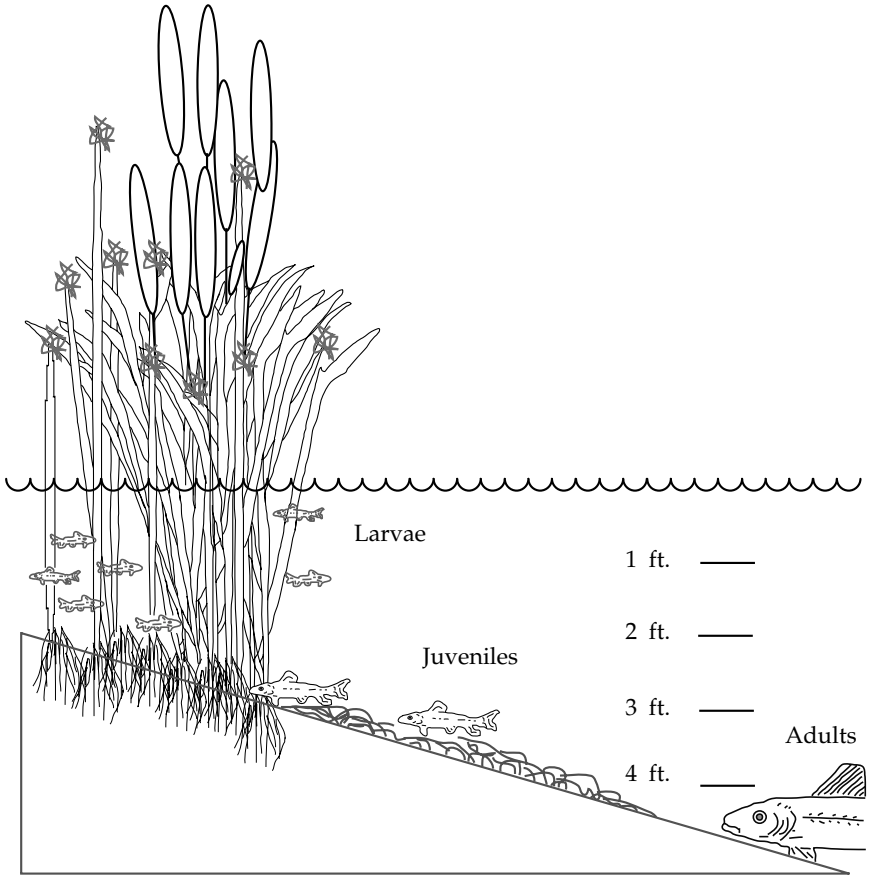


FIGURE 5-3 Generalized view of habitat of young suckers in Upper Klamath Lake. Source: USFWS 2002, p. 83.

Lake, larvae first concentrate near emergent vegetation at the mouth of the Williamson River for several weeks and then appear in other regions of the lake where emergent vegetation is found; that this process can continue for more than 2 mo is not surprising, given the protracted spawning period of the suckers (Cooperman and Markle 2000).

Studies of the larval use of habitat have focused on the importance of depth and vegetation as components of habitat. Observations by Coleman et al. (1988), Buettner and Scoppettone (1990), the Klamath Tribes (Klamath Tribe 1991; Klamath Tribe, Natural Resources Department, Chiloquin, Oregon, unpublished material, 1996), Cooperman and Markle (2000), and Reiser et al. (2001) indicate use of shallow water (less than 4.3 ft and

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often less than 20 in.) sometimes in areas devoid of cover but more usually near emergent vegetation, such as bullrush beds. Larvae use emergent vegetation primarily from early May through late June, although larvae may be found up to mid-July (see Reiser et al. 2001) because spawning continues into late May. Submerged aquatic vascular plants apparently are less important than emergent vegetation (Cooperman 2002), probably because macrophyte beds are seldom well developed in spring, when much of larval growth occurs. Larvae may not necessarily aggregate within dense vegetation itself but rather near it or in openings in the vegetation in areas described as "pockets of open water surrounded by emergent vegetation," or "the open water/emergent vegetation interface" (Reiser et al. 2001, p. 4–9).

Successful spawning and recruitment of suckers in Clear Lake, which is largely devoid of emergent and submerged vegetation, show that larvae can survive without such vegetation. Clear Lake is very turbid, however, and this may provide protection from visual predators. Laboratory tests show that predation on larvae by fathead minnows is highest when larvae lack cover (Dunsmoor 1993). Young and small fishes in freshwater and marine habitats worldwide often take refuge in dense vegetation when threatened by predators, although larvae of some species are entirely pelagic.

Clear Lake contains flooded annual grasses and herbs and emergent and submerged vegetation in tributaries that may be used by larvae, and it has fewer introduced predators, such as yellow perch and fathead minnows, than does Upper Klamath Lake (USFWS 2002). Thus, successful recruitment in Clear Lake does not demonstrate that vegetation is unimportant in Upper Klamath Lake. Successful spawning apparently does not occur in any of the main-stem reservoirs, which have steep shorelines, lack substantial emergent vegetation, have abundant predators, and may lack spawning areas (Desjardins and Markle 2000).

Juveniles (1–4 Inches)

Larvae are considered juveniles at a length of 1–4 in., which the suckers generally achieve by the end of July (USFWS 2002). Juveniles are termed young of the year (YOY) or age 0 through their first winter. They spend daytime near shorelines over clean, rocky bottoms composed of sand, gravel, and small boulders (Simon et al. 2000; Figure 5-3). YOY use both vegetated and unvegetated portions of shoreline, generally in water less than 4.3 ft deep (USFWS 2002). Knowledge of the extent to which vegetation is used is complicated by the difficulties of sampling juveniles in dense vegetation (Reiser et al. 2001). Abundance of YOY at first is greatest in the northeastern portion of Upper Klamath Lake; as summer progresses, young fish move southward in the lake and into deeper water and become less associated with shorelines, and they become more oriented toward the lake bot-

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tom (Gutermuth et al. 2000). Simon and Markle (2001) suggest that overwinter mortality of first-year juveniles approaches 90%. After their first year, juveniles are found throughout the lake but are most abundant in the northern one-third of the lake, as are adults, although it may be important that sampling has been concentrated on this area (Reiser et al. 2001). Juvenile Lost River suckers appear to depend less on shallow-water habitats than juvenile shortnose suckers, as shown by sampling with beach seines (Simon et al. 2000), and juvenile shortnose suckers are apparently more strongly oriented toward the lake bottom than juvenile Lost River suckers (Scoppettone et al. 1995).

Subadults (4–10 Inches) and Adults

Subadults are the least-studied age group. It is assumed that their requirements and habits are most like those of nonspawning adults but their behavior is obscure because they are too fast to catch in seines or trawls, too deep to catch in cast nets, and often too small to gillnet. Given that suckers may spend the first 3–8 yr of their lives as subadults, additional information on this stage could be important.

Lost River suckers grow rapidly for their first 5 or 6 yr to a length of 14–20 in. (Scoppettone 1988). Some males reach maturity (i.e., are capable of spawning) at 4+ yr and 15 in. and some females do so at 7+ yr and 21 in., but most fish mature at 8 or 9 yr; males often mature earlier than females. At maturity, growth slows (Scoppettone 1988, Buettner and Scoppettone 1990, Scoppettone et al. 1995, Perkins et al. 2000a). The largest and oldest fish are females. The oldest known Lost River sucker (43 yr) was obtained in Upper Klamath Lake during a fish kill in 1986 (Scoppettone 1988).

Female shortnose suckers apparently grow faster and larger than males. Both male and female shortnose suckers mature as early as 4+ yr. Males can be mature at 11 in. and females at 13 in., although maturation at 5–7 yr is more usual. The oldest known shortnose sucker (33 yr) was taken from Copco Reservoir in 1987 and was 19 in. long (Scoppettone 1988).

Adult Lost River suckers forage primarily on zooplankton and benthic (bottom-dwelling) macroinvertebrates (Coleman et al. 1988, Scoppettone and Vinyard 1991). The shortnose sucker, as could be predicted from the more terminal position of its mouth, feeds predominantly on cladoceran zooplankters (water fleas), although the guts of only a few adults have been examined (Coleman et al. 1988). The presence of detritus in the guts of shortnose suckers from Clear Lake indicates that shortnose suckers may also feed close to the bottom (Moyle 2002).

Adult suckers select water depths of 3–15 ft, as shown by daylight spring and summer observations; their strongest preference appears to be for 5–11 ft (Reiser et al. 2001, USFWS 2002). Their minimal use (1% of

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daytime observations) of shallower water could reflect avoidance of high light intensities and thus of aerial predators; limited use of the deepest water (about 4% of daytime observations), particularly in summer, may reflect avoidance of low concentrations of dissolved oxygen (Chapter 3).

Although adults of the Lost River suckers and shortnose suckers are captured together in many places in Upper Klamath Lake, some differences in their distribution suggest different habitat preferences. For example, in 2001, Lost River suckers were 2–3 times more abundant in trammel net samples from the western shoreline of Upper Klamath Lake, whereas shortnose suckers were 2–3 times more abundant in samples from the eastern shore (Coen et al. 2002). Possible habitat differences in these regions might be worthy of further investigation, although the differences could reflect chance encounters with aggregations of the two species.

Physiological Tolerances

Lake suckers in general are relatively tolerant of water-quality conditions that are unfavorable or even lethal for many other fishes. For example, suckers in good condition occur in Tule Lake, which periodically experiences extremes of dissolved oxygen, pH, and ammonia that are toxic to fathead minnows, a tolerant species (Dileanis et al. 1996, cited in USFWS 2002). Other lake sucker species are similarly tolerant. Endangered cui-ui evolved in the very alkaline (pH, 9.0–9.5) and saline (5 ppt) waters of Pyramid Lake, Nevada, where only five or six other native fish species persist. The only nonindigenous fish species to have successfully colonized Pyramid Lake is the Sacramento perch (G.G. Scoppettone, U. S. Geological Survey, Reno, Nevada, personal communication, 2002).

Most fishes cannot tolerate sustained pH in excess of 9 (Falter and Cech 1991). Upper Klamath Lake suckers can tolerate pH approaching 10, temperatures up to 31–33°C, concentrations of unionized ammonia up to 0.4–0.5 mg/L, and dissolved oxygen concentrations down to 1.5 mg/L. Beyond these thresholds, the suckers die in laboratory tests (typically conducted on juvenile fish); larvae are more sensitive than larger fish (Falter and Cech 1991, Martin and Saiki 1999, Saiki et al. 1999, Moyle 2002). Mortality is high in adult suckers below oxygen concentrations of about 1 mg/L (Chapter 6). Falter and Cech (1991) found that shortnose suckers had much lower tolerance of high pH (measured as pH at which swimming equilibrium was lost) than two other endemic fishes, the Klamath tui chub and the Klamath largescale sucker. Shortnose suckers lost equilibrium at a mean pH of 9.55, tui chub at 10.75, and Klamath largescale suckers at 10.73. Maximum pH in Upper Klamath Lake during summer phytoplankton blooms frequently exceeds 9.5 at the surface during daylight hours, but pH during episodes of mass mortality generally is about 7.5–8.5 (Perkins et

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al. 2000b), indicating that high pH does not cause mass mortality (Chapter 3). In Upper Klamath Lake in late summer, during times of physiological stress, suckers may seek higher water quality, such as that of springs and river mouths, even though such areas are otherwise avoided, probably because they are too shallow or too clear (USFWS 2002, Appendix D; Chapter 6).

Physiological tolerance tests generally are performed in a laboratory on single factors held at constant values, whereas factors in nature often vary over time and space, co-occur, and can operate synergistically. Summer conditions in Upper Klamath Lake typically involve episodes of high pH, high unionized ammonia, and low dissolved oxygen in combination with high temperatures that increase the oxygen demand of the fish. High concentrations of unionized ammonia can cause structural damage to gills, which can increase the susceptibility of fish to low concentrations of dissolved oxygen. High pH (over 9) inhibits ammonia excretion, thus creating stress (Lease 2000, cited in USFWS 2002). Susceptibility to columnaris disease, which is caused by the bacterium *Flavobacterium columnare*, increases with increasing temperature but decreases with increasing ammonia concentrations (Morris et al. 2000, Snyder-Conn et al. unpublished in USFWS 2002).

As an adjunct to laboratory studies, Martin and Saiki (1999) placed cages containing juvenile Lost River suckers in Upper Klamath Lake for 4-day periods. High mortality occurred at high pH, high concentrations of unionized ammonia, and low concentrations of dissolved oxygen; low dissolved oxygen was the strongest correlate with mortality. At sublethal temperatures and concentrations of unionized ammonia, fish were tolerant of higher pH than expected from the laboratory studies (fish tolerated pH as high as 10.8). The study suggests that laboratory tests of single factors should be viewed as being only indicative of the extremes that can be tolerated; they are not strictly predictive of responses in the field.

From the viewpoint of physiological stress on fishes generally, and especially for cold-water fishes, water-quality conditions are poor throughout much of the Klamath basin, as explained in Chapters 3 and 4. Physiological thresholds for suckers, however, are reached or exceeded less extensively than for most fishes because of the high tolerance of suckers. Harm to suckers caused by poor water quality is known for Upper Klamath Lake and may also occur in the Lost River and upper Keno Reservoir (Lake Ewauna). In other lacustrine or flowing-water environments of the basin, however, poor water quality may be much less important than other factors for suckers, although it may strongly affect some other fishes.

In Upper Klamath Lake, suckers are adversely affected by poor water quality, which is a byproduct of very high abundances of *Aphanizomenon flos-aquae*, a planktonic bluegreen (cyanobacterial) alga. Peak abundances

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of *Aphanizomenon* occurring in late summer or early fall cause very high pH. Under certain meteorological conditions overturn of a stratified water column and collapse of the *Aphanizomenon* population combine to cause depletion of oxygen throughout the water column and distribution of high concentrations of unionized ammonia (Chapter 3).

The adverse water-quality conditions in Upper Klamath Lake potentially have three types of effects on endangered suckers in Upper Klamath Lake: (1) mass mortality of large fish, (2) mortality, either episodic or continuous, of small fish or larvae, and (3) physiological stress on one or more age classes, which leads to physiological impairment but not necessarily death.

Poor water quality in Upper Klamath Lake is a documented cause of the episodic mass mortality of large suckers in the lake. The recent history of these episodes is given in this chapter, and the factors producing death are discussed in Chapter 3. Extensive research on the direct cause of mortality during episodes of mass mortality has led to the reasonably firm conclusion, supported by scientific evidence, that mortality is caused by inadequate amounts of dissolved oxygen. The two other potential direct causes of mortality, pH and unionized ammonia, appear not to control mass mortality. Dissolved oxygen, unlike pH and unionized ammonia, remains adverse continuously for many days during episodes of mass mortality, whereas pH and unionized ammonia do not. Thus, although additional studies of mechanisms leading up to mass mortality are warranted, the direct cause in large fish seems to be understood reasonably well.

There is insufficient evidence to show whether extreme water-quality conditions also cause mortality of juveniles and larvae. Laboratory experiments indicate such potential, but it has not been documented in the field. Field documentation, especially if mortality were steady rather than episodic, would be difficult for the smaller life stages of fish because of their quick deterioration and dispersal after death. The possibility that gradual or episodic mass mortality of small fish occurs should be studied.

Adverse water-quality conditions can affect fish indirectly, as explained above. Laboratory studies are useful, but field indicators of stress also are important in that sublethal responses to stress cannot always be produced in an interpretable way in the laboratory. Indicators of physiological stress include unusual or recurrent epizootics, poor body-condition factors, physical anomalies, and low growth rates compared with those in populations that are not exposed to adverse water-quality conditions, abnormally low fecundity or fertility of mature fish, and behavioral aberrations. Some attention has been given to the indicators—for example, physical anomalies in suckers of Upper Klamath Lake are common (USFWS 2002)—but a more comprehensive effort at evaluating indicators of stress probably is warranted.

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Overall, there is no doubt that poor water-quality conditions are suppressing the endangered suckers of Upper Klamath Lake through mass mortality of large fish. Less clear is the role of potential additional suppression through mortality of smaller fish or sublethal effects of physiological stress caused by poor water-quality conditions on any or all life stages.

Population Size

Abundances of larval and juvenile suckers have been estimated from field samples over the last several years (e.g., Simon et al. 2000). Calculated population sizes of adults have been based on recapture of tagged fish during fish kills. The confidence intervals around the numbers are very large and, because many of the assumptions of mark and recapture methods are not met by these estimates, the estimates are of limited value (R. S. Shively, USGS, unpublished memo, 5 March 2002; USFWS 2002).

Newspaper reports, eyewitness accounts, and data on catch per unit effort leave little doubt that the sucker population exploited by the snag fishery in the 1960s and earlier was much larger than it was by the 1980s. Relative estimates of the size of the spawning run of suckers in the Williamson River were first based on estimated catch rates and later on standardized recapture and electrofishing methods. The estimates showed a marked decrease in abundance of fish during the middle 1980s. In 1984, the run of spawning Lost River suckers was estimated at 23,000, but it fell to 12,000 in 1985. Catch per unit effort of electrofishing fell by 57% for Lost River suckers and by 83% for shortnose suckers from 1984 to 1986 before the major fish kill of 1986 (Scoppettone 1986, Bienz and Ziller 1987, Scoppettone and Vinyard 1991). The fishery was closed in 1987. More recent estimates of abundance depend on catch per unit effort in standardized trammel-net samples and can be compared only among collections for the years 1995–2001.

No universal or absolute estimates of the size of any age class of sucker are available. Estimates are relative, limited to specific sites (e.g., spawning areas), or are otherwise qualified from the viewpoint of making an overall numerical assessment of the population. While the use of qualified or relative estimates is beneficial, efforts to make more comprehensive population size estimates in the future would be desirable (see Chapter 6). For purposes of ESA actions, the critical facts, which are known with a high degree of certainty, are that the fish are much less abundant than they originally were and that they are not showing an increase in overall abundance. Thus, the point of departure for research and remediation in the future is the need to restore abundance of the listed suckers.

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Age-Class Structure

Most adult suckers in Upper Klamath Lake are large and old. The uneven age distribution has characterized the populations for several decades. Through the 1980s, the age distribution of Lost River suckers was heavily skewed to fish 19–28 yr old. In 1986, the year before fishing was banned, recruitment had apparently been poor for about 18 yr; 95% of adult Lost River suckers were 19–30 yr old (Figure 5-4; Scoppettone 1988). The data for Lost River suckers shown in Figure 5-4 are based on fish obtained during fish kills, a sampling method with unknown but multiple biases, including some evidence that older, larger fish suffer disproportionately high mortality (Chapter 6). Assuming that the fish collected during fish kills are representative of the adult population as a whole, it can be concluded that many age classes were essentially missing from the lake before 1988, when the fishery was active.

Closure of the fishery in 1987 greatly reduced mortality of spawners, after which additional mature fish began entering the spawning population (Figure 5-4B). Cessation of fishing apparently contributed to the production of a strong year class of both endangered sucker species in 1991, and to smaller but notable year classes also produced in 1990, 1992, and 1993 (Figure 5-4B; see Markle and Simon 1994, Cunningham and Shively 2001). These fish would have been expected to mature in the late 1990s, but the major fish kills that occurred in 1995, 1996, and 1997 affected not only old spawners but also probably young spawners. Spawning runs declined in the late 1990s, with little evidence of substantial recovery until 2000 (Figure 5-5). The upsurge in spawning numbers in that year and again in 2001 may represent maturation of fish from the 1991 and later year classes. It is possible that fish that lived through the fish kills of the middle 1990s were stressed by poor water quality and as a result experienced delayed maturation (e.g., Trippel 1995, Baltz et al. 1998), although Terwilliger et al. (M.R. Terwilliger et al., Oregon State University, Corvallis, OR, unpublished material, 2000) found no evidence of impaired growth associated with periods of poor water quality in juvenile suckers of Upper Klamath Lake. That spawning runs apparently increased in 1999–2001 shows that the species have substantial resilience, but this is no guarantee of recovery.

Comparisons between 2000 and 2001 data indicate a weak but significant trend toward increasing average size among all spawning shortnose suckers and female Lost River suckers in the Williamson River (Cunningham et al. 2002). A similar significant trend toward increased median size at a variety of nonspawning sites in Upper Klamath Lake was also found (Coen et al. 2002). When combined with evidence of low numbers of small river-spawning fish in recent years (Cunningham et al. 2002), the data could indicate year-class failure among fish that hatched in the middle 1990s and

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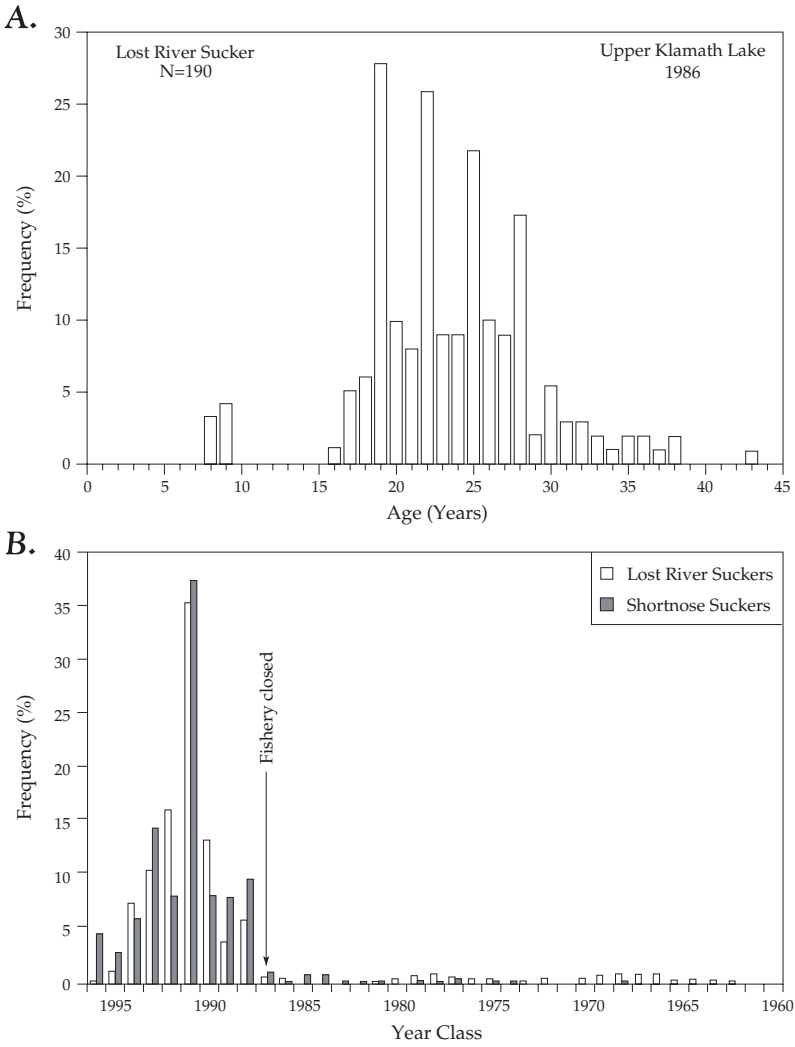


FIGURE 5-4 Age distributions of suckers in Upper Klamath Lake based on fish kills. (A) Age distribution of Lost River suckers in Upper Klamath Lake based on the 1986 fish kill. Multiple peaks indicate strong year classes estimated as 1958, 1961, 1964, 1967. Source: Scoppettone and Vinyard 1991. Pp. 359–377 in *Battle Against Extinction: Native Fish Management in the American West*, W.L. Minckley and James E. Deacon, eds. Copyright 1991 The Arizona Board of Regents. Reprinted by permission of the University of Arizona Press. (B) Age frequency distributions of Lost River suckers and shortnose suckers in Upper Klamath Lake based on fish collected from the 1997 fish kill. Effects of fishery closure in 1987 and of entry of successful 1991 year class are evident. Fish as old as 35 yr (spawned in 1962) were present. Source: Markle and Cooperman 2002, based on data from R. Shively, USGS.

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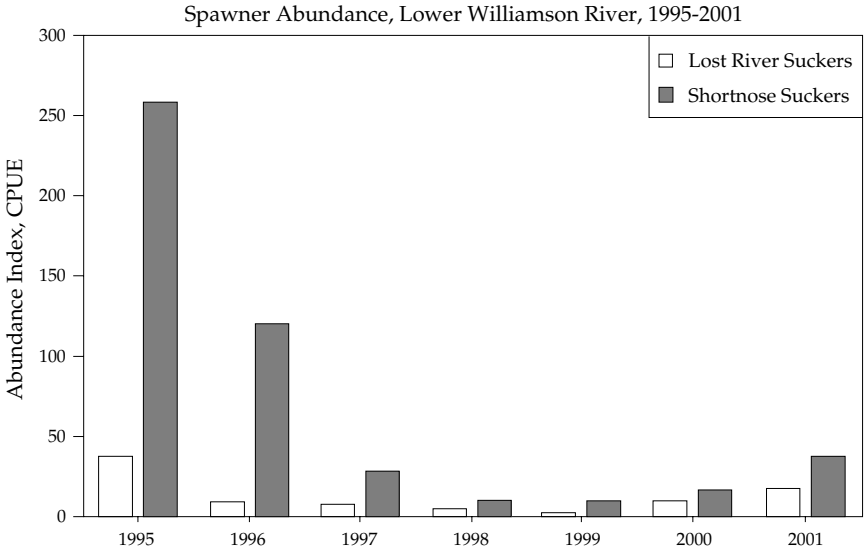


FIGURE 5-5 Spawning-run abundances of lake suckers, lower Williamson River, 1995–2001. Decline in spawners consistent with expected changes given fish kills of 1995–1997 is evident (1995 data were obtained before the fish kill that year). CPUE is a measure of catch per unit effort based on fish caught per unit of time spent fishing with trammel nets. Source: Modified from Cunningham et al. 2002, p. 30.

that would mature in the early 2000s. Concern over lost year classes might be tempered by an apparent trend in increased overall abundance among river spawners in 1999–2001 (Figure 5-5). Catches of both species from the Williamson River in spring 2002 decreased, however, by about 50% compared with 2001 (R. S. Shively, U.S. Geological Survey, Klamath Falls, Oregon, personal communication, October 8, 2002). Abundance index (catch per unit effort) for lake-spawning Lost River suckers do not indicate an increase in numbers of spawners (1999, 3.0 fish/h; 2000, 2.0 fish/h; 2001, 2.4 fish/h), and the average size of lake-spawning fish increased significantly between 2000 and 2001, suggesting lack of recent recruitment into the spawning population (Hayes et al. 2002). Catches at the shoreline areas in 2002 also decreased by about 15–20%. In fact, sampling in 2002 indicates that there has been no substantial recruitment into the adult population since 1999 (R. S. Shively, U.S. Geological Survey, Klamath Falls, Oregon, personal communication, October 8, 2002).

Observations on size of spawners since 1984 (Perkins et al. 2000b) indicates that very large Lost River suckers (over 25 in. for males, and

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over 28 in. for females) have been lost progressively from the population, that recent spawning aggregations are made up largely of medium-size fish (18–24 in.), and that the median age of spawners for Lost River suckers is 12 yr and for shortnose suckers is 9 yr (as judged from age-length relationships; Markle and Cooperman 2002). These findings suggest that successful year classes after 1991–1993 are largely absent, that is, that little recruitment of young spawners has occurred at the same time that the largest fish have been progressively removed by the fish kills; this raises a concern over future numbers of spawners and total reproductive output of the population.

As with Lost River suckers, knowledge of age distributions of shortnose suckers in Upper Klamath Lake comes chiefly from three fish kills in the 1990s, except that the data are even less complete and earlier data are lacking (Figure 5-4B). Indications from age distributions of fish collected after fish kills have indications similar to those for the Lost River suckers.

One other trend of note is that larger fish appear to spawn earlier in the season (Perkins et al. 2000b), but this trend may have been obscured in recent years by a relative lack of small spawners (Hayes et al. 2002). Regardless of cause, multiple strong year classes with temporal separation in spawning between year classes is potentially advantageous because it decreases the likelihood of failure of all the year's larvae if environmental factors vary for year to year during the breeding season (e.g., Trippel 1995).

Information on age distribution is a fundamental indicator of the status of a population, and it sometimes suggests reasons for failure of a species to recover. Although the 1990s, in apparent contrast with earlier years when the fishery was in place, have produced recruitment into the subadult and adult stages, the fish entering these stages have been killed in large numbers during episodes of mass mortality in Upper Klamath Lake. Thus, one reason for failure of the populations to recover is probably suppression of reproductive capacity of the population due to selective mortality of adult fish. This does not, however, rule out the possibility that part of the explanation for lack of recovery lies in suppression of the number of fish entering the subadult and adult phases. The fish collected during fish kills indicate recruitment into the subadult and adult stages in all years, and especially in some years with notably abundant year classes (such as 1991), but the amount of this recruitment may be insufficient to support overall growth of the population. Thus, one bottleneck almost certainly involves the mass mortality of large fish, and a second bottleneck could be at one or more places in the life cycle between laying of eggs and the entry of fish into the subadult and adult categories. As cited above, numerous efforts are under way to identify unusual mortality or suppression of vigor in young fish, but no conclusions are yet available on this important matter.

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Perspective on Age-Class Structure and Strength, Mortality, and Reproductive Output

Most fishes experience astronomically high mortality in their early life-history stages. The millions or even billions of individuals that hatch in a population are reduced by many orders of magnitude at the time of maturation. On the average, a male and female just replace themselves over a lifetime of spawning, even though they may produce millions of fertile eggs. These facts are relevant to sucker recovery in several ways. High mortality among larvae and small juveniles is to be expected, but the rates should plummet in later years, and old fish should show low mortality. Small percentage changes in mortality of young fish can translate into large population differences later because of the high numbers of young individuals. Thus, any steps that can be taken to increase larval and juvenile survival in Klamath Lake suckers could produce great benefits.

The high mortality experienced by very old fish during the fish kills of the middle 1990s is especially alarming given the reproductive potential of these fish (e.g., Conover and Munch 2002). Large, old fish of most species produce disproportionately more eggs than smaller fish. For example, in red snapper (*Lutjanus campechanus*), which is heavily fished and depleted throughout its North American range, a single 10-yr old female (26 lb, 24 in.) can contain 9 million eggs, which is equivalent to the total egg output of 212 adult females that are 3–4 yr old, weigh 2.2 lb each, and are 17 in. long. One 26 lb old fish produces more eggs than 250 lb of younger fish. Thus, loss of larger size classes in a population can have a disproportionate effect on egg production and future recruitment (Bohnsack 1994). The value of large fish, even in small numbers, is evident in the listed suckers. The number of young produced and eventually recruited into adulthood increased greatly just after the snag fishery was closed (see Figure 5-4B), demonstrating that even low numbers of large fish can produce large numbers of recruits (Markle and Cooperman 2002).

The disproportionately high contribution of old fish is even greater than fecundity would indicate. Because the quality of eggs (size and amount of yolk) produced by old females may be greatest, larvae hatching from these eggs may be larger and more likely to survive the early periods of high mortality (e.g., Trippel 1995). Although numbers of spawning fish in the Williamson River appear to have climbed in recent years, the reproductive potential of the population is lower than it was before the fish kills because the fish are smaller (Markle and Cooperman 2002). Reproductive output of a population is determined jointly by the number of spawners and the age distribution of spawners. Two populations of equal size that contain different size distributions of fish will not be equal in reproductive value; the population with more old, large fish will have much higher reproductive

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potential. Any alterations that can be made in the environmental conditions that directly affect the probability or severity of fish kills should receive especially careful consideration (Chapter 3).

Species that are long lived and late to mature, such as the endangered suckers of the Klamath basin, may respond slowly both to degradation and to restoration of habitat requirements, in contrast to other species that mature more quickly. Thus, the presence of old fish is not in itself evidence of a sound population. In fact, even if old fish are numerous, their failure to propagate would render them implicitly extinct until a reversal of the situation occurs. Similarly, improvement of environmental conditions may lead to beneficial changes in the population through recruitment of young age classes, but the final evidence of progress toward recovery, which is survival of these younger classes to maturity and old age, will not be evident for a decade or more. This special perspective on the long lived, slow maturing suckers must be maintained in any evaluation of prospects for extinction and response to remediation.

Endangered Suckers in Other Klamath Basin Waters

Suckers occurred naturally in Tule Lake, Sheepy Lake, and Lower Klamath Lake, from which spawning fish ran up the Lost River (Table 5-3). All three of the lake populations apparently were extirpated when their waters were drained for agricultural purposes around 1920 (Chapter 2). During the 1930s, after farming failed in the former lake bed, the lakes were to some extent reinundated, but not to their former depths. Suckers recolonized Tule Lake but not the other two lakes. There has been no evidence of successful spawning in Tule Lake, although fish from the lake evidently spawn in the lower Lost River.

Fish of both species, but mostly shortnose suckers, have been found regularly in the reservoirs between Keno and Iron Gate Dam (e.g., J. C. Boyle, Copco, Iron Gate). Apparently, they do not spawn. Fish in these impoundments probably consist of individuals that enter the Link River from Upper Klamath Lake and survive passage at Link River Dam; they tend to be old and large (Figure 5-6). The trip out of Upper Klamath Lake is one-way, inasmuch as no fish ladders suitable for suckers are located at Link River Dam or at any of the other dams along the Klamath River (Chapter 6). The great size and age of female fish as suggested by Figure 5-6 could make such fish valuable as transplants to more favorable habitats.

Reproducing populations of endangered suckers exist in Clear Lake, in Gerber Reservoir, and in portions of the Lost River downstream (the Lost River could receive fish from Gerber Reservoir in its upper portion and from Tule Lake in its lower 7 mi, below Anderson Rose Dam). Clear Lake,

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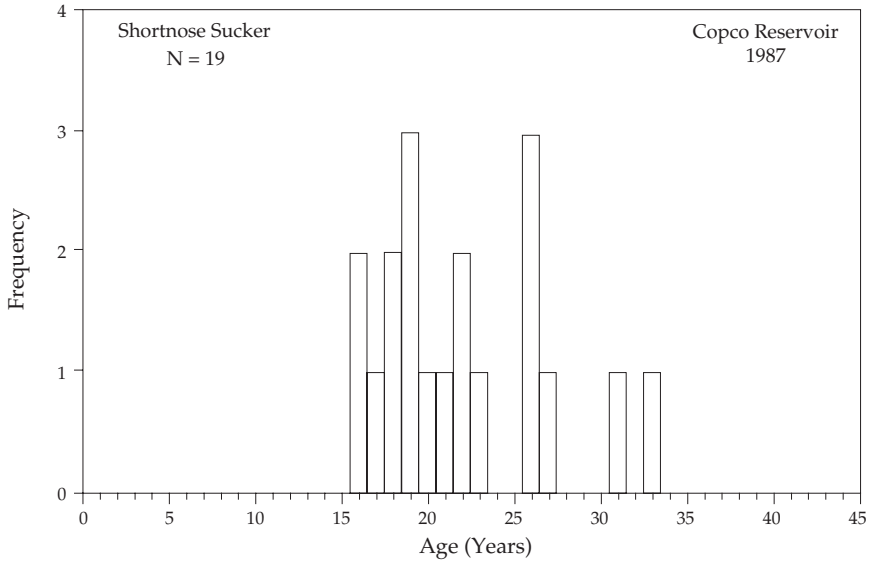


FIGURE 5-6 Age structure of a small sample of shortnose suckers taken from Copco Reservoir, 1987. Source: Scoppettone and Vinyard 1991. Pp. 359–377 in *Battle Against Extinction: Native Fish Management in the American West*, W.L. Minckley and James E. Deacon, eds. Copyright 1991 The Arizona Board of Regents. Reprinted by permission of the University of Arizona Press.

which was established in 1910, contains populations of both species (Scoppettone et al. 1995 estimated that 73,000 suckers occupied the lake), and both show recent evidence of diverse age structure and continued successful reproduction and recruitment. The reservoir is a source of irrigation water and can be drawn down during drought, which exposes the fish to multiple threats. Clear Lake was drawn down to as low as 5% of capacity during 1992, and fish collected after the drawdown and in the next spring were in poor condition, although their condition rebounded by the end of the next summer (USFWS 2002). Success of shortnose suckers and Lost River suckers in Clear Lake is encouraging in its own right and as a potential rescue population that could be used for restoring populations in other water bodies. Extreme drawdown, although prohibited by the USFWS biological opinion of 2002, is a threat if it should occur inadvertently, and the lake and its suckers presumably are vulnerable to major environmental disasters, such as a break in the dam (Moyle 2002). Unexpected changes in the spawning and rearing habitats in Willow and Boles Creeks above the reservoir also could affect sucker abundances.

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Gerber Reservoir, which was created in 1925, contains shortnose suckers but not Lost River suckers. Shortnose suckers in Gerber Reservoir exhibit a wide range of size classes, indicating successful reproduction and recruitment. Gerber Reservoir is not connected to any other sucker population, so there is no possibility of genetic exchange. Condition of fish in Gerber Reservoir is known to vary from poor to good; poor condition was associated with lowest water levels in 1992 (the lake was drawn down to 1% of capacity). The population has not received a great deal of attention.

Gerber Reservoir flows into the Lost River, which flows into Tule Lake (Figure 1-2). Historical sucker runs out of Tule Lake and up the Lost River were substantial; these runs supported commercial fisheries and canneries (USFWS 2002). Today, after the construction of multiple dams, only small numbers of the two endangered species occur in the Lost River; shortnose suckers are more common than Lost River suckers. It is not known whether these populations are self-sustaining (USFWS 2002). Spawning habitat is limited, and spawning has been observed at only about three locations, although several other sites appear to provide appropriate spawning habitat. Small numbers of larvae and juveniles have been collected in the river, but these fish could originate in Gerber Reservoir. Upstream movement from Tule Lake ends at Anderson Rose Dam, 7 mi above the lake. Spawning habitat in the 7-mi reach is scarce, and rearing habitat is compromised by poor water quality from water connected with Tule Lake sumps and agricultural return flows. Water quality in the Lost River is generally poor; the river fails to meet several Oregon state-specified water-quality thresholds. Gradients in portions of the river are unfavorably steep for suckers, and seasonal dewatering is common, as are dense plant growth and algal blooms associated with poor water quality. Both summer and winter fish kills were documented for the Lost River Diversion Canal region in the late 1990s. Brown bullhead (*Ameiurus nebulosus*) and pumpkinseed (*Lepomis gibbosus*) are abundant and nine of the 16 fishes in the river are warmwater nonnatives. USFWS (2002, Appendix E, p. 31) concludes that the Lost River is highly degraded and "can perhaps be best characterized as an irrigation water conveyance, rather than a river."

Tule Lake, once larger than Upper Klamath Lake but now less than 15% of its original size, contains populations of both endangered species amounting to perhaps a few hundred fish represented by a few size classes of old fish (for example, 16–24 in.; Scoppettone et al. 1995). Suckers in Tule Lake typically have higher condition factors and lower incidence of external parasites than suckers in other parts of the basin (USFWS 2002). The Tule Lake populations historically were maintained by spawning runs up the Lost River, which for reasons listed above now are extremely limited. Conditions within Tule Lake are deteriorating because of accumulation of sediment from agricultural sources. Alterations in water-management prac-

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tices, however, could arrest deterioration. Some changes might even restore spawning runs. In 1999, the U.S. Bureau of Reclamation began releasing 30 cfs during the spawning and incubation period (April–June), which led to detectable spawning activity below Anderson Rose Dam within 2 days (USFWS 2002). Such spawning could presumably lead to juvenile recruitment, but monitoring for presence of juveniles is needed. Collection of larvae reported by Shively et al. (2000a) is additional evidence of reproduction. The relatively good condition of suckers in Tule Lake makes these populations valuable for the long-term survival of both species of suckers, especially given the continuation of fish kills in Upper Klamath Lake.

Conservation Status

Lost River suckers and shortnose suckers were declared endangered by California in 1974 (Moyle 2002); Oregon placed both Lost River suckers and shortnose suckers on its protected list in 1987. USFWS first listed both sucker species as candidate (Category 2) species in 1982. They were proposed for listing as endangered in 1987 and were designated as endangered species in 1988 (53 Fed. Reg. 27130 [1988]). Despite the controversy surrounding the species in recent years, only 13 written comments were received by USFWS during the comment period before listing; 12 of the comments favored listing, one expressed no opinion, and there were no comments opposing the listing. Reasons for listing are given in Chapter 6. A federal recovery plan has been developed (Stubbs and White 1993). Critical habitat was proposed in 1994 (59 Fed. Reg. 61744 [1994]) but has not yet been formalized, nor has a recovery team been designated.

CONCLUSIONS

Human activities in the upper basin have affected not only the listed suckers, but virtually all the native species, several of which are greatly diminished in distribution and abundance. In particular, bull trout and slender sculpin have become rare in the basin in recent years. The Lost River system, which appears to have changed the most in the last 30 yr was dominated by blue chub, tui chub, and the three native sucker species, but it is now dominated by nonnative species. Upper Klamath Lake also has a high abundance of nonnative species, and most of its native species appear to be declining. A downward trend may be common, in fact, to native fishes in most aquatic habitats in the upper Klamath basin, although documentation is weak. The overall status and biology of the fishes of the basin, except for the two endangered suckers, is poorly known or at least poorly recorded. Research over the last 15 yr has produced many unpublished reports and extensive data but very few peer-reviewed papers. Thus, the

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utility of the available information is hard to judge. One possible remedy would be to provide funding for postdoctoral scholars to compile information and write papers by working with university and agency scientists who have collected data.

Future status of the suckers and other native fishes and the spread of nonnative species cannot be judged without periodic basin-wide survey of fishes. Monitoring is a key feature of adaptive management (see Chapter 10). Also, most information on the biology and status of the suckers and other native fishes has not been published in peer-reviewed journals or books. Also, further studies on the systematics of Klamath basin fishes are needed so that managers can avoid being surprised by the discovery of new endangered species, as are studies of the effects of nonnative species on the listed suckers and other native fishes. Introductions or spread of nonnative species already in parts of the basin are major threats to native species. The Sacramento perch in particular has the potential to spread through the canal system from the Lost River to Upper Klamath Lake, where it could become a predator of juvenile suckers and other native fishes.

Populations of the two listed sucker species in the upper Klamath basin have declined greatly in overall abundance and breadth of distribution. Stable reproducing populations of the two species occur now only in Clear Lake and Gerber Reservoir (Gerber Reservoir has only shortnose suckers). The formerly large populations of the two suckers in Upper Klamath Lake are drastically reduced, although no quantitative estimates are available for former or present population sizes. The sucker populations showed a substantial increase in recruitment, as indicated by year class strength, following the end of fishing in 1987. While the populations of Upper Klamath Lake are reproducing and all age classes are present, they are not rebounding in abundance. Episodic mass mortality of large endangered suckers is one explanation for failure of the populations of Upper Klamath Lake to rebound. Other age classes may be adversely affected in other ways, but these mechanisms are not as well documented. Prolonged low concentration of dissolved oxygen during the late summer of some years is probably the direct cause of mass mortality in Upper Klamath Lake.

The two endangered sucker species are present at other locations, but at none of these locations are substantial numbers of all age classes present. Large suckers are present in the five main-stem reservoirs of the upper Klamath basin and in the upper and lower portions of the Lost River main stem, as well as Tule Lake, but there is no recruitment. Spawning occurs in the Lost River but does not sustain a population of juveniles in Tule Lake, as once was the case. Dewatering of Tule Lake and Lower Klamath Lake and large physical and chemical changes in the Lost River almost certainly are the cause for failure of endangered suckers in the Lost River below Clear Lake and Gerber Reservoir to show recruitment or increase in abundance.

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6

Causes of Decline and Strategies for Recovery of Klamath Basin Suckers

When the Lost River and shortnose suckers were listed under the Endangered Species Act (ESA), the U.S. Fish and Wildlife Service (USFWS) and others identified numerous factors that could explain their decline and their failure to recover after elimination of the sucker fishery (Chapter 5, Scoppettone and Vinyard 1991). Since the listing, many of these factors have been studied. As a result, understanding of the biology of Klamath suckers and of requirements for their recovery has improved. Information on suckers is found in over 500 articles, reports, memoranda, and critiques, although most are unpublished and so have not benefited from scientific peer review. The number of persons working on the suckers has grown from a few ichthyologists to several dozen scientists, resource managers, policy developers, consultants, and informed citizens. New information derived from the increased pace of documentation and research supports increasingly firm judgments on the current status of the species, probable causes of their decline, priorities for further study, and actions that should and can be taken to move the species toward the ultimate goal of recovery, as described in this chapter.

CRITERIA FOR JUDGING STATUS AND RECOVERY OF SUCKER POPULATIONS

Criteria for the assessment of status and recovery provide a useful point of departure for the causal analysis of decline of the endangered suckers and for evaluating proposals for their restoration. Criteria presented here

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are intended as a tool of convenience for present purposes; other criteria might be useful for other purposes.

Because each life-history stage of a population is linked to all other stages, unusual suppression of any life-history stage may be reflected ultimately in the suppression of the population as a whole. Thus, trends in the abundance of any stage can be chosen arbitrarily as an index of the status of a population. For the endangered suckers, the most convenient life stage to use as an index of status is the adult. As explained in Chapter 5, other stages are difficult to observe or sample, especially in large lakes, although attempts to do so are essential to the diagnosis of mechanisms that affect specific life-history stages.

If adults are used as an index of the status of the populations, three criteria, taken together, would indicate recovery: diversity in the age distribution of adults, annual entry of at least some individuals into the adult stage in most years from the younger life stages coupled with entry of large numbers of such recruits in some especially favorable years, and a population size that reflects carrying capacity for an environment that is generally well suited, although not necessarily optimal, for the suckers. The presence of multiple age classes of adults would indicate past recruitment to the adult stage and persistence of conditions suitable for the maintenance of adults. The combination of new recruitment in most years and very high recruitment in some years would indicate the general welfare of younger stages and successful spawning. The maintenance of populations at a density that approaches expected carrying capacity would indicate that growth and reproduction occur at sufficient rates to offset mortality through the life cycle as a whole.

As indicated in Chapter 5, the status of geographically defined subpopulations of the two endangered suckers varies drastically. Table 6-1 summarizes the status of various geographic subpopulations on the basis of the adults. As shown in Table 6-1, Clear Lake and Gerber Reservoir support apparently stable subpopulations and therefore provide a basis for comparison with other subpopulations. The Upper Klamath Lake subpopulations, in contrast, do not meet the criteria for recovery, nor do they indicate recovery in progress. These subpopulations took an important positive turn after elimination of fishing in 1987, through the entry of new fish into the subadult and adult populations each year and through the production of one very strong year class (1991) and several moderately strong year classes during the decade of the 1990s (Chapter 5). Indications of no recovery without further environmental change, however, include the failure of adults to show an upward turn in overall abundances and the lack of a diversified age structure among older age classes, presumably because of repeated mass mortality of large fish.

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TABLE 6-1 Summary of Status of Geographic Subpopulations of Two Endangered Suckers in Upper Klamath Basin[a]

Geographic Subpopulations	Recovery Criteria[a]			Required Actions	Priority[b]	Specific Actions
	Age Structure	New Adults	Population Density			
Clear Lake	+	+	+	Protection	1	Prevent alteration of tributaries; no drawdown exceeding 1992
Gerber Reservoir[c]	+	+	+	Protection	1	Same as for Clear Lake
Upper Klamath Lake	–	+	–	Remediation	1	Numerous, see Figure 6-1
Tule Lake	–	–	–	Remediation	2	Create spawning habitat[d]
Lake of the Woods	0	0	0	Remediation	2	Remove present fish; stock suckers
Lower Klamath Lake	0	0	0	Remediation	3	Raise level; stock adults[d]
Main-stem reservoirs	–	–	–	Protection	3	Protect status quo or better

[a]According to Chapter 5 and three criteria described in text for evaluation of status and recovery.
[b]Priorities are based on the apparent ultimate value of subpopulation to recovery of population at large.
[c]Shortnose sucker only.
[d]Requires feasibility studies.
Abbreviations: +, meets criterion; –, does not meet criterion; 0, population absent.

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Fishes of Tule Lake (and of the associated Lost River) show no signs whatsoever of recovery according to the criteria shown in Table 6-1. Lack of recruitment of young fish into the subadult and adult stages indicates lack of reproduction or negligible survival of young fish. Two additional locations, Lower Klamath Lake and Lake of the Woods, are listed even though they lack endangered suckers. These are locations where sucker populations conceivably could be established in the future. The main-stem reservoirs also are listed but belong to a somewhat different category because, as explained in Chapter 5 and further in this chapter, the potential for creation of suitable conditions for the entire life cycle is probably lower for these waters than for Upper Klamath Lake or the other waters where the suckers originally thrived.

REQUIREMENTS FOR PROTECTION AND RECOVERY

The ESA requires both protection and recovery of listed species (Chapter 9). Protection is accomplished by prohibitions of take and preservation of habitat. Protection alone is insufficient, however, in that the populations as a whole have shown a drastic decline over the last several decades, and there is no evidence that the populations are recovering. At the subpopulation level, as indicated in Chapter 5, the balance between protection and remediation depends on location. Because the subpopulations of Clear Lake and Gerber Reservoir are the only ones in the upper Klamath basin that meet the criteria for recovery as outlined above, their protection is of utmost importance for the long-term survival of the two endangered sucker species in the upper Klamath basin as a whole. These subpopulations appear to depend entirely on tributary spawning. Therefore, maintenance of tributary conditions suitable for spawning is an essential element of their protection. It is important that neither of the reservoirs be drawn down to extremes that would produce summer or winter mortality. Given the historical experience of the 1990s, the requirements of the 2002 biological opinion appear to be adequately protective in this respect, but it is critical for these subpopulations that no errors in judgment lead to extremes in drawdown beyond that observed in the 1990s.

The subpopulations of Upper Klamath Lake also have high priority but have different status. As explained in Chapter 5, they showed some encouraging responses to the curtailment of the snag fishery, but the numerical abundance of adults and the continuing attrition of old fish appears to be holding the population down and may even be driving it closer to extirpation. The pathway to recovery for this population is not clear. A great deal of the analysis of cause and effect in the remaining part of this chapter is devoted to the Upper Klamath Lake subpopulations because of their his-

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torical numerical importance and the lack of clarity about the means of achieving their recovery.

The Tule Lake subpopulations consist of a very small number of apparently healthy adults, but they fail to meet all three of the criteria outlined above for recovery: there is no evidence of recruitment into the adult stage, there is no diversification of age structure for adults, and abundances per unit area are low. Because the suckers are long-lived, the adults of the Tule Lake population are of high value, and also could be supplemented with salvaged individuals from other locations. The first step toward recovery of the Tule Lake subpopulations would be to establish spawning capability, which would require intensive work with tributary waters. Acquisition of water rights and steps toward the creation of (potentially artificial) physical habitat suitable for spawning and for larvae would be necessary initial steps toward recovery of these subpopulations. The Tule Lake subpopulations, although small, need not be written off as unrecoverable.

Listed fifth in Table 6-1 is Lake of the Woods. As explained in Chapter 5, this was the location of a population probably consisting of shortnose suckers, but the population was eliminated. The present fish populations of Lake of the Woods should be eliminated, and adult shortnose suckers and other native fishes should then be reintroduced. If the suckers meet the recovery criteria outlined above after a number of years, fish biologists could consider the reintroduction of game fish (fish other than suckers probably will have colonized the lake by that time in any event).

Lower Klamath Lake lacks suckers and is probably unsuitable for them (Chapters 3 and 5), but alteration of these conditions could be feasible. Steps should be taken toward acquisition of water rights suitable for maintenance of higher water levels in Lower Klamath Lake if feasibility studies support this approach. Adult suckers from salvage (as described later in this chapter) should then be transferred to Lower Klamath Lake. Water quality and habitat conditions may be unsuitable, but suitability can be determined most effectively by monitoring of trial reintroductions. To the extent that maintenance of higher water levels would interfere with agricultural use of land, its establishment would require negotiations and compensation for acquisition of private rights.

The last subpopulations mentioned in Table 6-1 are the ones in main-stem reservoirs. These reservoirs have value primarily for long-term storage of large suckers. They do not have high priority for recovery, because they are not part of the original habitat complex of the suckers and probably are inherently unsuitable for completion of life cycles by the suckers. Maintenance of adults in these locations does, however, provide some insurance against loss of other subpopulations.

Construction of fish ladders for suckers at the dams might facilitate return of fish from main-stem reservoirs to Upper Klamath Lake. A fish

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ladder at Link River Dam, which is scheduled for completion in January 2006, should receive high priority; movements of fish through the ladder should be monitored.

SUPPRESSION OF ENDANGERED SUCKERS IN UPPER KLAMATH LAKE: CAUSAL ANALYSIS AND REMEDIES

For several reasons, causal analysis of the suppression of endangered suckers deserves more attention for the Upper Klamath Lake subpopulations than for other subpopulations. First, despite severe suppression of endangered suckers in Upper Klamath Lake, these subpopulations still contain many fish. Second, the subpopulations in Upper Klamath Lake were large as recently as 50 yr ago, so it seems reasonable, lacking evidence to the contrary, that they could be restored by a reversal of one or more critical human-induced impairments that have occurred over the last 50 yr. Third, water management involving Upper Klamath Lake is the responsibility of the federal government through the U.S. Bureau of Reclamation (USBR), which has access to substantial resources and also has legal responsibility for reversing or moderating any adverse effects of its management of Upper Klamath Lake if causal linkages between management and harm to the suckers can be established. Fourth, even though the subpopulations of endangered suckers are suppressed in Upper Klamath Lake, all life stages are present and some recruitment appears to be occurring from one life stage to another every year; recovery seems feasible if some key factors can be identified and changed.

Actual or potential cause-and-effect relationships that explain the status of a population are hierarchical. For present purposes, *immediate* causes can be explained in terms of suppression of one or more stages of the life cycle. For example, suppression of the entire population could be explained entirely or in part by exceptionally high mortality of larvae. Suppression of more than one component of a population could prevent it from recovering. There can be more than one immediate cause of suppression of a population.

Proximate causes are environmental factors. An example is poor water quality that leads to mass mortality of adult fish. A single proximate cause may be linked to more than one immediate cause. For example, poor water quality may suppress not only adults but also other life-history stages.

Ultimate causes, in the present context, are direct or indirect results of human actions. For example, operation of unscreened canals is an ultimate cause of mortality of fish in various life stages. Human actions that have led to changes in the water quality of Upper Klamath Lake are ultimate causes of mass mortality of large fish.

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Recovery of the populations of endangered suckers can be approached most efficiently through analysis of the three levels of causation that explain failure of the fish to recover. Because the possible combinations of cause and effect are numerous, remedial actions, which are expensive, must focus on chains of cause and effect that are most likely to produce recovery. Winnowing the importance of cause-and-effect relationships requires information, some of which must be quantitative to be useful. The task of the researcher or the monitoring team is to produce information, typically over a period of years, that can be used to support estimates of the suppression of the population by chains of causation involving specific life-history stages (immediate causes), specific environmental factors (proximate causes), and specific human actions (ultimate causes). Knowledge of causation can produce estimates of the beneficial effect of remediating the effects of human actions.

Intensive research on the endangered suckers has been under way for a relatively short time, especially in view of the complicating effects of natural variation caused by climate and other factors that are not under human control. Only a few causal relationships are known well enough to support remedial action with confidence, but some of these are among the most important because they explain notable mortality of one or more stages of the population. Eventually, some of the more subtle but still important types of impairment and their causes must be clarified, as indicated in the following overview and analysis of cause and effect.

The analysis of causal connectivity is summarized in Figure 6-1. The figure shows the life stages of the endangered suckers as presented in Chapter 5 and identifies potential proximate causes of suppression of each life stage. Because the life stages are interconnected developmentally, the underlying premises of the diagram are that suppression of any life stage contributes at least potentially to suppression of the overall population and that a potential remedy for the suppression of the population lies in the identification and reversal of the suppression of individual life stages. It is not a foregone conclusion, however, that reversal of a particular type of suppression on a specific life stage will move a population notably toward recovery.

Figure 6-1 shows connections between immediate, proximate, and ultimate causes as solid or dashed lines. Solid lines indicate causal connections that are well established scientifically; typically these connections involve phenomena that are easily observed or documented (such as mass mortality of adults or death due to entrainment). Dashed lines indicate causal connections that are under study and for which there is insufficient evidence to show them as unimportant, moderately important, or important.

The figure shows convergence of multiple lines on individual immediate causes in some cases. Thus, the diagram indicates the likelihood that

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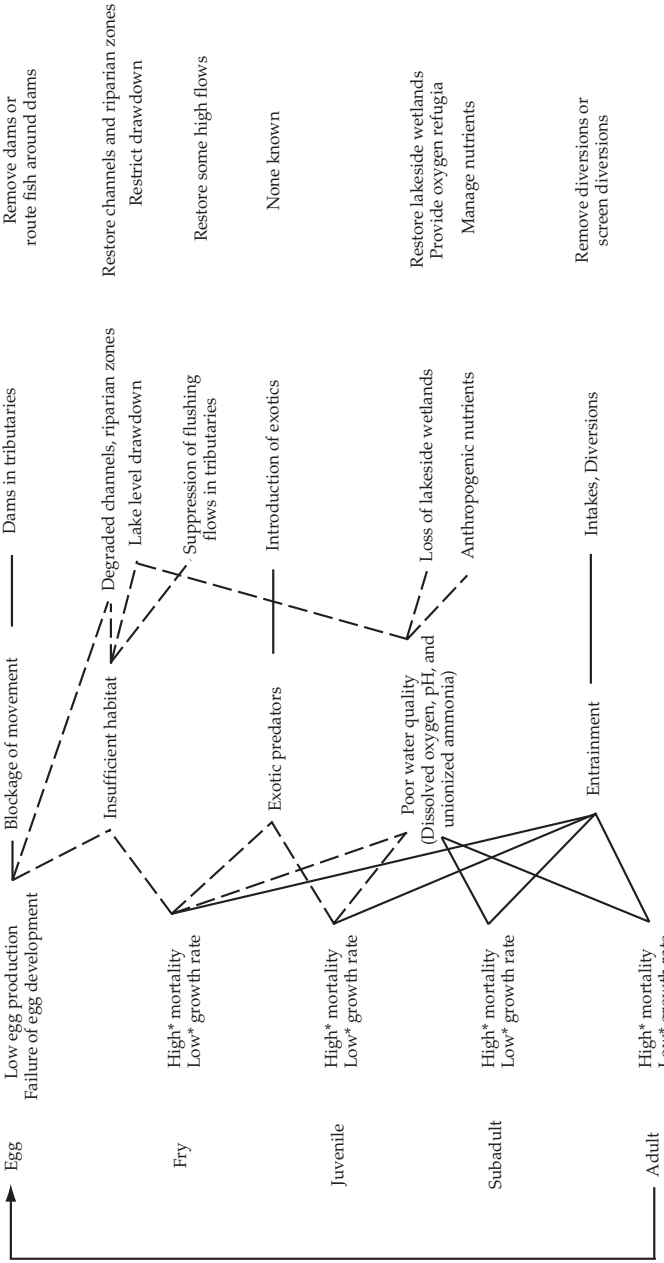


FIGURE 6-1 Diagram of possible causal connections in suppression of populations of endangered suckers in Upper Klamath Lake. Solid line = connection verified scientifically; dashed line = connection under study. "High mortality" and "low growth rate" are relative to rates in stable populations.

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some immediate causes of decline are explained by multiple factors and that the factors might interact in their effects on a specific life-history stage. In addition, the diagram indicates that some environmental factors (proximate causes) have multiple connections with immediate causes; that is, they can affect more than one life stage. This is also expected from the literature on fish populations. The last column in the diagram lists remedial measures; the degree of certainty in their effectiveness is discussed below. Even though the life-history stages are interdependent and so must be considered together in the final prescriptions for recovery, it is useful to consider them individually first because each stage is affected by a distinctive suite of environmental factors. The discussion therefore follows the life-history sequence.

Production and Viability of Eggs

The production of eggs is usually discussed in terms of spawning fish, which are much more easily observed than eggs. The eggs themselves are the concern, however, and successful spawning is only one element of their final value to the population. Low viability of eggs, for example, could undermine the effectiveness of successful spawning. No researchers have attempted to make a case that the viability of eggs differs in Upper Klamath Lake or its tributaries from what would be expected in an unimpaired environment. Thus, the present discussion focuses on spawning, but it should be noted that lack of discussion of the fate of eggs after spawning is due partly to lack of information.

Dams

Small dams are found in the tributaries of Upper Klamath Lake. Where it can be shown that the dams do not allow passage of fish attempting to spawn, they should be removed or, if a dam must be retained, it should be fitted with a functional bypass.

The only moderately large dam on a tributary to Upper Klamath Lake is Chiloquin Dam, which blocks the Sprague River near its confluence with the Williamson River (Figure 1-3). Construction of Chiloquin Dam in the early 1900s (1918–1924—the exact date is unclear) may have eliminated more than 95% of the historical spawning habitat in the Sprague River (53 Fed. Reg. 61744 [1988], p. 5). This possibility is based on total river miles above the dam and does not take into account unusable portions of the river or the ascent of the dam by at least a few spawning fish via the fish ladder each year. There are more fish below than above the dam, however, and few fish enter the fish ladder (e.g., Janney et al. 2002), although the actual number is unknown. Improved access to the upper Sprague River

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would increase the extent of spawning habitat and expand the range of times and the conditions under which larvae enter Upper Klamath Lake.

Proposals for improving access of suckers to spawning grounds on the upper Sprague River involve two possibilities: removal of the dam and improved fish passage at the dam. Scoppettone and Vinyard (1991) recommended removal of the dam, as have others since then (e.g., Klamath Water Users Association 2001). Stern (1990) estimated the cost of removing the dam at about $500,000 and of fish passage improvements at $560,000. CH2M HILL (1996) presented detailed plans for improvement of passage and estimated the cost at $1.445 million but gave no estimate for removal of the dam. The plan of CH2M HILL includes construction of a new vertical-slot ladder on the left bank (looking upstream) that would replace the present ladder, which is ineffective. The new ladder would be based on fish passage structures through which cui-ui (*Chasmistes cujus*) move up the Truckee River and into Pyramid Lake.

CH2M HILL (1996, p. 2) dismissed removal of Chiloquin Dam because of "too many environmental concerns . . . as well as a lack of local support." The environmental concerns were not enumerated; presumably they are related to release of sediment and the difficulty of predicting how fish would respond to the new hydraulic conditions (e.g., Stern 1990). Issues related to sediments arise with virtually any dam-removal project, but often they can be resolved (Heinz Center 2002). The response of the fish is unknown, but removal of the dam is likely to result in a natural migratory response, at least by young spawners that have not already developed the habit of spawning downstream of the dam.

Lack of local support for removal of Chiloquin Dam is explained in part by water delivery via the dam to the Modoc Point Irrigation District (MPID). MPID involves about 60 farms and irrigates 3,000–5,300 acres annually, or less than 3% of the irrigable acreage in the basin. The MPID apparently has "adopted a Resolution indicating its willingness to participate in a project to restore fish passage" (Klamath Water Users Association, undated memo, about 2001) and is willing to consider moving its point of diversion away from Chiloquin Dam (E. Bartell, The Resource Conservancy, Inc., Fort Klamath, Oregon, unpublished report, 2002). Cooperation with MPID is important to the removal of Chiloquin Dam.

Removal of Chiloquin Dam has high priority and should be pursued aggressively. In the interim, spawning fish could be captured at the base of the fish ladder and released immediately above it; some of the released fish should be fitted with transmitters. Such a program would immediately give more fish access to the Sprague River and would show what upstream areas are favored by the fish. Continued monitoring below the dam also would provide information on numbers of adults returning downstream and numbers of larval fish reaching the lake. A summer sampling program could

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determine whether juveniles are in the river and would demonstrate the status of other native fishes in the river.

Water Level in Upper Klamath Lake

Spawning occurs at shoreline sites around Upper Klamath Lake from late February to May; maximum spawning activity occurs in March and April. More than 60% of spawning occurs in water more than 2 ft deep at locations with inflowing stream water (e.g., Reiser et al. 2001; see also Chapter 5). Inundation to a depth of at least 2 ft may be necessary for successful use of spawning substrate. At Sucker and Ouxy springs, two of the most frequently used sites (Hayes et al. 2002), lake elevations below 4,142.5 ft place 55% and 67%, respectively, of the spawning area in water shallower than 2 ft. Reiser et al. (2001, p. 7-2), in a separate analysis, concluded that lake elevations below 4,142.0 ft "severely diminish available spawning habitat"; they recommend that Upper Klamath Lake be kept at full pool elevation (4,143.3 ft) from mid-March to as late as mid-May to provide adequate water depth for spawning. Under recent operating regimes, water levels have remained above 4,143 ft for extended intervals in wet years but have fallen well below 4,143 ft in dry years (Figure 6-2).

Figure 6-2 shows the effect of water-level regulation in Upper Klamath Lake on spawning area according to the criteria proposed by Reiser et al. (2001). Under natural conditions, spring water levels would have been at or near full pool (4,143.3 ft). Under conditions prevailing in 1990–2001, full pool elevation was achieved during the spawning interval in 6 of 10 yr; in

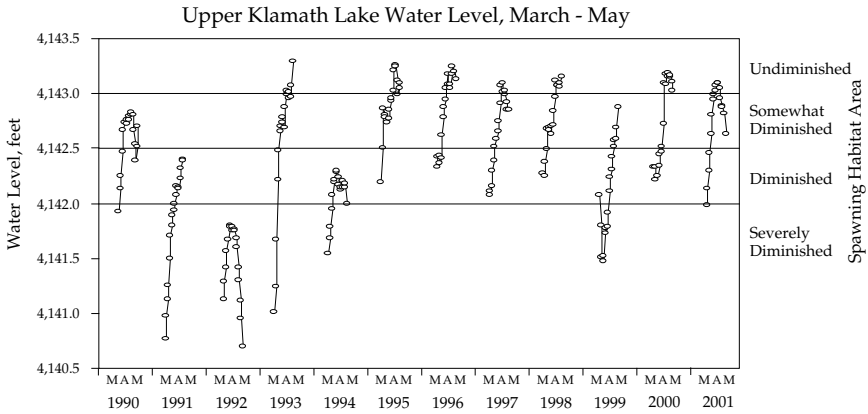


FIGURE 6-2 Water levels for 5-day intervals in Upper Klamath Lake over months of most vigorous spawning by suckers (March, April, and May—MAM), shown in context with spawning habitat designations given by Reiser et al. (2001).

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the other 4 yr the water level was slightly lower to much lower, with corresponding consequences for the inundation of spawning sites.

It seems clear that drawdown of Upper Klamath Lake decreases the area of lakeside spawning habitat for the endangered suckers. Thus, a reasonable hypothesis is that lake levels below 4,143 ft, and especially those below 4,142 ft, suppress the production of larvae by reducing production of viable eggs, thus potentially affecting the population. In the absence of scientific information on the recruitment of larvae or other stages in years showing various amounts of water-level drawdown, professional judgment would be the only recourse for assigning significance of variations in spawning habitat to the relationship between production of larvae and water level in the lake. As a result of intensive study of the suckers, however, there is some direct evidence by which the hypothesis can be tested in a preliminary way.

Larval suckers have been sampled systematically since 1995 (Simon and Markle 2001). If drawdown suppresses spawning success substantially, one would expect lower relative abundance of larvae in years of extreme drawdown. The relationship between water level and abundance of larvae or juveniles would not necessarily be linear; it might involve thresholds rather than gradual changes in production of viable larvae.

Figure 6-3 shows the relationship between water level of Upper Klamath Lake in April (in the middle of the critical period) and relative abundances of larvae as shown by the standardized sampling program. Minor differences in relative abundances of larvae should not be considered significant because the sampling variance for any given year is substantial (95% confidence limits extend 50–100% around the mean in most cases).

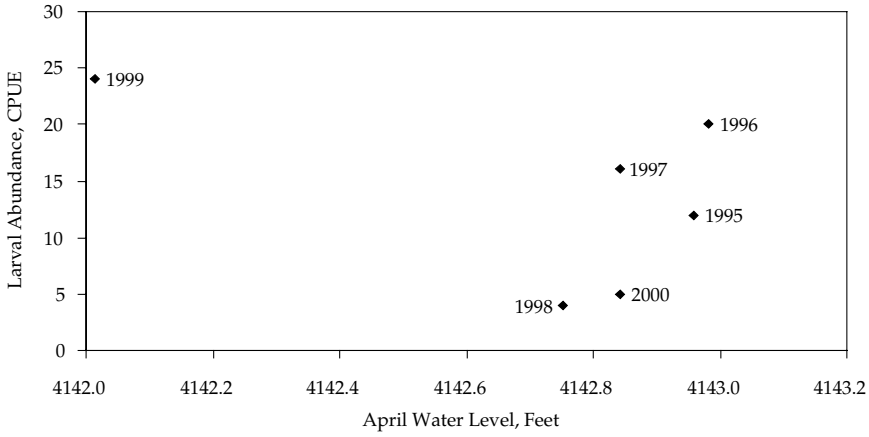


FIGURE 6-3 April water level and larval abundance (mean catch per unit effort [CPUE]) in Upper Klamath Lake. 95% confidence limits for annual means typically are 50–100% of the mean. Source: Simon and Markle 2001.

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Thus, 1998 and 2000 might be considered distinctive in their scarcity of larvae, whereas 1995–1997 and 1999 belong to a second category of years involving much higher larval abundances that are virtually indistinguishable from each other because of sampling variance.

The year of lowest water levels during April was 1999, during which spawning habitat varied from somewhat diminished to severely diminished according to the criteria of Reiser et al. (2001; Figure 6-2). In all other years of the 6-yr record, the restriction of area was substantially less than in 1999. Thus, the hypothesis that diminution adversely affects production of larvae from eggs is contradicted by this test. The test is not particularly strong, because extremes of diminution and repeated years of diminution are not available in the record. Further observation might demonstrate some relationship that is not now evident. For the present there is no indication of a strong relationship between spawning success, as inferred from abundance of larvae, and water level in Upper Klamath Lake.

One other empirical test is possible. It is more remote in a life-history sense because it involves the relative abundance of adult fish. Its advantage is that it involves data that extend into different water years from those available for testing through larval abundance. As explained in Chapter 5, mass mortality of fish provides insight into the age structure of the endangered sucker populations. Specifically, the relative abundance of age classes of subadult and adult fish can be judged on the basis of their relative frequency of appearance among fish that are collected after the fish kill. As indicated in Chapter 5, any use of this information must be considered provisional because the relationship between the actual age structure of the population and the age structure reflected in the fish kill is unknown.

Given the assumption that large fish are killed in relation to their abundance in the population, relative abundance of specific year classes of fish should reflect the developmental history of each year class. If repression of larval production through restriction of spawning areas is critical in years of low water level in the lake, years affected by low level should stand out as producing a reduced population of large fish, given that large fish are ultimately a byproduct of successful spawning. The relationship between lake level and relative abundance (percentage frequency) of fish is shown in Figure 6-4. As indicated in the figure, the 2 yr of extraordinarily low water levels (1992 and 1994), which would be expected to show most strongly the negative signal involving larval production, do not indicate any repression of the year classes related to water level.

Further research may show a relationship between inundation of the spawning area and larval recruitment. Present data suggest, however, that any such relationship would be either weak or indirect. Thus, the connection does not appear to be especially important for the population. This conclusion seems counterintuitive, but there are several potential explana-

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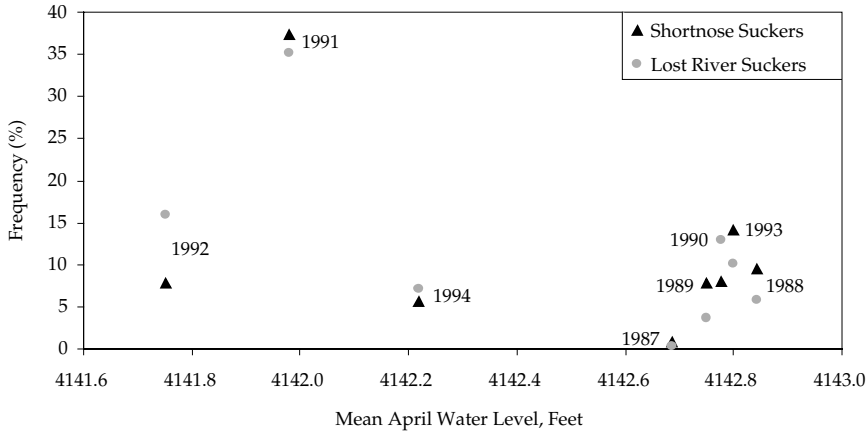


FIGURE 6-4 Relative abundance of year classes of suckers in Upper Klamath Lake, as inferred from fish recovered after mass mortality in 1997, in relation to water level during spawning interval when same year classes were produced. Source: USGS, unpublished data, 2001.

tions. First, the present population, which is much smaller than the original population, may have adequate spawning area even when spawning area is reduced, simply because it puts less total demand on the spawning area. Thus, progressive recovery of the population could produce a bottleneck related to spawning area in the future. Second, recruitment from spawning in streams may be more important than lake spawning under present circumstances. These and other possibilities cannot be distinguished at present. Overall, maintaining full pool elevation for promotion of spawning, although intuitively appealing, is difficult to defend scientifically.

Degradation of Spawning Areas

Some lacustrine spawning areas appear to be degraded, as indicated in Chapter 5. Where feasible, degraded spawning areas should be restored by introduction of additional gravel in appropriate type and size, removal of silt, or redirection of spring flows. It is unclear whether these actions will increase sucker spawning success, but they are not especially expensive and may be beneficial. Potential diminution of depth must be taken into account if restoration involves the addition of new substrate. Also, factors other than depth per se need to be studied more extensively with respect to the suitability of spawning areas. Wave action and other factors that have not yet been studied might be relevant, for example.

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While lakeside spawning areas for suckers in Upper Klamath Lake have been studied extensively, tributary spawning areas have received relatively little attention. Where tributary spawning occurs, the morphometric features and substrate composition favoring the suckers should be identified, and specific efforts should be made to offset any changes in these characteristics that may have occurred through anthropogenic mechanisms. In addition, potential adverse effects of suspended load should be identified. Improvement of appropriate conditions for spawning will likely require protection of riparian zones from grazing and other disturbances, reduction in transport of suspended load related to land disturbance through agricultural and other land-use practices, and restoration of wetland near channels. Furthermore, it may be effective to protect specific spawning regions of tributaries from human presence in order to reduce the possibility of harassment and to increase public awareness of the importance of specific locations for successful spawning by suckers.

Some tributaries and lakeside spawning areas that are known to support successful spawning by suckers may not require restoration but do require vigorous protection because of their special value to the population. Even subtle changes, which might involve pumping of groundwater in the vicinity of these spawning sites, land disturbance, recreational activities, poorly managed agricultural practices, and other human activities could easily degrade or even eliminate these sources of sucker fry.

Abandonment of Spawning Areas

Some historical spawning areas have been abandoned for no apparent physical reason. Reestablishment of population components with natal affinities to the areas should be attempted. The degree of benefit cannot be estimated from present information, but the work could be accomplished without great cost. Specific locations are as follows:

1. Harriman Springs in northern Upper Klamath Lake was last used in 1974; spawning was also reported historically at Odessa Creek on the western shore (Andreason 1975, USFWS 2002). Barkley Springs on the southeast shoreline of Upper Klamath Lake was a previous spawning site but has not been used since the late 1970s (Perkins et al. 2000a), because diking, ponding, and rerouting of water associated with the construction of Hagelstein Park in the 1960s apparently blocked access of the fish to the site. Spawning substrate was added and water-control devices designed to inundate the springs were constructed in 1995, but no spawning has yet been observed.

2. Spawning suckers were reported at a spring on Bare Island (in the northern portion of Upper Klamath Lake east of Eagle Ridge) in the early

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1990s, but spawning has not been observed at the site since then (Perkins et al. 2000a).

3. In the region of Agency Lake, spawning of suckers was observed in the late 1980s and early 1990s in Crooked Creek, Fort Creek, Sevenmile Creek, Fourmile Creek, and Crystal Creek. The Wood River has had the only recent spawning activity, most of it attributed to shortnose suckers. Adults were last seen in the Wood River in 1996, and larvae were last collected in 1992; no juveniles were found in 2000 (Simon and Markle 1997b, 2001; Cooperman and Markle 2003).

4. Additional, indirect evidence of abandoned spawning sites in Upper Klamath Lake itself has been obtained on the basis of lost fishing gear (Cooperman and Markle 2003). Shoreline surveys conducted during record low lake levels in 1994 revealed fishing gear on the bottom at known spawning sites, such as Ouxy and Sucker Springs. Lost gear also was found at four unnamed, flowing spring sites between Modoc Point and Sucker Springs. Failure to observe suckers spawning at these four sites during recent spawning surveys suggests that direct removal or harassment led to the elimination of the spawning aggregations.

The available evidence strongly suggests that lake and stream spawners mix only occasionally if at all and that spawning-site fidelity causes an abandoned spawning site to remain unused. Abandonment of apparently appropriate spawning sites indicates that the use of a spawning site is a social tradition, that is, that fish learn about spawning sites by following or observing other fish (e.g., Helfman and Schultz 1984). A good spawning site may remain unused by fish that show those characteristics if "teachers" are absent, as has been demonstrated for reef-spawning wrasses in the Caribbean (Warner 1988, 1990). Use of abandoned sites might be renewed spontaneously if populations of adults become substantially more abundant.

The possibility that sites are abandoned because of a break in tradition suggests a solution. Transplantation of spawning-ready fish of both sexes to historically used sites, perhaps accompanied by confinement of the fish in cages for a brief acclimation period, might initiate use of the abandoned sites. Feasibility of this approach is suggested by Warner's (1988, 1990) manipulations, which involved transplantation of fish to locales that had been experimentally depopulated, with subsequent establishment of site-specific, traditional spawning groups by transplanted individuals. Males might be attracted to caged females in spawning-ready condition; spawning readiness could even be induced, if necessary, by hormone injection. Fish could be transplanted from habitats that lack recruitment—such as Tule Lake, the Lost River, or the Klamath main-stem reservoirs—assuming that spawning-ready individuals are available. If fish from Upper Klamath Lake are used for such manipulations, they should probably be young, first-time

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spawners because fish with spawning experience are likely to abandon a new site for a site with which they are familiar.

Regardless of the cause of spawning-site abandonment, loss of spawning aggregations has several consequences for sucker recovery. If the aggregations at these sites represented genetically distinct groups of suckers, overall genetic diversity of the Upper Klamath Lake populations probably has been reduced. Even without genetic distinctness, the uniqueness of circumstances at each site creates potential differences in survival of larvae originating at different sites. Multiple spawning sites have a bet-hedging effect on larval survival: the more spawning sites a population uses, the more resistant the population is to exceptional loss at any one site.

Survival of Larvae and Juveniles

Mortality of larval and juvenile stages of all fishes is high, even in populations that successfully saturate their environment. High mortality in the young stages of the life history of a given fish population does not necessarily indicate that these stages are a bottleneck that leads to repression of the population. Survival of larval and juvenile stages in a repressed population could be usefully compared with those in a vigorous population; a bottleneck at the larval and juvenile stages would be indicated by substantially lower survival rates in the repressed population than in the vigorous population. However, estimation of survival rates of young life-history stages of fish is extremely difficult, and less direct indicators often are the only recourse for assessment of these stages, as is the case for sucker populations of Upper Klamath Lake.

Morphological Anomalies in Young Fish

Morphological anomalies—which may indicate parasitism, dietary deficiencies, or physiological stress during development—suggest abnormal losses of young fish during development. Where fish are not under physiological stress due to poor water-quality conditions, morphological anomalies seldom exceed 1% (Karr et al. 1986). In Upper Klamath Lake, however, the frequencies of anomalies among the larval and juvenile shortnose suckers averaged 8%, and among the Lost River suckers averaged 16% (Plunkett and Snyder-Conn 2000). The anomalies included deformities of the fins, eyes, spinal column, vertebrae, and osteocranium, as shown by Plunkett and Snyder-Conn (2000), who suspected chemical agents of human origin. These authors reviewed literature indicating high frequencies of anomalies in other fishes as well (fathead minnows and chub species) and in amphibians of the Upper Klamath Lake basin. Harmful agents have not yet been identified.

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Skeletal deformities in young fish can affect their swimming performance and indirectly increase their vulnerability to predation and impair their ability to escape unfavorable habitat conditions. Plunkett and Snyder-Conn (2000, p. 2) suggest that the relatively high rate of anomalies in young suckers could result in "early elimination of anomalous 0-aged suckers from Upper Klamath Lake populations." Direct comparisons with populations in Clear Lake and Gerber Reservoir, where populations are apparently stable, would be informative.

Entrainment of Larvae and Juveniles

Entrainment at and lack of passage through Klamath River dams and other irrigation structures were added to the list of threats to the endangered suckers after the original listing (e.g., USFWS 1992a). Entrainment into irrigation and power-diversion channels is now recognized as being responsible for loss of "millions of larvae, tens of thousands of juveniles, and hundreds to thousands of adult suckers each year" (USFWS 2002, Appendix C., p. 24). Sucker larvae appear at the south end of Upper Klamath Lake beginning in late April. Millions of young fish then are swept from Upper Klamath Lake into the Link River, whence large numbers are drawn into the A Canal (USFWS 2002), from which they cannot escape.

Speculation has developed about the source of the young fish that reach the Link River. They may come from known spawning sites along the northeastern portion of Upper Klamath Lake, from such tributary streams as the Williamson River, or from unknown spawning sites farther south. Because all known spawning sites are in the northern portions of the lake, the critical question is whether currents in the lake are strong enough and of proper alignment to deliver larvae to the Link River 18 mi to the south.

Some evidence indicates that larval and juvenile fish entering the Link River originate in known riverine and lake spawning areas. Prevailing winds are from the northwest when larvae are present and establish substantial south-flowing currents, according to a numerical model developed by Philip Williams & Associates (PWA 2001). The Philip Williams model suggests that it is very feasible for larvae produced from the Williamson and Sprague system to enter the south end of the lake within a few days of swimup, the time at which larvae first leave the substrate for the water column (R. S. Shively, U. S. Geological Survey, Klamath Falls, Oregon, personal communication, 2002). Whether entrainment is caused by natural movement of fish that would historically have entered Lower Klamath Lake or is an avoidance response to poor habitat or poor water-quality conditions is unknown. Regardless, given that these larvae likely originate in known spawning aggregations and that any larvae leaving the lake to the south are permanently lost from the population, entrainment

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of young fish is a potentially important contributor to failure of the populations to grow.

USBR was scheduled to place fish screens at the A Canal in the summer of 2003. These screens function effectively with fish larger than 30 mm (USFWS 2002). Although retention of fish smaller than 30 mm could be achieved, the likelihood that very young, fragile fish would survive impingement (along with algae and debris) on the screens is low, and the chances of salvaging them successfully are even lower. Juvenile fish may survive impingement but, unless they move against the current, will still be lost from source populations because fish screened from the A Canal will next pass through the Link River Dam and then enter other canals, be killed by turbines, or join nonreproducing populations downstream (Figures 1-2 and 1-4). Even so, the screening does prevent loss of subadults, adults, and some juveniles through the A Canal.

USFWS (2002) recommends coordination of intake at the A Canal with timing of juvenile movements, deflection barriers that would move juveniles away from intake structures, location of intakes above the water-column strata in which young suckers usually swim, and salvage. These measures seem reasonable and should be pursued. Salvage operations may be pointless, however, if emigration from the lake is an avoidance response to poor water quality. Salvaged fish possibly could be moved to a holding facility with good water quality before return to Upper Klamath Lake or could be transplanted to other sites to establish new populations.

Adequacy of Nursery Habitat for Larvae and Juveniles

Upper Klamath Lake has lost an estimated 66% of emergent marsh vegetation and submerged vegetation (USFWS 2002). Specific changes include the apparent loss of emergent vegetation in the region between the Williamson River mouth and Goose Bay that probably once was important larval habitat; vegetation should be restored in this area as soon as possible. In general, diking, draining, and water-level management have reduced emergent and submerged vegetation along shorelines by about 40,000 acres (USFWS 2002). Remaining marginal marshes around Upper Klamath Lake are reduced, patchy, and often dewatered by middle to late summer as water level falls.

Vegetation in shallow water is a consistent aspect of larval habitat and may be important to juvenile habitat as well (Chapter 5). Abundance of this habitat feature during the larval phase, which extends from April through July, in Upper Klamath Lake is in part related to water depth. Higher water levels in Upper Klamath Lake are associated with larger amounts of emergent vegetation (Table 6-2). Ignoring emergent vegetation, total shoreline area that is at least 1 ft deep at lake water levels of 4,142–4,143 ft accounts

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TABLE 6-2 Estimates of Larval Habitat Availability Calculated as Percentage of Lakeshore Inundated to a Depth of at Least 1 Ft for Lake Edge and Marsh Regions in Northeastern Upper Klamath Lake that Contain Emergent Vegetation, and Total Lake Shoreline Regardless of Vegetation

	% Larval Habitat Available		% Lake Shoreline Available	
Water Level, Lake (ft)	Dunsmoor et al. 2000	Reiser et al. 2001	Chapin 1997	Reiser et al. 2001 (All Shoreline)
4,143.0	–	–	–	85–100
4,142.8	80[a]	–	–	–
4,142.0	50[a]	100[b]	–	40–60
4,141.5	–	80[b]	–	–
4,141.2	–	80[c]	–	–
4,141.0	–	–	–	10–25
4,140.0	0[d]	0	0	–

[a]Shoreline emergent vegetation.
[b]All emergent vegetation.
[c]Marsh edge habitat only.
[d]Almost completely unavailable.

for at least 50% of the lake's perimeter, but this fraction declines rapidly with reduced water levels. Very little emergent vegetation is available to larval suckers below a lake level of 4,141 ft; emergent vegetation is essentially inaccessible below 4,140 ft (Reiser et al. 2001). Reiser et al. (2001) recommend maintaining water levels above 4,142 ft at least until July 15 to ensure access by larvae and juveniles, although the data on use of this habitat by juveniles are not clear.

Because the majority of suckers in Upper Klamath Lake now spawn in the Williamson and Sprague river system, use of habitat in the system by larvae could be important in determining production of larvae. Under current conditions (blockage of spawning migrations at Chiloquin Dam combined with a highly modified stream channel in the lower Williamson delta), a higher proportion of larvae may be produced in the lower Williamson than were produced there historically. As a result, the larvae may pass from the river to the lake more quickly and with less temporal dispersion than was the historical norm. Cooperman and Markle (2000) found that larvae left the Williamson River in as little as a single day and that 99% of larvae entering the lake had not yet developed a tail fin and so were not yet competent swimmers and feeders. The majority of larvae in the lower river sampled by Cooperman and Markle (2000) had empty guts. Thus, many larvae may be entering Upper Klamath Lake before they are ready to feed or to avoid predators (comparisons with Clear Lake and Gerber Reservoir

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populations would be useful but are not available). Modifications to the lower Williamson have reduced plant cover, and thus possibly reduced food production and shelter from predators. The Nature Conservancy is restoring the lower Williamson to a more natural, meandering, multiple-channel configuration that supports denser riparian and emergent vegetation. This project should be completed soon. Larvae descending from the Williamson system will find cover near the mouth of the river when vegetation and morphology have begun to recover, which may take some time.

Physical conditions that may impair spawning and support of fry in the rivers above Upper Klamath Lake have not been adequately studied. Changes in river channels have occurred as a result of removal of riparian vegetation, access of cattle to the streams, alteration of flows, and loading of the stream with fines. All of these factors should be documented and measures should be taken to reverse them on grounds that these changes are quite likely to interfere with successful spawning and larval survival.

Hypotheses about the significance of lake-level changes and capacity of Upper Klamath Lake to sustain larval suckers can be tested against information on the relative abundance of sucker larvae, as determined over the years 1995–2000. If interannual variation in lake levels is a dominant factor in the viability of larvae in the lake, years of higher lake level during the larval development period should be marked by higher larval abundance. To be of use in management, any beneficial effects of high water level should appear as higher CPUE (catch per unit effort) of larvae. This is not the case, however (Figure 6-5). In fact, the amount of larval habitat in spring varies across years much less (about 2-fold; compare Figure 6-5 with Table 6-2) than larval abundance per unit area (as indicated by CPUE—10-fold).

Additional testing is possible through use of information on relative abundance of year classes among fishes collected during episodes of mass mortality. If interannual variations in lake level correspond to relative degrees of repression of larval production, and this factor has a major effect on the populations, year classes produced in years of especially low water levels in Upper Klamath Lake should be exceptionally weak. Once again, this is not the case (Figure 6-6).

Lack of correspondence between larval abundance and indicators of year-class success based on either collection of larvae or collection of adults does not contradict the idea that inundated vegetation is critical habitat, that is, habitat that the suckers need in some unknown amount and distribution. It does call into question the idea that greater or smaller abundance of this habitat feature from one year to the next is regulating the populations. Cooperman and Markle (2003) have argued that complicating factors could mask an important relationship between water level in Upper Klamath Lake and production of larvae. From a scientific viewpoint, how-

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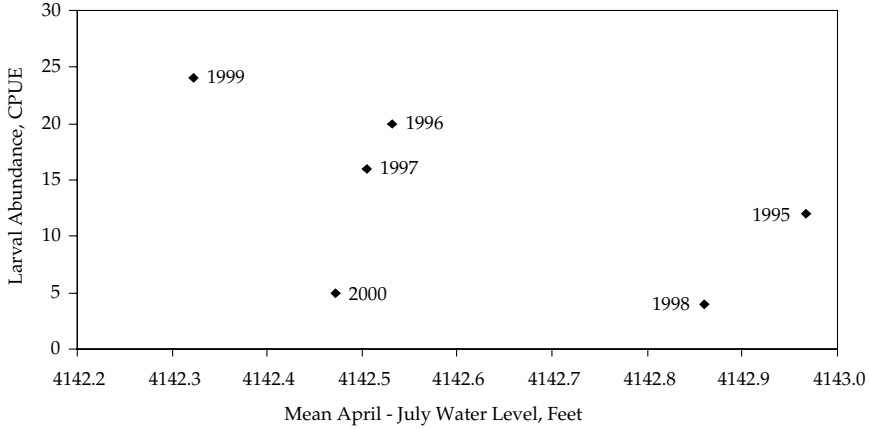


FIGURE 6-5 Relative abundance of larvae as determined by standardized sampling, shown in relation to mean water level of Upper Klamath Lake during the main interval of larval development (April–July). Source: Simon and Markle 2001.

ever, the water-level hypothesis is not supported because it fails empirical tests for the presently available data. An argument for a complex relationship involving water level would require empirical support, of which there is none. One potential line of investigation would be to examine the differences in larval production of the two sucker species. The two species appear to be responding in similar ways to environmental change, but the data

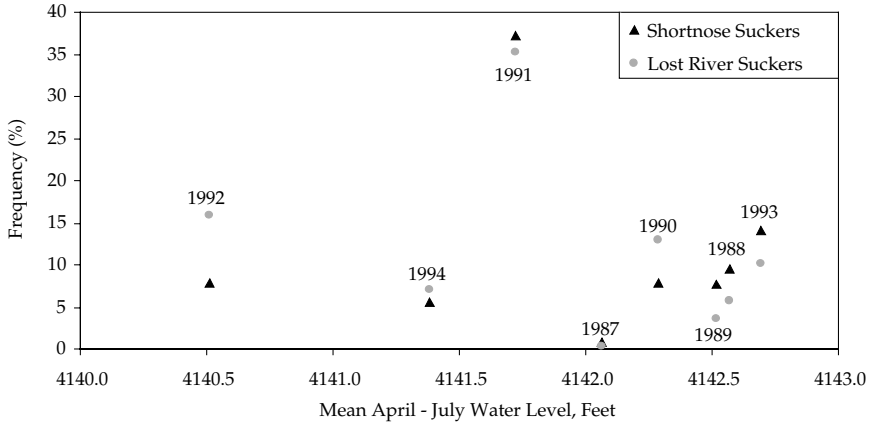


FIGURE 6-6 Relative abundances of year classes of endangered suckers collected from Upper Klamath Lake during the fish kill of 1997, shown in relation to mean water level over the interval of larval development for the same year classes. Source: USGS, unpublished data, 2001.

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suggest that the responses are not exactly the same. Differences related to timing or place of spawning may be important.

From a management perspective, the difficulty with a water-level hypothesis that involves unknown complications is that observations of higher water levels at present offer no evidence that would support maintenance of higher water levels. At the same time, the lack of a relationship between observed water levels and larval abundances cannot be taken as justification for broader manipulation of water levels, which at some extreme could be notably harmful.

Monitoring of larval abundance and year-class abundances as inferred from mass mortality indicate that the explanation for interannual variability at present lies in key factors other than the amount of shallow water or emergent vegetation. This conclusion should energize the investigation of other habitat features. For example, restricted availability or poor condition of tributary spawning areas could be critical. Interannual variability of year-class abundance as affected by delivery of larvae from tributary spawning areas would be an obvious subject for further study.

The known biology of the suckers indicates that particular depths are preferred at established spawning locales and that flooded emergent vegetation is primary larval habitat. The lack of relationship between water level in Upper Klamath Lake and larval production or larval survival indicates that other factors, such as degraded water quality or poor larval habitat, override the presumed benefits of depth-related habitat availability. Recommending maintenance of particular water levels to promote sucker recovery has no clear scientific basis until the factors that override water depth are better understood and, if possible, rectified. USFWS may retain an interest in water-level manipulations as justified by the need to minimize risk. Given limitations on the legitimate use of the need to minimize risk, however (Chapter 9), it might be difficult for USFWS to justify more stringent limitations on water level as a general operating rule. One alternative is for USFWS to work with USBR in testing various water-level combinations that can be achieved through such actions as experimental use of water-bank resources or by use of the excess water that may be available in some years.

Overview of Larval and Juvenile Production

As explained above, larvae were variably abundant in trawl catches throughout the 6-yr monitoring period 1995–2000. Catches were high in 1995, 1996, 1997, and 1999, and were relatively low in 1998 and 2000. No correlations are obvious between abundance of fish in spawning runs and larval abundance (Simon and Markle 2001, USFWS 2002) or between fish kills and larval abundance. Abundances of young of the year (YOY)

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also have high year-to-year variation and lack any detectable relationship with abundance of spawners. The year 1999 was good for larvae and juveniles regardless of sampling locale or method (Simon and Markle 2001, USFWS 2002), and 1991 must have been favorable as well, as judged from abundance of adults (monitoring of larvae did not begin until 1995).

As in most fish populations, abundance of young suckers in Upper Klamath Lake declines progressively through each summer and fall (Simon and Markle 2001). Declines could be explained by offshore movement as the fish grow, high mortality, high emigration rates from the lake, or a combination of these. Abundance of juveniles in spring (age 1+ yr) appear to reflect a 90% overwinter mortality or emigration (Simon and Markle 2001). High incidences of physical abnormalities in these fish (Plunkett and Snyder-Conn 2000) imply that mortality or export may repress recruitment of subadults and adults, although avoidance of sampling gear by postlarval fish creates difficulties in interpretation.

Some minimal number of spawners is necessary to produce a successful year class of larvae, but the lack of correlation between numbers of spawners and abundances of larvae implies that abundant spawners are no guarantee of high larval numbers and that, given the high fecundity of suckers, a small number of spawning fish may be sufficient to produce abundant larvae if conditions for larvae are good.

Adults

Entrainment

Fish that enter water-management structures typically cannot return to the habitat from which they came or enter another suitable habitat. For Upper Klamath Lake, the A Canal has long been recognized as a source of entrainment for all life-history stages, including adults, whose loss may be especially significant because of the importance of large fish in maintaining the fecundity of the population (Chapter 5). Scheduled screening of the A Canal, which will be ineffective for small fish < 30 mm, will block entrainment of subadult and adult fish, and could thus reverse an important historical source of mortality. The benefits of this measure to the population are unknown. Entrainment of fish from Upper Klamath Lake via the Link River still occurs through intake structures of the Link River Dam, which should be screened (USFWS 2002).

Mass Mortality

Unlike most other imperiled lakesuckers, suckers of Upper Klamath Lake suffer from episodic mass mortality of reproductive-age fish. Although such

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mortality probably inhibits recovery, fish kills are not new to Upper Klamath Lake. Records indicate periodic kills dating at least to the late 1800s; before the 1990s, large fish kills occurred in at least 1894, 1928, 1932, 1966, 1967, 1971, and 1986 (USFWS 2002). Whether episodic mass mortality has always occurred in Upper Klamath Lake is a matter of conjecture.

The actual numbers and sizes of fish killed are difficult to estimate because of sampling difficulties, differential sampling effort, loss of small fish to birds, and loss of fish that do not float after death. Mortality may reach tens of thousands in a severe episode (Perkins et al. 2000b). The effects of fish kills on spawning populations of suckers probably have been substantial. As much as 50% of the adult populations may have died in the 1996 fish kill; sizes of spawning runs indicate that the spawning populations of both species were reduced by 80–90% from 1995 to 1998 (USFWS 2002; Chapter 5).

The largest documented case of mass mortality occurred in 1971; it involved the loss of about 14 million fish, most of which were blue and tui chubs. Water level may or may not have played a role in conditions leading to the incident, but 1971 was the year of highest recorded water level since full operation of the Klamath Project began in 1960. It is unclear whether the extent or frequency of mortality is greater now than earlier. Incidents of mass mortality in 3 consecutive recent years (1995, 1996, and 1997) are a reason for special concern, but it is impossible to determine whether such episodes now are more frequent than in the past.

It could be argued that mass deaths of suckers is a natural phenomenon caused by very high abundances of algae that have always been characteristic of Upper Klamath Lake. Or it could be argued, without particularly strong support, that mass mortality is more frequent or more severe than it used to be. It is not necessary, however, to resolve this point for ESA purposes. Because the abundances of the endangered suckers have been drastically reduced, any factor that leads to a larger population should be favored as a step toward recovery of the species, even if it involves a natural mortality mechanism. Thus, reducing mass mortality, whether natural or not, should be counted as beneficial to the welfare of the species and should be pursued.

Conditions commonly associated with fish kills include high temperature, intense blooms of bluegreen algae, high incidences of copepod (*Lernaea*) infestations (see Table 6-3), cysts, lesions, infection with *Flavobacterium columnare* (columnaris disease), high pH, high concentrations of unionized ammonia, and low concentrations of dissolved oxygen (Perkins et al. 2000b, Chapter 3). Before kills, some fish apparently move to the Link River (Gutermuth et al. 1998), and others (mainly redband trout) become concentrated in specific refuge areas, including Pelican Bay, Odessa Creek, and the Williamson River mouth. Refuges often contain springs that offer much better water quality than the lake itself (Bienz and Ziller 1987).

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TABLE 6-3 Incidence (%) of Various Indicators of Stress in Suckers of Upper Klamath Lake Based on Visual Inspection

	Incidence, %				
	Lampreys Wounds	Copepods Infections	Eye Damage	Emaciation	Wounds
Lost River Suckers, Live Fish, 2001					
Lake spawning	40	22	4	0	1
River spawning	48	28	22	0	2
Lake non-spawning	51	18	8	1	2
Shortnose Suckers, Live Fish, 2001					
Lake spawning	53	30	3	0	0
River spawning	38	51	16	0	1
Lake non-spawning	48	33	8	0	4
Fish Kill					
1997		73[a]			

[a]Based on Foott 1997 and Holt 1997 in USFWS 2002; incidence of *Columnaris* disease was 92% and 80%, respectively, during the 1996 and 1997 fish kills (USFWS 2002).
Sources: Coen et al. 2002, Cunningham et al. 2002, Hayes et al. 2002.

Mortality of fish during routine sampling with trammel nets also increases during the weeks preceding a fish kill (USFWS 2002).

Although USFWS (2002) went to considerable lengths to examine the possible direct influence of high water levels in Upper Klamath Lake on sucker welfare, the data now on hand contradict the hypothesis that water level is associated with fish kills (NRC 2002, Figure 3; Chapter 3). Fish kills have occurred in years of low, average, and above-average median August lake levels. Water level may affect the accessibility of refuges that are reportedly used by large fish during periods of poor water quality and fish kills, but the data on this topic are largely anecdotal (see Buettner 1992 unpublished memo, USFWS 2002, Appendix C, and below).

High incidences of parasites, bacterial infections, and other anomalies imply that stressful conditions exist in Upper Klamath Lake for several weeks before the appearance of dead fish. Loftus (2001, cited in USFWS 2002) developed a "stress-day" index that accounts for multiple stress factors related to water quality. In 1990–1998, accumulated stress days were maximal in July and August during the fish-kill years of 1995 and 1997. The stress-day index approach is useful in that it involves regular, coordinated monitoring focused on water quality, meteorology, fish condition (parasite frequency, body condition, and so on), and attention to increased numbers of adults in the Link River or presumed refuges. When conditions and early warning signs converge, whatever remedial actions are

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feasible should be taken, possibly including oxygen supplementation at specific locales where suckers aggregate (Chapter 3).

In some lakes, mass mortality of fish occurs under ice ("winterkill"), usually in association with low concentrations of dissolved oxygen. Winterkill is not known to have occurred in Upper Klamath Lake or in any other lakes occupied by endangered suckers. Thus, the relevance of winterkill to Upper Klamath Lake remains hypothetical, as do management actions that would minimize its likelihood or effect.

Winter mortality (but not necessarily winterkill) has been postulated as the cause of a 90% reduction of first-year juvenile suckers in Upper Klamath Lake from late fall to early spring and population reductions in other species (Simon and Markle 2001). Comparable data are needed on winter mortality in surrounding water bodies with better water quality (such as Clear Lake) to determine whether the 90% mortality figure is extreme.

Concern over winterkill is justified, especially if water quality deteriorates further or if an exceptionally cold winter results in an unusually long period of ice cover. Improvement in water quality in the lake probably would reduce the likelihood of winterkill, but may be infeasible over the short term. Winter monitoring of oxygen should be undertaken in any event (Chapter 3).

Loss of Habitat

Adult Lost River suckers and shortnose suckers prefer open water; they use flowing waters chiefly for spawning. Total lake habitat available to suckers throughout the Klamath basin is a fraction of its original extent because of drainage and other water-management practices (Chapter 2). Even where it persists, habitat for adults may be compromised during late summer. Adult suckers appear to prefer water that is deep and turbid, and thus dark (USFWS 2002), but degraded water quality in summer apparently forces fish to use specific areas of shallow, clear water, such as the mouth of Pelican Bay in Upper Klamath Lake.

Factors Relevant to All Life-History Stages

A number of factors, some of which have already been mentioned, are potentially relevant to all life-history stages, although further research may show them to be more relevant to some stages than to others. Most prominent is poor water quality, which is linked not only to mass mortality of adults but potentially to undocumented mortality of other stages and to stress, which in turn may be a cause of anomalies, parasitism, and disease in multiple life-history stages. A second complex of factors that may apply broadly across stages, but still in unknown ways, falls under the heading of

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predation and competition, primarily from nonnative fishes. A final factor that cannot yet be attached to any particular life-history stage is hybridization, which may change populations genetically.

Water Quality

Suckers of Upper Klamath Lake suffer from varied deformities, parasites, lesions, cysts, and infections. The afflictions of adult suckers include eroded, deformed, and missing fins; lordosis; pughead; multiple watermold infections; reddening of the fins and body due to hemorrhaging; cloudiness of the skin caused by low mucus production; loss of pigmentation; external parasitic infection by copepods and leeches; lamprey wounds; ulcers; gas emboli in the eyes; exophthalmia; cataracts; and a high incidence of gill, heart, and kidney abnormalities after fish kills. Plunkett and Snyder-Conn (2000) reported body-anomaly rates of 8–16% in larval and juvenile suckers. Juvenile suckers suffered infestation with copepods and trematodes of 0–7% in 1994–1996 and 9–40% in 1997–2000; shortnose suckers generally show higher rates of infestation than Lost River suckers (USFWS 2002 based on Carlson et al. 2002). Data on both species in Upper Klamath Lake and at river spawning sites also indicate relatively high frequencies of abnormalities in adults (Table 6-3). Spawning and nonspawning fish do not show substantial differences in the incidence of such indicators, except that copepod infestations appear to be higher in shortnose suckers and eye damage is higher in river-spawning fish of both species. The latter finding might reflect crowding of fish downstream of Chiloquin Dam or injuries to the fish as they attempted to negotiate the unsuitable fish ladder at the dam.

The widely used Index of Biotic Integrity (Karr et al. 1986) incorporates 1% as a threshold criterion for anomalies; sites with fish above this threshold receive the lowest metric scores for their ability to support a diverse biota. The appropriate threshold may vary geographically and by taxa, however. For the Willamette River, Hughes and Gammon (1987) identified 6% as a threshold. Hughes et al. (1998) proposed a more general threshold of 2%. Most collections from all size classes of Upper Klamath Lake suckers exceed these thresholds. It is not known why Clear Lake, with its better water quality and apparently stable population, also is characterized by "heavy parasite loads on suckers and other fish" (Snyder-Conn, personal communication cited in USFWS 2002, Appendix E, p. 38).

Even if infections and afflictions do not lead directly or even indirectly to death, they are likely to inhibit growth (e.g., M.R. Terwilliger et al., Oregon State University, Corvallis, Oregon, unpublished material, 2000) and reproduction and may compromise an individual's ability to resist other sources of stress. Without better baseline and reference values for suckers in other water bodies in and out of the Klamath basin, it is difficult

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to state categorically that the incidence of anomalies is extraordinary, but field researchers who work with fish seldom observe affliction rates approaching those found in Upper Klamath Lake.

Nonindigenous Species as Predators and Competitors

Eighteen of the 33 fish taxa in the upper Klamath basin are nonnative (Chapter 5). The nonnatives dominate numerically in many habitats and probably influence native species, including the endangered suckers, through predation and competition. Competition is particularly difficult to quantify in nature (Fausch 1988, 1998). Thus, it is not often possible to invoke competition as a major cause of problems in a population, and it also is difficult to moderate competition even where it can be demonstrated. In contrast, predation on native fishes by nonnative fishes is easily demonstrated; it can have devastating effects on native fishes (e.g., Fuller et al. 1999). In Upper Klamath Lake, introduced fathead minnows may prey on larval suckers, as shown in laboratory enclosures (Dunsmoor 1993, cf. Ruppert et al. 1993), although the applicability of the laboratory studies to conditions in nature is uncertain. Juvenile and adult yellow perch and juvenile largemouth bass consume larvae, as may Sacramento perch, most other centrarchid sunfishes, and the two bullhead species present in Upper Klamath Lake. Juvenile and adult largemouth bass also could feed on juvenile suckers, although adult suckers reach a body size that provides them refuge from fish predators. Comparisons of Upper Klamath Lake with other lakes in this regard could be useful. With the exception of Sacramento perch, Clear Lake apparently has been spared significant introductions of nonnative fishes, and its populations appear to be stable. A species list for Gerber Reservoir is not readily available.

The presence of numerous and diverse nonnative fishes in the Klamath system complicates recovery efforts. Nonnative species typically do well in disturbed systems (Moyle and Leidy 1992). Given that attempts to reduce abundances of nonnative fishes usually are unsuccessful, the best tactics for decreasing the success of these invaders are to discourage future introductions (especially of predators), to restore water quality if possible, and to prevent movement of nonnative fishes within the basin. Selective control of nonnative species has been pursued in some environments (Ruzycki et al. 2003), however, and should not be ruled out entirely for Upper Klamath Lake.

Hybridization and Introgression

Hybridization results in wasted spawning and loss of genetic diversity through elimination of rare alleles. Introgression (backcrossing of hybrids

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with parental species) can harm a rare species, as apparently has happened to the endangered June sucker, *Chasmistes liorus liorus*, which hybridizes readily with the more abundant Utah sucker, *Catostomus ardens* (Echelle 1991). The original ESA listing document for Klamath suckers (53 Fed. Reg. 27130 [1988]) cited apparently high rates of hybridization among the three Upper Klamath Lake sucker species, especially between shortnose suckers and Klamath largescale suckers, and cited hybridization as a potential contributor to loss of genetic integrity and decline of species. Apparent hybrids, as indicated by morphological intermediacy, are commonly found in the Williamson River downstream of Chiloquin Dam and in sucker populations of Clear Lake, where crosses between Lost River suckers and Klamath largescale suckers are most frequently suspected (e.g., Cunningham et al. 2002; Moyle 2002; D. Markle, Oregon State University, Corvallis, Oregon, personal communication, 2002). Recent anatomical studies of hybridization, however, imply that it is a rare occurrence. Among spawning fish captured in Upper Klamath Lake in 2001, 0.2% of fish from shoreline spawning sites, 4% from the lower Williamson River, and 6% occupying the area below Chiloquin Dam were apparent hybrids (Cunningham et al. 2002, Hayes et al. 2002, Janney et al. 2002). In contrast, one-third of fish caught at Chiloquin Dam in 2000 appeared to be anatomically intermediate. Morphological studies may overestimate hybridization; allozyme frequency and nuclear genetic data indicate that recent hybridization is rare, that nominal species are all valid, and that little genetic divergence has occurred among populations within species (D. Buth, University of California at Los Angeles, Los Angeles, California, personal communication, 2002; Dowling 2000; T. Dowling, Arizona State University, Tempe, Arizona, personal communication, 2002). Microsatellite data indicate, however, that the three species present in the Lost River (largescale, shortnose, and Lost River suckers) are significantly different from suckers in Upper Klamath Lake and the upper Williamson River (G. Tranah, Harvard School of Public Health, Boston, Massachusetts, personal communication, 2002).

Overall, morphological data indicate that hybridization has occurred, but current genetic analyses reveal that Lost River suckers and shortnose suckers are distinct and that the identity of the species has not been eroded by extensive hybridization. High priority should be attached to further genetic analysis that will give more information on hybridization and on the genetic structure of currently isolated populations.

Before the Klamath Project was completed, all sucker habitats were subject to interchange of fish (Chapter 2). Dams and irrigation canals isolated populations to an extent that could ultimately affect the genetic diversity of the species. None of the primary dams in the Klamath basin allow passage of suckers. Efforts to protect the species with regard to

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range fragmentation should focus on habitat protection and improvement of all subpopulations and on construction of ladders of proven effectiveness or removal of barriers to improve exchange among subpopulations.

Other Issues Relevant to Recovery

Other Natives and the Paradox of Persistent Endemics

Shortnose and Lost River suckers apparently are more susceptible to degraded habitat conditions or other factors, such as predators, than any of the 14 other native species. Blue chub and tui chub do appear in some fish kills, sometimes in large numbers, but their populations remain large in Upper Klamath Lake, as do populations of Klamath Lake sculpins and redband trout. Even the Klamath largescale suckers in the upper Klamath basin and Klamath smallscale suckers in the lower basin seem not as affected by anthropogenic change as Lost River and shortnose suckers, although the Klamath largescale sucker is listed as a species of special concern in California (Moyle 2002). Introduced species, such as yellow perch and fathead minnow, appear to be unaffected by poor water quality. Sacramento perch, which have been greatly reduced throughout their native range (Moyle 2002), apparently are doing well in the Klamath basin. Explanations for the exceptional vulnerability of shortnose and Lost River suckers could be applied to recovery efforts.

One line of evidence is related to physiological tolerances among species, but this information is limited. Falter and Cech (1991) found that shortnose suckers were less tolerant of elevated pH than were Klamath tui chub and Klamath largescale suckers (Chapter 5). Additional comparative studies of physiological responses to water-quality degradation in the Klamath basin are needed. Overall, more and better information is needed on the biology and population status of nonsucker species in the upper basin (Chapter 5). Because all native Klamath fishes are endemics, any significant declines in their populations could trigger ESA actions. Although research efforts directed specifically at native fishes other than the listed suckers would be desirable, information on them can be collected in conjunction with studies of suckers. Some of the species can be used as indicators of water quality and habitat conditions and would provide insight into the welfare of the endangered suckers, especially where differences in physiological tolerance can be demonstrated. Comparisons between endangered Klamath suckers and other catostomid species in the Klamath basin and between Klamath suckers and lake suckers elsewhere could provide additional, invaluable insight into solutions to problems in the Klamath basin.

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Captive Propagation

Captive propagation is a controversial means of protecting endangered species. Successful propagation can lead to complacency about the condition of natural populations and to delay in the correction of the original causes of decline, but it also can serve as insurance against catastrophes. Although Klamath suckers have not reached the point where captive propagation is necessary, many conservation practitioners recommend against waiting until there is no alternative to captive propagation, because by then genetic resources are diminished and problems with rearing methods may be disastrous.

The Klamath Tribe has established a sucker holding and rearing facility (the Klamath Tribes Native Fish Hatchery) at Braymill near Chiloquin. The facility has been used for physiological and behavioral studies and for fertilization and larva-rearing trials (e.g., Dunsmoor 1993; L. K. Dunsmoor, Klamath Tribes, Chiloquin, Oregon, personal communication, September 3, 2002). The facility could serve as the core of a captive-propagation effort if populations continue to decline. Methods already developed there can be used, perhaps with advice based on successful propagation of cui-ui at the David Koch Cui-ui Hatchery in Sutcliffe, Nevada, if captive propagation proves necessary.

Critical Habitat

Critical habitat, as defined by the ESA (Chapter 9), was not identified for the Klamath suckers at the time of original listing, and has yet to be completed for either endangered species, although a draft proposal appeared in 1994 (59 Fed. Reg. 61744 [1994]). On the basis of established ESA criteria (for example, water quantity and quality; physical habitat appropriate for spawning, rearing, and feeding; and protection from predation and climatic stress), USFWS identified six critical-habitat units (CHUs) in the basin: Clear Lake and its watershed, Tule Lake, the Klamath River, Upper Klamath Lake and its watershed, the Williamson and Sprague Rivers, and Gerber Reservoir and its watershed. All except Gerber Reservoir are habitat units for both sucker species; Gerber Reservoir contains only shortnose suckers, but Lost River suckers presumably could live there.

The draft critical-habitat determination (59 Fed. Reg. 61744 [1994]) and its recommendations should be reviewed and revised in light of recent findings. The process of identifying critical habitat for both species needs to receive higher priority and should be more specific. In designating Upper Klamath Lake a CHU, USFWS (59 Fed. Reg. 61744 [1994]) did not identify specific areas of particular value. The CHU approach could be expanded to include the needs of specific life-history stages, for example, east coast springs for spawning, Williamson River mouth and nearby shorelines as a

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nursery region, Modoc Point and Goose Bay as staging areas before spawning, and west coast bays as postspawning aggregation areas (see Chapter 5). Buettner (1992) identified sites that have the greatest potential as adult refuges at low lake levels on the basis of their size, proximity to the main lake, relative water quality, and density of submerged vegetation. The issue of water-quality refuges needs more study relative to critical habitat. If the postulated patterns can be verified and the location and use of these apparent water-quality refuges can be confirmed, they might be designated as critical habitat and considered for special protection.

Although there is only weak pressure for development in the Klamath basin, the human population of the area has grown, and future growth is likely (Chapter 2). Proposals for new construction or use of the lake should take into account possible adverse effects on suckers. For example, an article in *SAIL* magazine for July 2002 identified Howard Bay, Pelican Bay, and Harriman Springs as desirable destinations for boaters. Howard Bay apparently is a preferred aggregation area for postspawning shortnose suckers (Coen et al. 2002); Pelican Bay was identified by Buettner (1992) as a refuge for suckers during the fish kills of July 1971 and August 1986 and was considered the best sucker refuge site on the west shoreline when lake levels drop; and Harriman Springs is a former spawning site. Increased boat traffic, development, groundwater pumping, or other activities may adversely affect these sites.

LESSONS FROM COMPARATIVE BIOLOGY OF SUCKERS

Of the 63 species of suckers in the world, 61 are endemic to North America. Among the few known extinctions of freshwater fishes in North America, suckers figure prominently. Previously abundant, sometimes widespread species have disappeared, including the harelip sucker (*Lagochila lacera*) and the Snake River sucker (*Chasmistes muriei*). Fully 35% of sucker species are imperiled (Warren and Burr 1994), and eight have federal endangered or threatened status (50 CFR 17.11 [1999]).

Populations of large suckers in general and lake suckers in particular have declined largely because of anthropogenic factors. Although there is an obvious need for concern about these very American fishes, comparative data indicate that they can survive long periods of interrupted recruitment and can recover from these remarkable hiatuses in reproduction if factors causing decline are reduced. For example, decline has occurred in other lake suckers: cui-ui experienced no known recruitment from 1950 to 1969; June suckers had experienced at least 15 yrs without recruitment by the middle 1980s, and that probably continued into the 1990s; some populations of razorback suckers (*Xyrauchen texanus*) experienced 20–30 yr without recruitment; and Utah suckers (*Catostomus ardens*) did not reproduce successfully between the middle 1960s and the early 1990s.

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Despite extended interruptions in breeding, several species of suckers have responded successfully to recovery programs. Cui-ui successfully spawn in the Truckee River because of enhanced flows and are propagated in a hatchery managed by the Paiute Tribe, from which they are regularly transplanted into Pyramid Lake, where they are abundant (USFWS 1992b). Efforts to promote recovery of June suckers have been under way since the early 1990s and appear to have been successful; they include water-allocation agreements, refuge-population establishment, and captive breeding and release (USGS 1998). The robust redhorse, *Moxostoma robustum*, a large sucker thought to have undergone population declines in Atlantic slope drainages, is now propagated and planted and has shown successful recaptures in three southeastern rivers (Jennings et al. 1998; C. Jennings, U. S. Geological Survey, Athens, Georgia, personal communication, 2002). An extensive recovery program for razorback suckers instituted in 1988 includes captive rearing and transplantation, habitat acquisition and protection, and control of nonindigenous species; success has been mixed (Minckley et al. 1991, Mueller and Marsh 1995). This general picture of decline, public concern, multifaceted efforts at recovery, and evidence of success can suggest actions that might be successful with the Klamath basin sucker species.

All four living lake suckers (shortnose sucker, Lost River sucker, cui-ui, and June) are relatively large and long-lived (Chapter 5). High tolerance of poor water quality implies that the fishes evolved in habitats that periodically experience extremes of water quality. Long life in these suckers may reflect an evolutionary history that included harsh conditions that often resulted in reproductive failure, perhaps for many consecutive years. Exceptional longevity is a cause for optimism in that it allows the fish to recover from population declines once conditions favorable to survival are restored (Scoppettone and Vinyard 1991).

Age distributions in Upper Klamath Lake suckers, as reflected in the fish-kill data, show apparent resilience in Klamath species (e.g., Cooperman and Markle 2003). Heavy fishing pressure resulted in low numbers of old suckers until 1987, when the fishery was eliminated. Numbers of adults later increased sharply (Figure 5-4). The rapid increase demonstrates the positive effect of closing the fishery. More important, the increase shows that even after prolonged population declines brought about by overfishing, a relatively small number of large, highly fecund individuals can produce many young and help to restore a population (Cooperman and Markle 2003). Even slight improvements in conditions favorable to suckers in Upper Klamath Lake, its tributaries, and surrounding water bodies could contribute to recovery.

CONCLUSIONS

Despite elimination of fishing for the shortnose and Lost River suckers in 1987, these two listed species have failed to show an increase in overall

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abundance. Apparently stable populations with regular recruitment and the presence of all life-history stages at appropriate abundance are found only in Clear Lake and Gerber Reservoir. Thus, the listed suckers at these two locations require special degrees of protection, both in the lakes themselves and in tributary waters where the suckers spawn.

The two listed suckers are present in Upper Klamath Lake, where they reproduce and show the full spectrum of age classes indicating successful maturation of at least some individuals. This population has not increased in abundance, however, because of episodes of mass mortality affecting large fish and possibly other factors as well. Populations at other locations (the main-stem reservoirs, the main stem of the Lost River, and Tule Lake) are of very low abundance and consist primarily of adults; no full representation of age classes is present at these locations. Suckers have been eliminated entirely from the middle portion of the main stem of the Lost River, from Lower Klamath Lake, and from Lake of the Woods.

Small irrigation dams and the larger Chiloquin Dam across the main stem of the Sprague River impede the movement of suckers attempting to spawn in the tributaries to Upper Klamath Lake. Elimination of Chiloquin Dam could greatly expand any potential spawning area, although channel and riparian improvements to the upper Sprague might be necessary to achieve the full benefit of dam removal.

Spawning of suckers in tributaries to Upper Klamath Lake is successful in producing fry, but the spawning areas do not receive special protection and are poorly studied. Physical restoration of tributary spawning areas is a matter of high priority and will involve exclusion of livestock and other measures designed to promote conditions that favor spawning of the suckers. Physical restoration near the mouth of the Williamson River as it enters Upper Klamath Lake is also important.

Water level in Upper Klamath Lake shows no relationship to water-quality conditions that result in mass mortality of adult suckers or other potentially adverse water-quality conditions. In addition, water level shows no relationship to year-class strength or to abundance of fry or juveniles over the years during which standardized sampling is available. Thus, maintenance of water levels above recent historical levels in order to increase the abundance of suckers by maximizing the area of habitat where young suckers are found is not supported by the currently available evidence. Water levels lower than recent historical levels could have undocumented adverse effects and therefore are inadvisable. Experimental maintenance of specific water levels could be incorporated into a management plan, however, through agreements between USFWS and USBR, if USFWS sees merit in further studies of water-level control.

The two listed suckers spawn in specific lakeside areas of Upper Klamath Lake, typically in association with the presence of springs. Some

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spawning areas have been abandoned entirely, possibly because of the elimination, through fishing, of specific groups of fish that habitually used these areas. Some spawning areas show signs of anthropogenic degradation. Selective restoration of these areas and manipulation of stocks to encourage bonding of specific groups of suckers to the unused sites could be beneficial in spreading the reproductive risk of the sucker populations.

Suckers of all ages in Upper Klamath Lake historically have been entrained into the A Canal, which is the main supply conduit for USBR's Klamath Project. Screening of this source of mortality is scheduled for summer of 2003, but it cannot be expected to prevent mortality of very small fish. Refinement of the operation of the screens as recommended by USFWS (2002) might reduce the mortality of very young fish. The Link River Dam intake units remain unscreened, and thus remain a source of mortality for fish of all ages.

Suckers of Upper Klamath Lake and at other locations where suckers are present in the upper basins share their habitat to varying degrees with nonindigenous species, some of which are known to prey upon or compete with young suckers. Elimination of nonindigenous species over very large systems such as Upper Klamath Lake is beyond the current state of the art, but programs designed to prevent additional introductions and prevent the spread of presently nonindigenous species would be highly advisable. Because the actual effect of the nonindigenous species on the suckers is poorly known, it is difficult to judge the importance of this factor based on current information.

Hybridization among sucker species was an original concern of considerable importance to the listing of the suckers. Subsequent studies have reduced the level of this concern, but it would be advisable to have more information on the genetic identities of suckers at various locations in the upper basin.

Captive propagation is a possibility and could be conducted on a pattern that has been developed for populations of related suckers at other locations. Captive propagation is probably disadvantageous at present, however, in that it tends to undermine incentives for return of the populations to a self-sustaining basis, which may still be possible in the Klamath basin. Continued decline of the population sizes or loss of any major subpopulations would indicate a need for captive propagation.

The long life-history of suckers requires extended observation as a means of judging population trends. Benefits of restoration actions will not necessarily be evident until the fish benefiting from these actions have achieved spawning capability. Similarly, the negative effects of mortality focused on large fish may become evident only gradually, but could extinguish entire subpopulations.

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Fishes of the Lower Klamath Basin

Native fishes of the lower Klamath basin are mainly anadromous species that use productive flowing-water habitats and a few nonmigratory stream fishes typical of cool-water environments. Because the watershed has been drastically altered by human activities, it has become progressively less favorable for anadromous fishes, including coho salmon. Given that the native anadromous fishes support important tribal, sport, and commercial fisheries and have high iconic value, there is widespread support among stakeholders, both inside and outside the basin, for restoration of these fishes to their earlier abundances. Restoration efforts would most rationally apply to all native fishes, not just those listed or proposed for listing under the federal Endangered Species Act (ESA). If broadly based restoration does not occur, additional anadromous species are likely to be listed under state and federal endangered species acts. Furthermore, because actions that are perceived to benefit one species may do harm to another, the species cannot be treated as isolated units.

The lower Klamath basin supports 19 species of native fishes (Table 7-1). Thirteen (68%) of the 19 are anadromous, and two are amphidromous (larval stages in salt water); thus, 80% of the fishes require salt water to complete their life histories. The remaining four species spend their life entirely in freshwater and show close taxonomic ties to fishes in the upper basin or adjacent basins. The species composition of native fishes supports geologic evidence that the Klamath River in its present form is of relatively recent origin. One of the resident fishes (the lower Klamath marbled sculpin), however, is distinctive enough to be recognized as a subspecies and

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TABLE 7-1 Native Fishes of the Lower Klamath River and Its Tributaries

Name[a]	Life History	Status in Lower Klamath and Trinity Rivers[a]	Comments
Pacific lamprey, *Lampetra tridentata*	A	Declining	TTS, probably multiple runs
River lamprey, *L. ayersi*	A	Uncommon	Poorly known
Klamath River lamprey, *L. similis*	N	Common	Poorly known
Green sturgeon, *Acipenser medirostris*	A	State special concern, proposed for listing	TTS, important fishery
White sturgeon, *A. transmontanus*	A	Uncommon	May not spawn in river
Klamath speckled dace, *Rhinichthys osculus klamathensis*	N	Common, widespread	Most widespread fish in basin
Klamath smallscale sucker, *Catostomus rimiculus*	N	Common, widespread	Found also in Smith and Rogue rivers
Eulachon, *Thaleichthys pacificus*	A	State special concern	TTS, huge runs now gone, lowermost river only
Longfin smelt, *Spirinchus thaleichthys*	A	State special concern	Small population mainly in estuary
Prickly sculpin, *Cottus asper*	Am	Common	Larvae wash into estuary
Coastrange sculpin, *C. aleuticus*	Am	Common	Larvae wash into estuary
Lower Klamath marbled sculpin, *C. klamathensis polyporus*	N	Common?	Endemic
Threespine stickleback, *Gasterosteus aculeatus*	A/N	Common	Migratory close to ocean, anadromous; upstream forms nonmigratory
Coho salmon, *Oncorhynchus kisutch*	A	Federally threatened	Being considered for state listing, TTS
Southern Oregon-Northern California ESU			
Chinook salmon, *O. tshawytscha*			TTS
Southern Oregon-Northern California ESU	A	Commonest salmon below mouth of Trinity River	Much reduced in numbers
Upper Klamath and Trinity rivers ESU			
Fall run	A	Commonest salmon in both rivers	Much reduced, focus of hatcheries

(continued on next page)

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TABLE 7-1 continued

Name[a]	Life History	Status in Lower Klamath and Trinity Rivers[a]	Comments
Late fall run	A	Possibly extinct	Presence uncertain
Spring run	A	Endangered but not recognized as ESU	Distinct life history, adults require cold water in summer
Chum salmon, *O. keta*	A	Rare, state special concern	Southernmost run of species, TTS
Pink salmon, *O. gorbuscha*	A	Extinct	Breeding in basin poorly documented, TTS
Steelhead (rainbow trout), *O. mykiss* Klamath Mountains Province ESU	A, N	Common but declining; proposed for listing	Resident populations above barriers, TTS
Winter run	A	Most abundant	Distinct life history
Summer run	A	Endangered but not recognized as separate ESU	Distinct life history, adults require cold water in summer
Coastal cutthroat trout, *O. clarki clarki*	A, N	State special concern	Only in lower river and tributaries, resident populations above barriers, TTS

[a]Evolutionarily significant unit.
Abbreviations: A, anadromous; Am, amphidromous; N, non-migratory; TTS, tribal trust species.

several of the anadromous species have distinct forms adapted to the special conditions of the Klamath basin.

In addition, 17 nonnative species of fishes have been recorded in the basin (Table 7-2); only two of these are anadromous. For the most part, these fishes are confined to human-created environments—such as reservoirs, ponds, and ditches—although individuals constantly escape into the streams, where they may take advantage of favorable habitats created by human activity. In addition, nonnative fishes come down continually from the upper Klamath basin.

COHO SALMON

The coho salmon (Figure 7-1) once was an abundant and widely distributed species in the Klamath River and its tributaries, although its historical numbers are poorly known because of the dominance of Chinook salmon. Snyder (1931) reported that coho were abundant in the Klamath

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TABLE 7-2 Nonnative Fishes of the Lower Klamath and Trinity Rivers

Name	Life History	Status	Comments
American shad, *Alosa sapidissima*	A	Uncommon	Small annual run in lowermost reach of river
Goldfish, *Carassius auratus*	N	Uncommon	Ponds and reservoirs
Fathead minnow, *Pimephales promelas*	N	Uncommon	Invading from upper basin where extremely abundant
Golden shiner, *Notemigonus chrysoleucas*	N	Uncommon	Important bait fish in California
Brown bullhead, *Ameiurus nebulosus*	N	Locally abundant	Ponds and reservoirs, especially Shasta River; some in main stem
Wakasagi, *Hypomesus nipponensis*	N	Locally abundant	In Shastina Reservoir but a few downstream records
Kokanee, *Oncorhynchus nerka*	N	Locally abundant	Reservoirs
Brown trout, *Salmo trutta*	N, A	Common in some streams	Sea-run adults rare
Brook trout, *Salvelinus fontinalis*	N	Common	Only in headwater streams and lakes
Brook stickleback, *Culea inconstans*	N	Locally abundant, spreading	Recent introduction into Scott River
Green sunfish, *Lepomis cyanellus*	N	Common	Warm streams, ditches, and ponds
Bluegill, *L. macrochirus*	N	Common	Ponds and reservoirs
Pumpkinseed, *L. gibbosus*	N	Uncommon	Abundant in upper basin
Largemouth bass, *Micropterus salmoides*	N	Common	Ponds and reservoirs
Spotted bass, *M. punctulatus*	N	Locally common	Only in Trinity River reservoirs
Smallmouth bass, *M. dolomieui*	N	Locally common	Only in Trinity River reservoirs
Yellow perch, *Perca flavescens*	N	Locally common	Abundant in upper basin, including Iron Gate Reservoir

Abbreviations: A, anadromous; N, non-migratory.

River but also indicated that reports of the salmon catch probably lumped coho and Chinook. Historically, coho salmon occurred throughout the Klamath River and its tributaries, at least to a point as high up in the system as the California-Oregon border. It is possible that they once migrated well into the upper Klamath basin (above Klamath Falls), as did Chinook and

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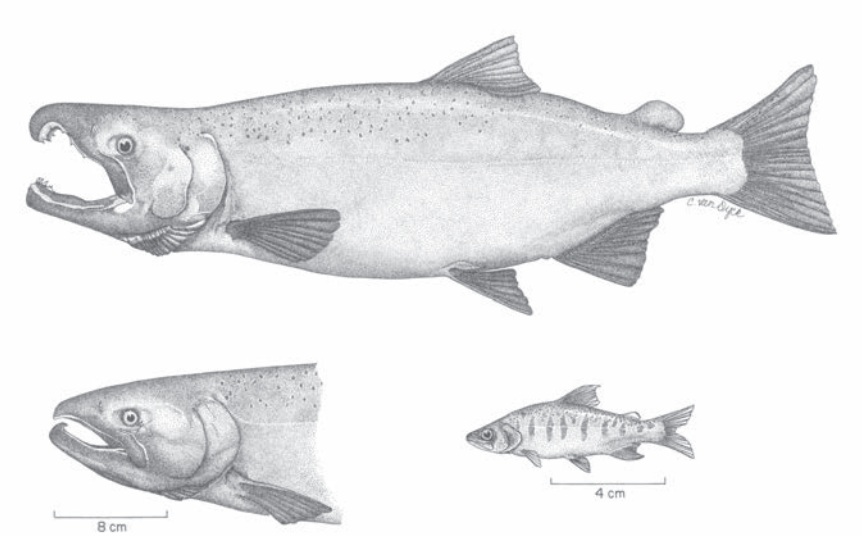


FIGURE 7-1 Coho salmon male (top), female (head), and parr. Source: Moyle 2002. Drawing by Chris M. Van Dyck. Reprinted with permission; copyright 2002, University of California Press.

steelhead, but there are no records of this, perhaps because most people are unable to distinguish them (Snyder 1931).

Today coho salmon occupy remnants of their original range wherever suitable habitat exists and wherever access is not prevented by dams and diversions (Brown et al. 1994, Moyle 2002). Because the coho salmon is clearly in a long-term severe decline throughout its range in California, all populations in the state have been listed as threatened under both state and federal endangered species acts (CDFG 2002).

Life History

Coho salmon in the Klamath basin have a 3-yr life cycle (3 yr is the time from spawning of a parent to spawning of its progeny), about the first 14–18 mo of which is spent in freshwater, after which the fish live in the ocean until they return to freshwater to spawn at the age of 3 yr. The main variation in the cycle is that a small percentage of the males return to freshwater to spawn early (in their second year, before spending a winter at sea) as "jacks." A few juveniles may also remain in freshwater for 2 yr (e.g., Bell et al. 2001), although this has not been documented for Klamath basin coho. Adults typically start to enter the river for spawning in late Septem-

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ber. They reach peak migration strength between late October and the middle of November. A few fish enter the river through the middle of December (USFWS, unpublished material, 1998). Adult coho generally enter streams when water temperatures are under 16°C and rains have increased flows (Sandercock 1991). The presence, however, of small numbers of adult coho in the fish kill of September 2002, indicates that some coho begin migration without these stimuli. Most spawning takes place in tributaries, especially those with forested watersheds, but some main-stem spawning has been recorded (Trihey and Associates 1996). Spawning usually takes place within a few weeks of the arrival of fish in the spawning grounds. Females dig redds (nests) in coarse gravel and spawn repeatedly with large, hooknose males and with small jacks over a period of a week or more. The fertilized eggs are covered with gravel after each spawning event. Adults die after spawning.

Embryos develop and hatch in 8–12 wk, depending on temperature. Alevins (hatchlings with yolk sacs attached) remain in the gravel for another 4–10 wk (Sandercock 1991). In forested watersheds with relatively stable slopes and stream channels, mortality is lower for embryos and alevins than it is in disturbed watersheds (Sandercock 1991). Major sources of mortality include scouring of redds by episodes of exceptionally high flow and smothering of embryos by silt. When most of the yolk sac is absorbed, the alevins emerge from the gravel as fry (30–35 mm) and seek the shallow stream margins, where velocities are low and small invertebrates are abundant. Fry start emerging in late February and typically reach peak abundance in March and April, although fry-sized fish (up to about 50 mm) appear into June and early July (CDFG, unpublished data, 2000, 2001, 2002). Fry are nonterritorial and have a tendency to move around (Kahler et al. 2001); this allows them to disperse. Thus, some fry are captured in outmigrant traps at the mouths of the Shasta and Scott rivers from May to early July (CDFG, unpublished data, 2000, 2001, 2002), although most probably stay in the tributaries close to the areas in which they were spawned.

There is no sharp separation between fry and juvenile (parr) stages; juveniles are typically over about 50–60 mm and partition available habitat among themselves through aggressive behavior (Sandercock 1991). Juveniles develop in streams for a year. Typical juvenile habitat consists of pools and runs in forested streams where there is dense cover in the form of logs and other large, woody debris. They require clear, well-oxygenated water and low temperatures. Preferred temperatures are 12–14°C, although juvenile coho can under some conditions live at 18–29°C for short periods (McCullough 1999, Moyle 2002). For example, Bisson et al. (1988) planted juvenile hatchery coho in streams that had been devastated by the eruption of Mount St. Helens 3–4 yr earlier and found that they showed high rates of

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growth and survival in areas where maximum daily temperatures regularly exceeded 20°C and occasionally reached 29°C. Early laboratory studies in which juvenile coho were reared under constant temperatures indicated that exposure to temperatures over 25°C, even for short periods, should be lethal (Brett 1952). But laboratory studies in which temperatures were increased gradually (for example, 1°C/hr) suggest that lethal temperatures range from 24 to 30°C, depending on other conditions and the temperature to which the fish were originally acclimated (McCullough 1999). In the laboratory, juvenile coho can be reared at constant temperatures of 20–23°C if food is unlimited (McCullough 1999); but in hatcheries, they typically are reared at lower temperatures because of their reduced growth and increased mortality from disease at higher temperatures. Coho at Iron Gate Hatchery are reared at summer temperatures near 13–15°C (Bartholow 1995).

Consistent with the experiences of hatcheries, most coho develop and grow where water temperatures are at or near the preferred temperatures for much of each 24-hr cycle. For example, in tributaries to the Matolle River, California, Welsh et al. (2001) found that juveniles persisted through the summer only in tributaries where the daily maximum temperature never exceeded 18°C for more than a week. In the Klamath basin, such suitable conditions exist today mainly in portions of tributaries that are not yet excessively disturbed (Figure 1-1). NMFS (2002) has identified, in addition to the Shasta, Scott, Salmon, and Trinity rivers, six creeks between Iron Gate Dam and Seiad Valley, 13 creeks between Seiad Valley and Orleans, and 27 creeks between Orleans and the mouth of the Klamath as important coho habitat in the Klamath basin.

The explanation of seemingly contradictory information on temperature tolerance lies in the realm of bioenergetics. Juvenile coho can survive and grow at high daily maximum temperatures provided that (1) food of high quality is abundant so that foraging uses little energy and maximum energy can be diverted to the high metabolic rates that accompany high temperatures, (2) refuge areas of low temperature are available so that exposure to high temperatures is not constant, and (3) competitors or predators are largely absent so that the fish are not forced into physiologically unfavorable conditions or energetically expensive behavior (such as aggressive interactions). Thus, in the streams around Mount St. Helens cited above, food was abundant and temperatures were low much of the time. Temperatures dropped well below 15°C at night even after the hottest summer days, were below 16°C for 65–80% of the time, and rarely exceeded 25°C (Bisson et al. 1988). There were also areas of cool groundwater inflow that served as refuges on hot days, although the extent of their use by coho was not documented. And coho were the only species present. In some rivers, however, interactions of coho with juvenile Chinook and

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steelhead cause shifts of coho into energetically less favorable conditions (Healey 1991, Harvey and Nakamoto 1996). For example, coho juveniles occupying tributaries at the Matolle River faced not only limited food supplies but also energetically expensive interactions with juvenile steelhead (Welsh et al. 2001) and so were restricted to cool water.

Observations of juvenile coho in the main-stem Klamath River during summer suggest that juvenile coho live in the main stem despite temperatures that regularly exceed 24°C and are usually over 20°C for much of the day from late June through the middle of September (M. Rode, CDFG, personal communication, USFWS, unpublished data, 2002). Temperatures at night typically drop to 18–20°C during the warmest period. The coho occupy mainly pools at the mouths of inflowing streams where temperatures are usually 2–6°C lower than the water in the main river. The pools apparently are the only cool-water refugia in the river and occupy only a small area (B. A. McIntosh and H. W. Li, unpublished report, 1998). The coho in the pools appear to move into warmer water to forage on the abundant aquatic insects (D. Hillemeier, Yurok Tribe, personal communication). Thus, it is at least possible that coho could, from a bioenergetic perspective, occupy the main stem. Snorkel surveys of mouth pools in 2001 show, however, that juvenile coho, in contrast with Chinook and steelhead, occupied 16% of the tributary-mouth pools in June but only a single pool in August and September (T. Shaw, USFWS, unpublished material, 2002; Table 7-3).

Most of the tributary mouth pools contain juvenile Chinook salmon, steelhead, or both (Table 7-3). These fishes can compete with and prey on juvenile coho (and each other) and are somewhat more tolerant of high temperatures than coho. While many of these juveniles resulted partly from natural spawning, many of them likely came from Iron Gate Hatchery.

TABLE 7-3 Pools Containing Juvenile Coho Salmon, Chinook Salmon, and Steelhead Along Main Stem of Klamath River, 2001, as Determined in Snorkeling Surveys[a]

Month of Survey	No. of Mouth Pools Surveyed	No. (%) of Pools with Juvenile Fish		
		Coho	Chinook	Steelhead
June	31	5 (16)	26 (84)	26 (84)
July	46	7 (15)	41 (89)	43 (93)
August	39	1 (3)	26 (67)	34 (87)
September	32	1 (3)	13 (41)	28 (88)

[a]The data are comprehensive in that they include all tributaries large enough to form a cool pool, and include some tributaries below the Trinity River (e.g., Blue Creek).
Source: T. Shaw, USFWS, unpublished material, 2002.

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Many large (70–90 mm) juvenile Chinook from the hatchery move down the river from late May through July, as do large numbers of hatchery steelhead smolts in March and April. Interactions among hatchery and wild fish of all species may cause wild fish, which are smaller, to move downstream prematurely when cool-water habitat becomes limiting in summer, although this possibility has not been documented for the Klamath River. The number of pools occupied by Chinook salmon declines by August and September, as does the number of Chinook present in each pool that has fish (T. Shaw, USFWS, unpublished material, 2002); this reflects the normal outmigration of both wild and hatchery juvenile Chinook. Steelhead remain in most pools throughout the summer.

Although 2001 was a year of exceptionally low flows, Table 7-3 suggests that coho juveniles are uncommon in the main stem in early summer and become progressively less common as the season progresses. Juvenile coho are virtually absent from the main stem, including pools at tributary mouths, by late summer, even though juvenile Chinook and steelhead persist in these habitats. Although the overall rarity of coho in the Klamath basin may contribute to their absence from the mouth pools, their presence early in the summer and the reduced densities of juvenile Chinook salmon as summer progresses suggest that juvenile coho would be noticed by observers in late summer if they were present. In one respect, the near absence of coho by late summer is surprising because juvenile coho do move about and should be continually dropping into the pools from tributaries (Kahler et al. 2001). Movement of coho juveniles may be prevented by the warming or drying of the lower reaches of tributaries in late summer.

Overall, it appears that the bioenergetic demands of juvenile coho prevent them from occupying the main stem. Even with abundant food, the thermal refugia (the pools at mouths of tributaries) are inadequate: nighttime temperatures stay too high for them, and the energy costs of interactions with Chinook and steelhead, both of which are much more abundant in the pools, are probably high. Coho juveniles in the pools during June and July may die by late summer. Alternatively, they could be moving back into tributary streams, but temperatures in the lower reaches of the tributaries are similar to those of the mouth pools by late summer, and barriers to reentry (such as gravel bars) are often present. It is also possible that coho juveniles move to the estuary, perhaps traveling at night, when temperatures are lowest. Estuarine rearing of juvenile coho has been documented in other systems (Moyle 2002). A rotary-screw trap set near Orleans on the lower river for 10 yr (1991–2001) caught juvenile coho from April through July, after which the trap was taken from the river; peak numbers were observed in May and June—5 times higher than in July (T. Shaw, USFWS, unpublished data, 2002). Annual seining data from the estuary (1993–2001) indicate, however, that coho are absent from the estuary or are very

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rare from July through September, when temperatures often exceed 18°C (M. Wallace, CDFG, unpublished memorandum, 2002). Thus, the evidence points to the conclusion that juvenile coho are not occupying either the estuary or the main stem through the summer.

One proposal for increasing the survival of juvenile coho in the main stem in summer has been to release more water from Iron Gate Reservoir to increase the habitat for juvenile coho, as defined by analogy with habitat used by juvenile Chinook salmon, and to reduce daily temperature fluctuations in the river, thus removing the potentially lethal temperature peaks (Chapter 4). The water available from Iron Gate Reservoir, however, is quite warm in summer (18–22°C or more) and, because it is increasingly warm as it moves downstream, is unlikely to ameliorate high temperatures very much. Modeling suggests that additional flows may indeed reduce maximum temperatures some distance downstream but that they will also increase minimum temperatures (Chapter 4). From a bioenergetic perspective, increasing minimum temperatures may be especially unfavorable for coho in the main stem because nocturnal relief from high temperatures would be reduced.

The low abundance of juvenile coho in the main stem in summer, the known thermal regimes of the main stem, and the bioenergetic requirements of coho together suggest that the most crucial rearing habitat for juveniles is that of cool tributaries. Today, cool tributaries are mainly small streams that flow directly into the Klamath or into the Shasta, Scott, Salmon, and Trinity rivers. With its large, cold springs in the headwaters, the entire Shasta River was probably once favorable habitat for coho juveniles in most years, but diversions and removal of riparian vegetation have made it generally lethal thermally for salmonids in summer. If warming occurs with future climate change, it would likely exacerbate other factors that have led to warming of the tributaries (see Chapter 8).

Even a stream that has suitable summer habitat for juvenile coho may be unsuitable in winter. Studies in Oregon and elsewhere indicate that overwintering habitat is a major limiting factor where summer conditions are favorable (Nickelson et al. 1992a, b). Juveniles need refuges from winter peak flows. The refuges are side channels, small clear seasonal tributaries, logjams, and other similar areas. Simplification of channel structure through removal of woody debris or channelization eliminates much of the overwintering habitat. The condition of winter habitat for coho in the Klamath basin has not been evaluated.

Barred juveniles (parr) transform into silvery smolts and begin migrating downstream in the Klamath basin between February and the middle of June (USFWS, unpublished material, 1998) when they are about 10–12 cm long. Most smolts captured in the Orleans screw trap are taken in April and May (T. Shaw, USFWS, unpublished material, 2002) and appear in the

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estuary at about the same time (M. Wallace, CDFG, unpublished memorandum, 2002). Typically, coho smolts migrate downstream on the declining end of the spring hydrograph. About 60–70% of the smolts are of hatchery origin (M. Wallace, CDFG, unpublished memorandum, 2002). They are largely gone from the estuary by July. The transformation of juveniles into smolts appears to be triggered by light (perhaps moonlight) and other changing environmental conditions. Smoltification results in profound physiological and morphological changes in the fish. Smolts are compelled to move to the marine environment and will actively swim downstream to do so, especially at night. Exact timing of the downstream movement appears to be affected by flow, temperature, and other factors (Sandercock 1991). Higher flows in the river in April and May probably decrease transit time of the smolts. Low transit time could reduce predation rates and reduce energy consumption in swimming, although this has not been demonstrated in the Klamath River.

Smolts may feed and grow in the estuary for a month or so before entering the ocean (e.g., Miller and Sadro 2003). Coho entering the ocean generally have their highest mortality rates in their first few months at sea (Pearcy 1992). The first month or so after entry may be especially important due to predation, which suggests that smolts will have higher survival rates if they are large before going out to sea (C. Lawrence, UCD, personal communication, 2002). Once at sea, they spend the next 18 mo or so as immature fish that feed voraciously on shrimp and small fish, and grow rapidly.

Ocean survival depends on a number of interacting factors, including the abundance of prey, density of predators, the degree of intraspecific competition (including that from hatchery fish), and fisheries (NRC 1996). The importance of these factors in turn depends on ocean conditions (productivity, predation, and other factors), which vary widely on both spatial and temporal scales. Even relatively small changes in local and annual fluctuations in temperature, for example, can be related to changes in salmon survival rates (Downton and Miller 1998). Even more important are multidecadal (20–50 yr) fluctuations in ocean conditions, which can result in drastic changes in ocean productivity for extended periods of time (Hare et al. 1999, Chavez et al. 2003). Prolonged climatic shifts have caused significant shifts in salmonid populations to the north or south through modification of ocean temperatures (Ishida et al. 2001). Global warming thus could result in a shift in salmonid distribution to the north, and cause an overall decrease in abundance of salmonids (Ishida et al. 2001).

When the ocean is in a period of low productivity, survival rates may be low, and thus result in reduced runs coming into the streams. Commercial fishing is most likely to affect salmon populations during periods of natu-

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rally low ocean survival, but the fishery for wild coho salmon has been banned in California since 1997 and the fishery for Chinook has been greatly reduced (Boydstun et al. 2001). A fishery for coho still exists off the Oregon coast, but only hatchery fish, which are marked, can be retained.

Historically, the abundance of coho spawners reflected a balance between ocean survival and freshwater survival (Figure 7-2). A year of especially poor conditions for survival in freshwater (e.g., created by drought) could be compensated for if conditions in the ocean (e.g., high regional productivity: Hobday and Boehlert 2001) enhanced survival there. Persistently poor conditions in freshwater, such as exist throughout the Klamath basin today, make the recovery of populations difficult, however, even when ocean conditions are favorable and fisheries have been shut down or reduced. When ocean conditions are poor, the positive effects of restoring of salmonid habitat in streams may be masked (Lawson 1993, NRC 1996). Thus, only long-term monitoring can reveal effects of restoration.

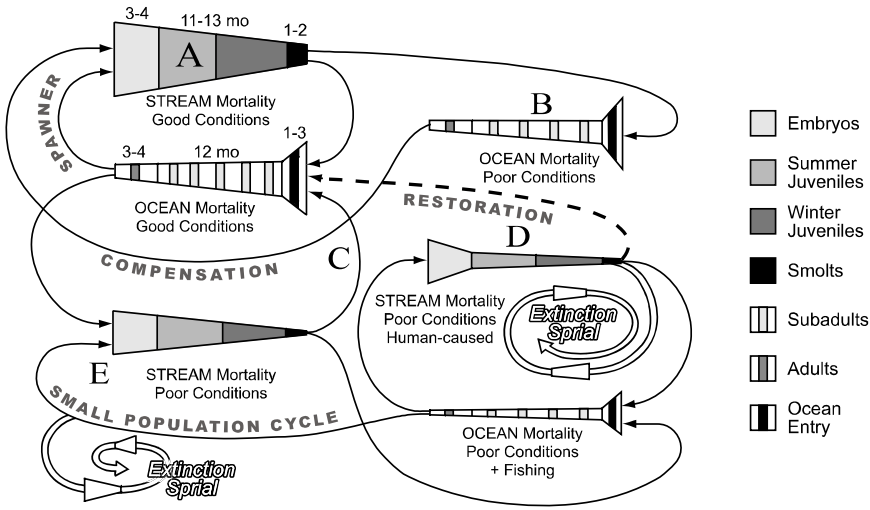


FIGURE 7-2 Population cycles of coho salmon in California. If conditions are favorable in spawning and rearing streams (A) and conditions are also favorable for high survival rates in the ocean, large populations of salmon will result. Even if conditions for survival are relatively poor in the ocean (B), large populations of coho may be maintained (although not as well as in cycle A) as long as production of coho in freshwater is high. Likewise, poor conditions in freshwater from natural causes (C) can be partially compensated for if ocean survival rates are high. If coho streams are degraded by human activity (D) and ocean conditions are poor, combined mortality may result in downward spiral of population size. If conditions in both fresh and salt water result in low survival (E), extinction may occur. Source: Based on information in Moyle 2002.

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Hatcheries

Coho salmon have been an important part of the Klamath basin fish fauna since prehistoric times (CDFG 2002), and many attempts have been made to augment their populations in the Klamath basin. The first attempt occurred in 1895, when 460,000 fish from Redwood Creek—part of the same evolutionarily significant unit (ESU) as Klamath River coho—were stocked in the Trinity River. It is not known whether these fish, which were taken from a small stream, survived and contributed to later populations. Hatchery production of coho salmon in the Klamath basin began in the 1910–1911 season and continued for another 5 yr. From 1919 to 1942, six additional plants of hatchery-reared fish, all apparently of local origin, were conducted (CDFG 2002). The principal hatcheries today are the Iron Gate Hatchery (operating since 1966) on the Klamath and the Trinity River Hatchery (operating since 1963) on the Trinity River. Faced with a declining egg supply, operators of the two hatcheries at various times brought in fertilized eggs from the Eel and Noyo rivers in California and the Cascade and Alsea rivers in Oregon (CDFG 2002). Thus, present hatchery stocks probably are of mixed origin. Although a few hatchery fish have been planted in tributaries, hatchery fish are for the most part released as smolts into the main stem on the assumption that they will head directly to the sea.

Genetic studies of the contribution of hatchery coho to wild populations in the Klamath basin are not available. Brown et al. (1994) inferred that most wild coho stocks in the basin were partially mixed with hatchery stocks because the two hatcheries are at the far upstream end of coho distribution and produce large numbers of fish. In recent years, the Trinity River Hatchery has released an average of 525,000 coho per year and the Iron Gate Hatchery about 71,000 per year (CDFG 2002), although historically the Iron Gate Hatchery has released about 500,000 coho per year (CDFG, unpublished data, 2002). The coho typically are reared to the smolt stage and marked with a maxillary clip before release, which occurs between March 15 and May 1. They reach the estuary in concert with wild smolts, which peak in late May and early June, but typically are longer than the wild fish—about 170–185 mm vs 135–145 mm (M. Wallace, CDFG, unpublished data, 2002). Although the effect of large numbers of hatchery coho on wild coho is not known for the Klamath, hatchery fish may dominate wild fish when the two are together (Rhodes and Quinn 1998). In any event, hatchery fish are apparently more numerous than their wild counterparts. In 2000 and 2001, 61% and 73%, respectively, of the smolts captured in the estuary were of hatchery origin (M. Wallace, CDFG, unpublished data, 2002).

The percentage of hatchery fish in the spawning population has not been estimated directly, but Brown et al. (1994) estimated that 90% of the

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adult coho in the system returned directly to the hatcheries or spawned in the rivers in their immediate vicinity. Other hatchery coho no doubt stray into other streams, but the percentage is not known (CDFG 2002). In a survey of spawning coho in the Shasta River in 2001, individuals from the Iron Gate and Trinity River hatcheries were identified; seven of 23 carcasses examined were hatchery fish (CDFG, unpublished data, 2001). Regardless of origin, natural-spawning coho in the basin's tributaries have managed to maintain timing of runs and other life-history features that fit the basin's hydrologic cycle well.

Status

Coho salmon populations in California in general and in the Klamath basin specifically have declined dramatically in the last 50 yr (Brown et al. 1994, Weitkamp et al. 1995, CDFG 2002). The Southern Oregon-Northern California Coast (SONCC) ESU, of which Klamath stocks are part, was listed as threatened by the National Marine Fisheries Service (NMFS) as a consequence. The California Department of Fish and Game (CDFG 2002) recommended listing the ESU as threatened under the California state endangered species act, and the recommendation was adopted by the Fish and Game Commission as official state policy. Analysis by CDFG (2002) suggests that SONCC populations have stabilized at a low level since the late 1980s but could easily decline again if stream conditions change. Surveys in 2001 indicated that 17 (68%) of 25 historical coho streams in the Klamath basin contained small numbers of juvenile coho (CDFG 2002). In the Trinity River, wild coho stocks have experienced reduction of about 96% (USFWS/HVT 1999). The role of coho spawners of hatchery origin in maintaining these populations is not known, but marked fish of hatchery origin have been found among the spawners.

CHINOOK SALMON

Chinook salmon were and continue to be the most abundant anadromous fish in the Klamath basin, and their management potentially influences the abundance of coho in the basin and vice versa. They support important commercial, sport, and tribal fisheries. Annual runs have ranged from about 30,000 to 240,000 fish in the last 25 yr (CDFG, unpublished data, 2002), although runs were much larger historically (Snyder 1931). Chinook salmon spawn and grow primarily in the main stem of the Klamath River, in the larger tributaries (such as the Salmon, Scott, Shasta, and Trinity rivers), Bogus, Indian, Elk, and Blue creeks, and also in some smaller tributaries. Large numbers once spawned in the Williamson, Sprague, and

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Wood rivers above Upper Klamath Lake, but these runs were eliminated by the construction of Copco Dam in 1917 (Snyder 1931).

Two ESUs are recognized for Klamath basin Chinook: the Southern Oregon and Coastal (SOCC) ESU and the Upper Klamath and Trinity rivers ESU (Myers et al. 1998). The SOCC ESU consists only of fall-run Chinook that spawn in the main-stem Klamath roughly from the mouth of the Trinity River to the estuary and is tied to other runs in coastal streams from Cape Blanco, Oregon, to San Francisco Bay. The Upper Klamath and Trinity rivers ESU encompasses the rest of the Chinook in the basin, including Trinity River fish. It consists of three runs (fall, late fall, and spring). Runs are named for the season of entry and migration up the river, which is not necessarily the same as the spawning time. Thus, spring-run Chinook migrate upriver during the spring, but spawn in the fall. The spring run differs in its life history from other runs and diverges slightly from them genetically as well; it may merit status as a separate ESU (Myers et al. 1998). Because studies of Chinook salmon and fisheries in the Klamath basin do not separate fish from the two ESUs (e.g., Hopelain 2001, Prager and Mohr 2001), Chinook salmon are treated here as either fall-run or spring-run. The late fall-run Chinook in the basin is either extinct or poorly documented (Moyle 2002). The vast majority of the fish today are fall-run fish of both wild and hatchery origin.

Fall-Run Chinook Salmon

Life History of Fall-Run Chinook Salmon

Fall-run Chinook in the Klamath have the classic ocean type of life-history pattern: juveniles spend less than a year in freshwater (Healey 1991). This pattern allows the salmon to take advantage of streams in which conditions may become unfavorable by late summer (Moyle 2002). Adult Chinook salmon that have the ocean type of life-history pattern also typically spawn in the main channels of large rivers and their major tributaries. Historically, the fall run in the Klamath was known as a summer run because fish started entering the estuary and lower river in July, peaked in August, and were largely finished by late September (Snyder 1931). Today, the run peaks in early September and continues through late October (Trihey and Associates 1996; USFWS, unpublished material, 1998). The 2- to 4-wk shift in run timing suggests that the main-stem Klamath and Trinity rivers have become less favorable to adult salmon in summer, presumably because of high temperature (Bartholow 1995), or perhaps because of excessive harvest of early run fish. Even with the shift in timing, temperature during the time of the spawning run probably is stressful to the migrating salmon and may result in increased mortality of spawning adults. Literature re-

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viewed by Bartholow (1995) suggests that temperatures under 14°C are optimal for adult migration and that chronic exposure of migrating adults to 17–20°C can be lethal, although they can endure temperatures as high as 24°C for short periods. McCullough (1999, p. 75), commenting on adult migration primarily with data from the Columbia River, concludes that spring Chinook migrate at 3.3–13.3°C, summer Chinook migrate at 13.9–20.0°C, and fall Chinook migrate at 10.6–19.4°C.

Fall-run Chinook reach upstream spawning grounds 2–4 wk after they enter the river; they then spawn and die (USGS 1998). In 2001, adult Chinook were first recorded entering the Shasta River on September 11; the run peaked on October 1, and 95% of the run had entered the system by October 27 (CDFG, unpublished data, 2001). In 1993–1996, spawning in the reach between Seiad Creek and within 40 mi of Iron Gate Dam on the main stem began in the second week of October, peaked in the last week of October, and was completed by the middle of November (USGS 1998). This spawning period coincides with declining temperatures, which by early November are within the optimal range for incubation of developing embryos (4–12°C); 2–16°C is the range for 50% mortality (Healey 1991, Myrick and Cech 2001).

Time to emergence from the gravel varies with the temperature regime to which the embryos are exposed. In the main-stem Klamath River, alevins can emerge from early February through early April, but peak times vary from year to year (USGS 1998). In the Shasta River, newly emerged fry have been captured as early as the middle of January (USGS 1998). After they emerge, fry disperse downstream, and many then take up residence in shallow water on the stream edges, often in flooded vegetation, where they may remain for various periods. As they grow larger, they move into faster water. Some fry, however, keep moving after emergence and reach the estuary for rearing (Healey 1991). This pattern seems to be common in the Klamath River, although the small juveniles in the estuary leave, apparently for the ocean, after only a few weeks (Wallace 2000). The time that juveniles spend in the estuary may depend on upstream conditions (Wallace and Collins 1997). When river conditions are relatively poor (for example, warm), the juveniles move into the estuary when smaller and stay there longer. In other systems, juveniles may live in the estuary through the smolt stage and this can be important for allowing juvenile Chinook of the ocean life-history pattern to grow to larger sizes before entering the ocean (Healey 1991). Juveniles are found in the Klamath estuary from March through September (the sampling season), over which time new fish constantly enter and older fish leave (Wallace 2000; unpublished data 2002).

Other juvenile fall-run Chinook rear in the river or large tributaries for 3–9 mo, but downstream movement is fairly continuous. During June and July, movement of wild fish may be stimulated by the release of millions of

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juvenile salmon from Iron Gate Hatchery; the hatchery fish probably compete with wild fish for space. An outmigrant trap set at Big Bar, near Orleans, for 10 yr (1991–2001) captured juveniles from late February through late August, although the trap was usually set only from early April through July (T. Shaw, USFWS, unpublished material, 2002). Time of peak catch varied from year to year but usually was between late May and the middle of July. Outmigrant traps on the Scott and Shasta rivers catch Chinook fry, parr, and smolts from early February through July in most years. Peak numbers occur in March or early April for the Shasta River and from the middle of April to the middle of May in the Scott River. A survey of main-stem pools at the mouths of creeks in 2001 indicates that juveniles can be found in the main stem from January through September, but abundances are considerably reduced by August and September (T. Shaw, USFWS, unpublished material, 2002). Thus, there appears to be a steady movement of fish down the main stem throughout summer; the fry stay for various periods in the main stem at temperatures of 19–24°C. That pattern is consistent with the thermal tolerances of juvenile Chinook salmon, which can feed and grow at continuous temperatures up to 24°C when food is abundant and other conditions are not stressful (Myrick and Cech 2001). Under constant laboratory conditions, optimal temperatures for growth are around 13–16°C. Continuous exposure to 25°C or higher is invariably lethal (McCullough 1999). Juveniles can, however, tolerate higher temperatures (28–29°C) for short periods. Depending on their thermal history, fish in wild populations may experience high mortality at temperatures as low as about 22–23°C (McCullough 1999). In the lower Klamath River, the presence in late summer of refuges that are 1–4°C cooler than the main stem and lower temperatures at night may increase the ability of the fry to grow. The abundance of invertebrate food also makes the environment bioenergetically favorable, although intense intraspecific competition may occur around the refuge pools.

What limits the survival of Chinook fry in the main stem is not known. Food is apparently abundant, and summer temperatures, although potentially stressful, are rarely lethal. It is possible that shallow-water rearing habitat is limiting for fry, especially if there is competition for space with other salmonids, including hatchery-reared Chinook and steelhead (e.g., Kelsey et al. 2002). Fry (under 50 mm) require shallow edge habitat for feeding and protection from predators. Thus, increasing flows to increase edge habitat may be desirable for as long as small fish are present. Some fall-run Chinook apparently remain in the river long enough to become smolts before they migrate to the sea; the rest do not (migration to the estuary is known to occur without smoltification in some cases). Timing of migration may be critical. Baker et al. (1995) indicated that prolonged exposure of outmigrating smolts to temperatures of 22–24°C in the Sacra-

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mento River resulted in high mortality. Juvenile Chinook salmon that transform into smolts at temperatures over 18°C may have low ability to survive in seawater (Myrick and Cech 2001).

Once the Chinook are at sea, they grow rapidly on a diet of shrimp and small fish (Healey 1991). They can move widely through the ocean but typically are most abundant in coastal waters, where growth and survival are strongly influenced by ocean conditions. They return to the Klamath mainly as 3-yr-old fish, but jacks (2-yr-old males) and 4-yr-old fish also are common.

Hatcheries

Hatcheries for Chinook salmon have been operating continuously since 1917. Both the Iron Gate Hatchery and the Trinity River Hatchery produce large numbers of spring-run (13%) and fall-run (87%) juvenile Chinook of native stock (Myers et al. 1998). The hatcheries release 7–12 million juveniles into the river each year (about 70% from the Iron Gate Hatchery, all fall-run). The fish generally have been released over 2–3 days in late May or early June and take 1–2 mo (mean, 31 days) to reach the estuary (M. Wallace, CDFG, unpublished data, 2002), although some fish probably remain in pools for most of summer. Smaller fish take longer than larger fish to reach the estuary, but because they are feeding and growing on the way downstream, all juveniles are about the same size when they reach it. About 40% of the juvenile fish in the estuary in 2000 were of hatchery origin (CDFG, unpublished data, 2000); this is presumably a fairly typical figure. Adult Chinook returning to the hatcheries are roughly one-third of the total run—30% in 1999, 44% in 2000, and 28% 2001 (CDFG, unpublished data, 2001). There has been an increase in the percentage of hatchery fish in the run in recent years—up from 18% in 1978–1982, and 26% in 1991–1995 (Myers et al. 1998). Their contribution to natural spawning is not known, but estimates for the Trinity River suggest that it is roughly the same as the percentage of hatchery returns (Myers et al. 1998).

Status

The fall-run Chinook salmon in the Klamath basin overall probably has declined in abundance, but it is still the most abundant salmonid in the basin. In the first major study of Klamath salmon, Snyder (1931) stated that "the actual contribution of the river to the entire salmon catch of the state is not known, nor can it be known. . . . The fishery of the Klamath is particularly important, however, because of the possibility of maintaining it, while that of the Sacramento probably is doomed to even greater depletion than now appears." Snyder did not provide estimates of run sizes, but the river harvest

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alone in 1916–1927 was 35,000–70,000 fish (as estimated from Snyder's data showing an average weight of 14 lb/fish and a harvest of 500,000–1,000,000 lb each year). If, as Snyder's data suggest, the river harvest was roughly 25% of the ocean harvest in this period, annual total catches were probably 120,000–250,000 fish. This in turn suggests that the number of potential spawners in the river was considerably higher than the number spawning in the river today. Since 1978, annual escapement has varied from 30,000 to 230,000 adults. In both 2000 and 2001, runs were over 200,000 fish. If it is assumed that fish returning to the hatcheries are, on the average, 30% of the population and that 30% of the natural spawners are also hatchery fish, then roughly half the run consists of salmon of natural origin (including progeny of hatchery fish that spawned in the wild).

Additional evidence of decline is the exclusion of salmon from the river and its tributaries above Iron Gate Dam in Oregon, where fairly large numbers spawned, and the documented decline of the runs in the Shasta River. The Shasta River once was one of the most productive salmon streams in California because of its combination of continuous flows of cold water from springs, low gradients, and naturally productive waters. The run was probably already in decline by the 1930s, when as many as 80,000 spawners were observed. By 1948, the all-time low of 37 fish was reached. Since then, run sizes have been variable but have mostly been well below 10,000. Wales (1951) noted that the decline had multiple causes, most related to fisheries and land use in the basin, but laid much of the blame on Klamath River lampreys: the lampreys preyed extensively on the salmon in the main stem when low flows delayed their entry into the Shasta River.

In some respect, it is remarkable that fall-run Chinook salmon in the Klamath River are doing as well as they seem to be. Both adults migrating upstream and juveniles moving downstream face water temperatures that are bioenergetically unsuitable or even lethal. As explained later in this chapter, the vulnerability of the run to stressful conditions was dramatically demonstrated by the mortality of thousands of adult Chinook in the lower river in late September 2002.

Spring-Run Chinook

Life History

Like coho, spring-run Chinook have a stream type of life history, which means that juveniles remain in streams for a year or more before moving to the sea (Healey 1991). In addition, the adults typically enter freshwater before their gonads are fully developed and hold in deep pools for 2–4 mo before spawning. In California, this strategy allows salmon to spawn and develop in upstream reaches of tributaries that often are inaccessible to fall-

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run Chinook because of low flows and high temperatures in the lower reaches during fall (Moyle 2002). Major disadvantages of such a life-history pattern in the present system are that low flows and high temperatures during the adult and smolt migration periods can prevent the fish from reaching their destinations or greatly increase mortality during migration (Moyle et al. 1995, Trihey and Associates 1996).

Spring-run Chinook enter the Klamath system from April to July, although the fish that appear later apparently are mainly of hatchery origin (Barnhart 1994). The Chinook aggregate in deep pools, where they hold through September. Temperatures below 16°C generally are regarded as necessary for spring-run Chinook because susceptibility to disease and other sources of mortality and loss of viability of eggs increase as temperature increases (McCullough 1999). In the Salmon River, temperatures of pools holding spring-run Chinook often exceed 20°C (West 1991, Moyle et al. 1995). Spawning peaks in October. Fry emerge from the redds from March to early June; the fish reside through the summer in the cool headwaters (West 1991). Because most of the streams in which they reside also are likely to be used by juvenile coho salmon, interactions between the two species are likely (see O'Neal 2002 for information specific to the Klamath). Some juveniles may move down to the estuary as temperatures decline in October, although most do not move out until the following spring (Trihey and Associates 1996); they spend summer in the same reaches as the holding adults. More precise details of the life history of spring-run Chinook in the Klamath basin are unavailable.

Status

Spring-run Chinook may once have been nearly as abundant as fall-run Chinook in the Klamath basin. Perhaps 100,000 fish spread into tributaries throughout the basin, including the Sprague and Williamson rivers in Oregon (Moyle 2002). The Shasta, Scott, and Salmon rivers all supported large runs. Spring-run Chinook suffered precipitous decline in the 19th century caused by hydraulic mining, dams, diversions, and fishing (Snyder 1931). The large run in the Shasta River disappeared coincidentally with the construction of Dwinnell Dam in 1926 (Moyle et al. 1995). In the middle to late 20th century, the decline of the depleted populations continued as a result of further dam construction (for example, of Trinity and Iron Gate Dams) and, in 1964, heavy sedimentation of habitat that resulted from catastrophic landslides due to heavy rains on soils denuded by logging (Campbell and Moyle 1991). By the 1980s, spring-run Chinook had been largely eliminated from much of their former habitats because the cold, clear water and deep pools that they require were either absent or inaccessible. In the Klamath River drainage above the Trinity, only the population

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in the Salmon River and Wooley Creek remains; it has annual runs of 150–1,500 fish (Campbell and Moyle 1991, Barnhart 1994). Numbers of fish in the area continue to decline (Moyle 2002). Because the Trinity River run of several thousand fish per year is apparently sustained largely by the Trinity River Hatchery, the Salmon River population may be the last wild (naturally spawning) population in the basin. The Trinity River Hatchery releases over 1 million juvenile spring-run Chinook every year, usually in the first week of June. Apparently, all spawners in the main-stem Trinity River below Lewiston Dam are of hatchery origin.

NMFS debated designation of the Klamath spring-run Chinook as a distinct ESU, but decided that it was too closely related to fall-run Chinook to justify separation (Myers et al. 1998). Nevertheless, the presence of genetic differences and of great differences in life history suggest that it should be managed as a distinct ESU (as was done for the Sacramento River spring-run Chinook) or as a distinct population segment. Protection and restoration of streams used by spring-run Chinook salmon would provide additional protection for coho salmon because the two salmon have similar temperature and habitat requirements.

STEELHEAD

Steelhead (anadromous rainbow trout) are widely distributed and common in the Klamath basin. They consistently co-occur with coho salmon in streams, and the juveniles of the two species can have strong interactions (e.g., Harvey and Nakamoto 1996). All populations are considered by NMFS to be part of the Klamath Mountains Province ESU. Besides having genetic traits in common, the populations share a life-history stage called the half-pounder, which is an immature fish that migrates to the sea in spring but returns to spend the next winter in freshwater (Busby et al. 1994, Moyle 2002). Two basic life-history strategies are recognized in the basin: summer steelhead (stream-maturing) and winter steelhead (ocean-maturing). Barnhart (1994) and Hopelain (1998) divide the winter steelhead further into early (fall-run) and late (winter-run), but the two forms have similar life histories and will be treated together here as winter steelhead.

Winter Steelhead

Life History

Winter steelhead are the most widely distributed anadromous salmonids in North America. Key factors in their success in a wide variety of habitats include an adaptable life history, higher physiological tolerances than those of other salmonids, and ability to spawn more than once (Moyle

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2002). The flexibility in life-history pattern is reflected in the fact that most populations have juveniles that spend 1, 2, or 3 yr in freshwater and adults that spend 2–4 yr in the ocean and return one to four times to spawn. This variability virtually ensures that runs can continue through periods of adverse conditions unless the stream habitat becomes chronically unfavorable to survival of steelhead.

Winter steelhead enter the Klamath River from late August to February (Barnhart 1994). They disperse throughout the lower basin and spawn mainly in tributaries but also show some main-stem spawning. Snyder (1933) noted that fish entering the Shasta River in 1932 came in bursts of 2–3 days over a 7-wk period. Spawning, which can take place any time from January through April, apparently peaks in February and March. Mature fish first return to spawn after a year, at 40–65 cm; the smallest fish are those that spent a winter in freshwater as half-pounders (Hopelain 1998). Up to 30% of the mature fish spawn a second time, after another year at sea; up to 20% spawn a third time; and a very few a fourth time (Hopelain 1998).

Fry emerge from the gravel in spring and most (80–90%) spend 2 yr in freshwater before going to sea. The rest spend either 1 or 3 yr in freshwater (Kesner and Barnhart 1972, Hopelain 1998). The juveniles occupy virtually all habitats in the basin in which conditions are physiologically suitable. They can tolerate minimal depths and flows and so can be found in the smallest accessible tributaries and in the main river channels. Although spawning occurs mainly in tributaries, the juveniles distribute themselves widely, and many move into the main stem. For example, large numbers of parr have been observed moving out of the Scott and Shasta rivers in early July (W.R. Chesney, CDFG, unpublished reports, 2000, 2002). Habitat preferences change with size: bigger fish are more inclined to use pools or deep runs and riffles, and the larger juveniles prefer water at least about 50–100 cm deep with water-column velocities of 10–30 cm/s and deep cover (Moyle 2002). Juveniles feed primarily on invertebrates, especially drifting aquatic and terrestrial insects, but fish (including small salmon) can be an important part of the diet of larger individuals. Aggressive 2-yr-old steelhead (14–17 cm) often dominate pools.

A key to the success of steelhead in freshwater is their thermal tolerance, which is higher than that of most other salmonids. Preferred temperatures in the field are usually 15–18°C, but juveniles regularly persist in water where daytime temperatures reach 26–27°C (Moyle 2002). Long-term exposure to temperatures continuously above 24°C, however, is usually lethal. Steelhead cope with high temperatures by finding thermal refuges (springs, stratified pools, and so on) or by living in areas where nocturnal temperatures drop below the threshold of stress. Persistence in thermally stressful areas requires abundant food, which steelhead will shift

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their behavior to find. Thus, Smith and Li (1983) found that juvenile steelhead persisted in a small California stream in which daytime temperatures sometimes reached 27°C for short periods by moving into riffles where food was most abundant; these fish, however, were at their bioenergetic limits for survival. Overall, the ability of steelhead to thrive under the summer temperatures experienced in the lower Klamath and the different habitat requirements of juvenile steelhead of different sizes indicate that they will benefit from the expansion of habitat created by increased flows in the main-stem Klamath and tributaries, as long as water quality, especially temperature, remains suitable for them.

Steelhead juveniles become smolts and move into the estuary from early April to the middle of May (Kesner and Barnhart 1972). Small numbers continue to trickle into the estuary all summer (M. Wallace, CDFG, unpublished data, 2002). A majority of the early fish that return each year to the river in September are immature (half-pounders, 25–35 cm). These fish usually stay in the lower main stem of the Klamath through March before returning to the sea. This life-history trait allows the steelhead to consume eggs of the large numbers of Chinook salmon that enter the river at the same time (USGS 1998). Half-pounders that return to spawn in the following winter are much smaller (40–50 cm), however, than the first-time spawners that skipped the half-pounder stage (55–65 cm) (Hopelain 1998).

Hatcheries

The Iron Gate Hatchery produces about 200,000 and the Trinity River Hatchery about 800,000 winter steelhead smolts per year (Busby et al. 1994). The fish are released into the rivers in the last 2 wk of March, and most reach the estuary about a month later (M. Wallace, CDFG, personal communication, 2002), coincident with the emigration of wild smolts. Diets of outmigrating smolts are similar to those of wild smolts, although the consumption of a greater variety of taxa and fewer organisms by the hatchery fish than by wild fish suggests that they have lower feeding efficiency than wild fish (Boles 1990). Otherwise, the interactions between hatchery and wild fish in the Klamath are not known, although hatchery steelhead released into a stream will dominate the wild steelhead (McMichael et al. 1999), potentially increasing the mortality in wild fish from predation, injury, or reduced feeding. Hatchery steelhead also can have adverse effects on juveniles of other salmonids, especially Chinook and coho salmon, through aggressive behavior and predation (Kelsey et al. 2002).

In the 1970s and early 1980s, adults of hatchery origin made up about 8% of the run of Klamath River steelhead and 20–34% of the run in the Trinity River (Busby et al. 1994). As numbers of wild steelhead decline, the percentage of hatchery fish in the population presumably will increase.

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There is some indication that the runs most heavily influenced by hatchery steelhead in the Trinity River have a lower frequency of half-pounders in the population than do wild populations (Hopelain 1998).

Status

Historical numbers of winter steelhead in the Klamath River are not known, but total run sizes in the 1960s were estimated at about 170,000 for the Klamath and 50,000 for the Trinity (Busby et al. 1994). Historical numbers for the Klamath River above the Trinity undoubtedly were much higher because by 1917 all access to the upper basin was eliminated and habitat in the tributaries was greatly degraded or blocked. In the 1970s, Klamath River runs were estimated to average around 129,000; by the 1980s, they had dropped to around 100,000 (Busby et al. 1994). Similar trends were noted for the Trinity River. Numbers presumably are still declining, although all estimates of abundance, past and present, are very shaky. NMFS considered winter steelhead in the Klamath to be in low abundance and to be at some risk of extinction (Busby et al. 1994) but has not listed them under the ESA.

Summer Steelhead

Life History

Summer (spring-run) steelhead have the same relationship to winter steelhead that spring-run Chinook salmon have to fall-run Chinook salmon in the Klamath River. They are closely related but have different life histories. Summer steelhead enter the Klamath River as immature fish from May to July and migrate upstream to the cool waters of the larger tributaries (Barnhart 1994, Moyle 2002). They hold in deep pools roughly until December, when they spawn. Temperature requirements of adult summer steelhead are not well documented, but maximum daytime temperatures of less than 16°C seem to be optimal, and temperatures above 20°C increase stress substantially (Moyle et al. 1995) through susceptibility to starvation (they do not feed much while holding) and disease. High temperatures also decrease viability of eggs inside the females. Juveniles probably occupy mainly the same upper stream reaches in which they were spawned, that is, above the areas in which most winter steelhead spawn and rear but where coho are likely to be present. Other aspects of their life history are similar to those of winter steelhead, including a predominance of 2-yr-old smolts and the presence of half-pounders (Hopelain 1998). There is some evidence, however, that summer steelhead have higher repeat spawning rates and grow larger in the ocean (Hopelain 1998). As is the case with spring-run

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Chinook salmon, major disadvantages of the summer steelhead's life-history pattern in the present system are that reduced flows and increased temperatures during the adult and smolt migration periods prevent the fish from reaching their destinations or greatly increase their mortality during migration (Moyle et al. 1995, Trihey and Associates 1996).

Status

Summer steelhead once were widely distributed in the Klamath and Trinity basins and were present in most headwaters of the larger tributaries (Barnhart 1994). In the 1990s, estimated numbers were 1,000–1,500 adults divided among eight populations; the largest numbers were in Dillon and Clear creeks (Barnhart 1994, Moyle et al. 1995, Moyle 2002). Numbers presumably are still declining because of loss of habitat, poaching in summer, and reduced access to upstream areas during migration periods as a result of diversions. Summer steelhead and winter steelhead probably are different ESUs. NMFS considers the stocks depressed and in danger of extinction (Busby et al. 1994). Summer steelhead are not produced by Klamath basin hatcheries.

OTHER FISHES

Pink Salmon

Small runs of pink salmon probably once existed in the Klamath River and elsewhere on the coast. The pink salmon now appears to be extirpated as a breeding species in California, although individuals stray occasionally into coastal streams (Moyle et al. 1995, Moyle 2002).

Chum Salmon

Periodic observations of adult chum salmon and the regular collection of small numbers of young suggest that this species continues to maintain a small population in both the Klamath and Trinity rivers (Moyle 2002). It was more abundant in the past and occasionally was harvested, but it has never been present in large numbers. The run in the Klamath basin is the southernmost of the species. The life history of this species in the Klamath basin, including timing of spawning runs and outmigration of juveniles, is probably similar to that of fall-run Chinook salmon.

Coastal Cutthroat Trout

Because of their similarity to the more abundant steelhead, coastal cutthroat trout have been largely overlooked in the Klamath basin. They

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occur mainly in the smaller tributaries to the main stem within about 22 mi of the estuary. They also have been observed further upstream in tributaries to the Trinity River (Moyle et al. 1995). Their life history in the Klamath River is poorly documented but is apparently similar to that of winter steelhead. Adults enter the river for spawning in September and October, and juveniles grow in the streams for 1–3 yr before going to sea. Cutthroat trout can spawn two to four times. Competition for space by spawners and juveniles with the dominant steelhead is reduced by the ability of cutthroat to use habitats higher in the watersheds than are typically used by steelhead (Moyle 2002). Voight and Gale (1998) suggest that in small tributaries in the lower 22 mi of the Klamath River, cutthroat may actually be more abundant in headwater streams than they were historically because they have become resident above migration barriers created by human activities, such as log jams and debris flows. The life history of one such population on the nearby Smith River is documented by Railsback and Harvey (2001).

The general absence of cutthroat trout from streams higher in the Klamath basin presumably results from their general intolerance of water that exceeds 18°C (Moyle 2002) and from competition with the more tolerant steelhead and perhaps other salmonids. Juveniles move downstream when they reach 12–20 cm during April through June, coincidentally with the outmigration of juvenile Chinook salmon, a major prey (Hayden and Gale 1999, Moyle 2002). Adults apparently do not move far once they reach salt water and some may return to overwinter in freshwater; others may move up in summer. Movements into freshwater by nonbreeding fish may be triggered by abundance of juvenile salmon, which are prey; the timing of such movements into the lower Klamath appears to vary greatly from year to year (Gale et al. 1998). Large numbers of adult cutthroat are observed every summer in lower Blue Creek, where they seek refuge from poor conditions in the main-stem Klamath (Gale et al. 1998).

Eulachon

The eulachon or candlefish is a smelt (Osmeridae) that reaches the southern extent of its range in the Mad River, Redwood Creek, and the Klamath River (Moyle 2002). Historically, large numbers entered the river to spawn in March and April, but they rarely moved more than 8 mi inland. Spawning occurs in gravel riffles, and the embryos take about a month to develop before hatching and being washed into the estuary as larvae. The eulachon in the Klamath River once was an important food of the American Indians in the region (Trihey and Associates 1996). Since the 1970s, their numbers have been too low in most years to support a fishery. The causes of the decline are not known but probably are tied to changing ocean conditions and poor habitat and water quality in their historical spawning areas (Moyle 2002).

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Green Sturgeon

Probably 70–80% of all green sturgeon are produced in the lower Klamath River and Trinity River, where several hundred are taken every year in the tribal fishery, which is the principal source of life-history information on this species (Moyle 2002). Green sturgeon enter the Klamath River to spawn from March to July; most spawning occurs from the middle of April to the middle of June at temperatures below 14°C. Spawning takes place in the lower main stems of the Klamath and Trinity rivers in deep pools with strong bottom currents. Juveniles occupy the river until they are 1–3 yr old, when they move into the estuary and then to the ocean. Optimal temperatures for juvenile growth in the river appear to be 15–19°C. Temperatures above 25°C are lethal (Mayfield 2002). After leaving the river, green sturgeon spend 3–13 yr at sea before returning to spawn and often move long distances along the coast. They reach maturity at 130–150 cm and are repeat spawners. Large adults (250–270 cm) typically are females that are 40–70 yr old (Moyle 2002). There is some evidence that green sturgeon populations are in decline, but reduction of the marine commercial fishery for them may have alleviated the decline somewhat (Moyle 2002). In 2003, NMFS rejected a petition to have them listed as a threatened species.

Pacific Lamprey

Lampreys once were so abundant in the coastal rivers of California that they inspired the name Eel River for the third largest river in the state. They supported important tribal fisheries. Today, their numbers are low and declining (Close et al. 2002, Moyle 2002). Their biology is poorly documented, but they probably have multiple runs in the Klamath basin. Most adults (30–76 cm) enter the river from January through March to spawn from March to June, although movement has also been observed in most other months (Moyle 2002). How far upstream lampreys moved historically is not known, but it is certain, as shown by the genetics of resident lampreys, that they entered the upper basin above Klamath Falls at least occasionally. Most spawning appears to take place in the main stem or larger tributaries. Like salmon, lampreys construct redds for spawning in gravel riffles, although the tiny larvae emerge from the gravel in just 2–3 wk. They are washed downstream once they emerge, and they settle in sand and mud at the river's edge. The larvae (ammocoetes) live in burrows in these quiet areas for probably 5–7 yr and feed on algae and other organic matter. During the larval stage, they move about frequently, so they are commonly captured in salmon outmigrant traps. Factors limiting the survival of ammocoetes are not known, but it is likely that rapid or frequent

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drops in flow deprive them of habitat and force them to move into open water, where they are vulnerable to predation. They do not appear to be limited by temperatures in the basin, but anything that makes their shallow-water habitat less favorable (such as pollution and trampling by cattle) is likely to increase mortality.

The blind, worm-like ammocoetes undergo a dramatic transformation into eyed, silvery adults when they reach 14–16 cm, after which they migrate to the sea (Moyle 2002). Downstream migration usually is coincidental with high flows in the spring, but movement has also been observed during summer and fall (Trihey and Associates 1996). In the ocean and estuary, they prey on salmonids and other fish for 1–2 yr before returning to spawn. The Pacific lamprey is a tribal trust species with a high priority for recovery to fishable populations (Trihey and Associates 1996). Its cultural importance to American Indians is largely unappreciated (Close et al. 2002).

Native Nonanadromous Species

Speckled dace, Klamath smallscale sucker, lower Klamath marbled sculpin, threespine stickleback (some of which are anadromous), and Klamath River lamprey are quite common in the lower river and its tributaries of low gradient. With the possible exception of the sculpin, these species probably all have fairly high thermal tolerances (Moyle 2002). In the reaches within 30 mi or so of the ocean, marbled sculpin apparently are replaced by the two amphidromous species, prickly sculpin and coastrange sculpin. With the exception of the lamprey, which feeds on fish, all the resident fishes feed mainly on aquatic invertebrates. The relationship between the native nonanadromous and anadromous species has not been worked out in the Klamath, but the dace, stickleback, sculpins, and suckers are probably subsidized by nutrients brought into the streams by the anadromous fish and may suffer heavy predation, especially in the larval stages, by juvenile salmon and steelhead.

Nonnative Species

The lower Klamath basin is still dominated by native fishes, but other species have a strong presence in highly altered habitats, such as reservoirs and ponds. The Shasta River, once a cold-water river, now supports large populations of brown bullheads and other warm-water, nonnative species because summer flows consist largely of warm irrigation-return water. There also is a continuous influx of nonnative fishes from the upper Klamath basin, where they are extremely abundant. Because there is a positive relationship between degree of habitat disturbance and abundance of nonnative fishes

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(Moyle and Light 1996), improving habitat for native fishes should reduce the likelihood that nonnative species will become more abundant.

MASS MORTALITY OF FISH IN THE LOWER KLAMATH RIVER IN 2002

During the last half of September 2002, mass mortality of fish (fish kill or fish die-off) occurred in a reach of the Lower Klamath River extending about 30 mi up from the confluence of the river with its estuary (Figure 1-1). In responding to the general need for a timely assessment of the conditions leading to this mortality, CDFG released in January 2003 a report that describes the extent of the mortality and its distribution among species, hydrologic and meteorological conditions that accompanied the mortality, some aspects of water quality, and the results of physical examination of both living and dead fish. A second CDFG report will deal with long-term consequences of the mortality. Also during 2003, USGS released a report dealing with the mortality of September 2002 (Lynch and Risley 2003). The USGS report documents environmental conditions that coincided with the mortality, but does not attempt to reach conclusions as to its cause.

The sponsors of the NRC study on endangered and threatened fishes asked the NRC committee to study information on the fish kill of 2002 and include the analysis in its final report. While it is reasonable that this issue be covered in the committee's report, it is also important to note that the fish kill primarily affected Chinook salmon, for reasons that are explained below, and not the threatened coho salmon that is the focus of attention for the NRC committee in its work on the lower Klamath basin. Furthermore, the NRC committee was only able to consider the two reports cited above and unpublished records on weather and temperature; other reports to be issued in the future might provide additional information that would influence conclusions about the cause of the fish kill. The fish kill of 2002 in the Klamath lower main stem is unprecedented in magnitude. It raises questions as to whether human manipulation of the Klamath River or the adjoining estuary was directly or indirectly responsible and, if so, what might be done to prevent its recurrence. A full and final explanation of mortality probably is not possible, however, given that the fish kill was not anticipated and therefore the conditions leading to it were not well documented.

Extent of Mortality

CDFG, quoting USFWS, has estimated the total mortality of fish in the last half of September 2002 at about 33,000. This estimate, which is subject

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to revision, is likely to be conservative. The projected run size of fall-run Chinook salmon, which was the most abundant of the fish that died, was estimated at 132,000. Thus, regardless of any adjustments that might be made in the final estimate of mortality, a substantial portion of the Chinook salmon run was lost before spawning.

Both CDFG and USFWS estimated the species composition of the fish kill, which extended beyond salmonids to other taxa, including the Klamath River smallscale sucker, but percentage estimates from CDFG are limited to the salmonids. A sample of 631 dead fish collected under the supervision of CDFG showed 95.2% Chinook salmon, 4.3% steelhead trout, and 0.5% coho salmon. These estimates differ only slightly from the USFWS estimates. Further details may appear in reports yet to be issued. Among both Chinook and steelhead, nonhatchery fish appeared to have died in greater numbers than fish of hatchery origin. A similar determination for coho salmon is complicated by the fact that only small numbers of coho were found. If the coho had been in peak migration at the time when mortality occurred, more dead coho probably would have been found. The coho migration occurs later than the Chinook migration, which probably explains why few coho were affected.

Direct Causes of Mortality

CDFG has given infection as the direct cause of death of the fish. Both living and dead fish were infected with *Ichthyopthirius multifilis,* a protozoan, and *Flavobacter columnare,* a bacterium. As indicated by CDFG, these two pathogens are widespread and, when they become lethal to fish, typically are associated with high degrees of stress. Crowding may be considered an additive agent to stress in that it facilitates efficient transmission of pathogens from one fish to another. A combination of crowding and stress thus would be especially favorable for the development of these pathogens in sufficient strength to cause mortality of fish. Potential agents of stress, which may have acted in combination rather than alone, include high temperature, inadequate concentrations of dissolved oxygen (undocumented), and high concentrations of unionized ammonia (undocumented).

Indirect Causes of Mortality

Low flow in the Klamath River main stem is the most obvious possible cause of stress leading to the lethal infections of fish in the lower Klamath River during 2002. Low flow can cause crowding of the fish in their holding areas as they await favorable conditions for upstream migration and can be associated with high water temperature and with lower than normal

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concentrations of dissolved oxygen. CDFG therefore reviewed information on flow in the main stem, as did USGS (Lynch and Risley 2003).

The flow of the Klamath River at Klamath, which is just a few miles above the estuary, is shown in Figure 7-3 for dry yrs used by CDFG in its overview of low flows in the river. The flows at Iron Gate Dam, about 185 mi upstream, are given for comparison. For an extended span of years not restricted to drought, September flow at Iron Gate Dam is about one-third of the flow at Klamath. For example, mean September discharge at Klamath was 2,973 cfs for 1988 through 2001 (excluding 1996, 1997) and the same statistic for the Klamath River at Iron Gate Dam is 1,130 cfs, as determined from USGS gage records.

The USGS elected not to use data for the Klamath gage because the accuracy of the gage at low flow is subject to errors greater than 15%. Figure 7-3 shows the sum of the gages at Orleans (main stem above the Trinity) and at Hoopa (on the lower Trinity), both of which produce discharge readings within 10% of the true value, for comparison with the flows in the main stem at Klamath. The two sets of values are separated by some additional discharge (undocumented) that accumulates below the

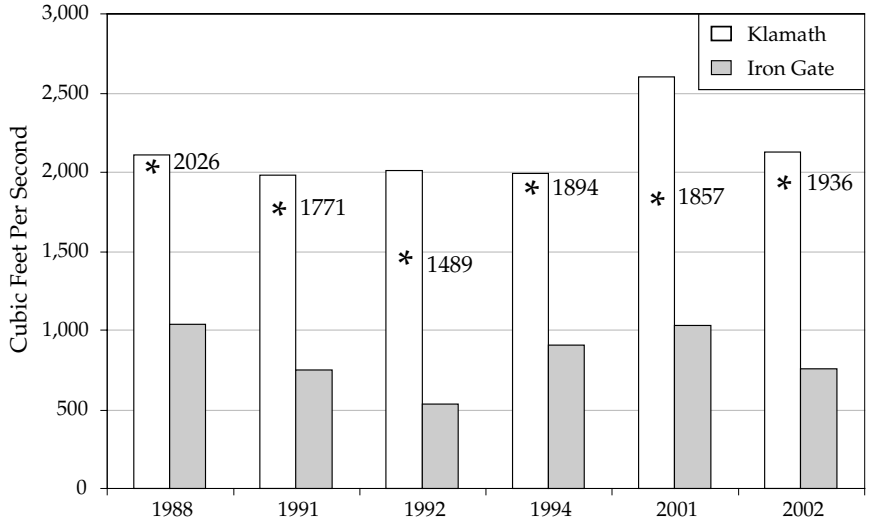


FIGURE 7-3 Mean flows of the Klamath main stem at Klamath (near the site of the 2002 fish kill) and at Iron Gate Dam (about 185 mi upstream) in September for 6 low-flow years considered by CDFG in its analysis of the fish kill. The asterisk shows the sum of flows for the Klamath at Orleans and the Trinity at Hoopa, as a check on the Klamath gage (this sum omits small tributaries below the Trinity). Sources: Data from CDFG 2003 and USGS gages.

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Trinity. The Klamath gage data and the sum of the two gages above it show essentially the same picture qualitatively, as does the analysis by USGS based on the Orleans gage alone. Also, USGS restricted its analysis of flows to 1–24 September, which coincides better with observed mortality than 1–30 September, but the mean gage readings for these differing intervals are essentially identical (< 1% difference at Klamath). All data indicate that flows comparable with those of 2002 have occurred a number of times over the last 15 yr without causing mass mortality of salmonids. This does not rule out the possibility that low flow was a factor, but it does suggest that the occurrence of flows similar to those of 2002 has not in the past been sufficient by itself to cause mass mortality.

The USGS analysis adds a new dimension to future concerns related to flow in that it shows a substantial increase in distance to the water table over 2001 and 2002, both of which were dry years. Because shallow alluvial water reaches the tributaries and main-stem Klamath as groundwater, which supports flow in dry weather, drawdown of the water table by pumping should be taken into account in any future evaluation of low flows, particularly if pumping is a growing response to water scarcity during drought. Flow could be related to crowding on a conditional basis through run size or timing of run. CDFG considered this possibility by using estimates of run timing and run size of Chinook salmon, which accounted for most of the fish biomass in the river during the last half of September. The analysis showed that the run of Chinook was only slightly larger than average and that it was bracketed by run sizes both smaller and larger for other comparably dry years. Thus, run size does not show evidence of being a conditional influence related to flow.

The August–October run of Chinook appears to have peaked earlier in 2002 than in other years of record, and this suggests a conditional relationship with low flow in causing mortality. CDFG was reluctant, however, to attribute great significance to this possible relationship, given the small amount of information on which it is based. The data available to CDFG indicated that air temperatures were not unusually high during September 2002 compared with other years of low flow when no fish kills occurred. Information on water temperature is sketchier, but also indicates that average maximum water temperatures fell within the range of water temperatures in previous years of low water when there were no fish kills. The USGS made comparisons of the Klamath River with the Rogue River, which is located nearby and has more comprehensive temperature records. Both water and air temperatures on the Rogue River were approximately 2°F higher in 2002 than the mean for the period of record. While the difference is small, the threshold for harm to salmonids lies close to September temperatures, even in years of average flow. The USGS analysis, like the CDFG analysis, did not suggest that temperatures in 2002 were extreme by com-

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parison with other years of low flow when no fish kills occurred. Thus, if temperature is a factor governing mortality, it would involve coincidence of high temperatures with some other factor, the nature of which is not clear from the presently available information.

Tests of water quality did not indicate the presence of toxicants, although the water was not sampled until seven days after the onset of the first observation of dead fish (CDFG 2003). It is always possible that toxicants not tested were involved, but this seems unlikely, given that the fish kill occurred over an extended period and that there is no circumstantial evidence of the role of toxicants other than possibly ammonia generated by the fish themselves.

CDFG also considered fish passage. According to CDFG, high flows in 1997 and 1998 may have caused aggradation and expansion of channel bars that inhibited fish passage during extremes of low flow. These changes did not result in fish kills during the low-water year of 2001, but flows in 2001 were not as low as those in 2002. Thus, a current hypothesis of CDFG is that a change in channel geometry has created new conditions that are detrimental to fish at low flows even though such flows previously did not lead to high mortality. The hypothesis is speculative in that changes in channel conditions have not been established by measurement, but it should remain under consideration until further relevant evidence is collected.

Summary of Explanations

The possibility that passage is inherently more difficult at low flows now than it was before 1997–1998 was the only explanation of unique conditions leading to the fish kill that CDFG could not rule out in preparing its January 2003 report. Because of the limited data about conditions before and during the kill, other hypotheses probably will emerge as other reports are prepared. One hypothesis that has not been evaluated by CDFG involves the effect of temperature extremes during the fish kill. As explained earlier in this chapter, mean water temperature is less important for salmonids than extremes of water temperature. Thus, for example, the failure of temperatures to decline sufficiently at night when mean temperature is high could place unusual stress on salmonids but could be overlooked in a consideration of mean and maximum temperatures alone. Such conditions could occur, for example, when back radiation is so low (perhaps as a result of cloudiness or high humidity) that a typical amount of cooling would not occur at night.

A sequence of events involving daily minimum temperature rather than fish passage might be a cause of mortality. A large number of salmon moved up the river coincident with a series of days in which water temperatures were high enough to inhibit migration. McCullough (1999) states

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that, based on studies in the Columbia River, Chinook salmon cease migrating when maximum water temperatures exceed 21°C. Lynch and Risley (2003) indicate that during the time of the kill, maximum water temperatures in the river at Orleans, 30 mi upstream of the kill, averaged 20.3°C, and that the average minimum was 19.7°C. Thus it seems likely that temperatures in the Klamath River at the site of the kill reached or approached the inhibitory temperatures. As they commonly do, the salmon held in pools when the temperatures were high, waiting for conditions to improve before continuing upstream. The temperature and flow data given by Lynch and Risley (2003) indicate, however, that conditions did not improve and that nocturnal temperatures were not much lower than daytime temperatures. Because salmon are more vulnerable to infectious diseases at higher temperatures (McCullough 1999), crowding encouraged the disease outbreak that resulted in the kill.

The fish-passage hypothesis of CDFG or the minimum temperature hypothesis given above may or may not justify additional release of flow from Iron Gate Dam. It is unclear whether low flows actually blocked upstream migration or, as suggested by the literature, that most of the fish stopped moving because of high temperature (CDFG cites evidence that at least a portion of the run was capable of moving upstream during these low-flow conditions). The emergency release of 500 cfs of additional water from Iron Gate Dam by USBR, which arrived long after the fish kill had ended, lacked any specific justification. For relief of physical blockage, if it occurs, only a large amount of water (e.g., 1,500 cfs) would be of use. Additional water from the Trinity could be especially valuable in that it would be cooler, if released in quantity.

If passage is the key issue, the recurrence of low flows similar to those of 2002 will probably be accompanied by mass mortality of fish. If other explanations, including minimum temperature, are the key explanation of mortality, recurrence is less likely, although higher temperatures over the long term caused by climate change could increase the likelihood that such kills would occur. Aggressive pursuit of some recommendations related to coho salmon (see information on augmentation of cold-water tributary flows in Chapter 8) could, if successful, reduce the risk of mass mortality of Chinook salmon. In any case, it is clear that increased monitoring of water quality and channel conditions in relation to flows in the lower main stem is needed in support of measures that may be necessary to prevent loss of Chinook salmon.

CONCLUSIONS

The lower Klamath basin is a geologically dynamic region that historically had large runs of anadromous fishes with diverse life histories. The

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fishes were widely distributed in the basin; some even entered the rivers that fed Upper Klamath Lake. The Salmon, Scott, Shasta, and Trinity rivers—all of which are major tributaries of the Klamath River—were major salmon and steelhead producers. The Shasta River in particular, with its cold flows and high productivity, was once especially productive for anadromous fishes. In the Klamath basin as a whole, Chinook salmon were and are the most abundant salmonid, followed by steelhead. Coho salmon rank third, but are well below Chinook and steelhead in abundance.

Virtually all populations of anadromous fishes have declined considerably from their historical abundances, although documentation for some species, such as Pacific lamprey and green sturgeon, is poor. Three of the most distinctive forms—coho salmon, spring-run Chinook, and summer steelhead—are on the verge of extinction as naturally maintained populations in the basin. It is significant that these three are the most dependent on summer water temperatures below 18°C and that they historically spawned and developed in tributary streams, many of which now are too warm for them. The anadromous fishes have been in decline since the 19th century when dams, mining, and logging severely altered many important streams and shut off access to the upper basin. The declines continued through the 20th century with the development of intensive agriculture with its dams, diversions, and excessively warm water both inside and outside the basin. Continued logging in headwater areas and commercial fishing also have contributed to the decline.

The main-stem Klamath River has become a challenging environment for anadromous fishes because of decreased flows and increased summer water temperatures. Although it is inhospitable to juvenile coho, it is still important for the rearing of juvenile Chinook salmon and steelhead, but increases in temperatures in July–September of 1–3°C may make it unsuitable even for them in the future. Increased flows down the river in summer are likely to benefit anadromous fishes only if temperatures can be kept within bioenergetically favorable ranges. This is particularly true for the lowermost reach of the main stem, below the Trinity River, which may be either cooler or warmer in late summer than the main stem, depending on the amount of water being released from Lewiston Dam.

Millions of juvenile fish, including Chinook salmon, steelhead, and coho are released into the Klamath and Trinity rivers each year by the Iron Gate and Trinity River hatcheries, which were built to mitigate salmonid losses created by large dams. These hatcheries have helped to maintain fisheries for coho and Chinook salmon, but their effect on wild populations of salmonids in the basin is not well understood. It is likely, however, that interactions between the hatcheries and wild juveniles in the river are having an adverse effect on the survival of wild juveniles through competition for space and food and aggressive interactions (e.g., McMichael et al. 1999,

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Kelsey et al. 2002), to the extent that the contributions of hatchery fish to fisheries are at least partially offset by the decreased contribution of wild fish (Levin et al. 2001). A high percentage of naturally spawning adult coho and Chinook salmon are of hatchery origin.

Native nonanadromous fishes are widespread and common in the drainage, but their relationships to anadromous fishes are not known. Nonnative fishes are uncommon in the lower basin except where drastically altered habitats favor them. If habitat degradation continues, the Klamath River and its main tributaries will probably favor nonanadromous native and nonnative fishes increasingly at the expense of anadromous fishes. The hierarchical nature of watersheds assures that many environmental changes, some of which are quite small individually, collectively affect fish populations not only in their immediate vicinity but also both upstream and downstream because of the extensive movement of fishes (Fausch et al. 2002).

The problems with coho salmon are a reflection of larger problems with poor habitat and water quality for anadromous fishes generally in the basin. Restoration efforts that benefit coho salmon should benefit most, but not necessarily all, declining species. Prevention of further listings under the ESA requires a systematic, basin-wide approach to restoration and management. Some major gaps in knowledge are as follows:

1. Information on the biology of coho and other salmonids in the basin is largely unsynthesized; synthesis and interpretation of data on historical trends and present conditions would be especially valuable.
2. Studies on anadromous fishes other than fall-run Chinook, winter steelhead, and coho are very limited or lacking, particularly for summer steelhead, spring-run Chinook, and Pacific lamprey. It cannot be assumed that management strategies favoring species of primary interest also favor other species.
3. The biology of nonanadromous native fishes and macroinvertebrates in the basin is largely unknown, including basic descriptions of life histories and environmental requirements and their relationships to coho salmon and other anadromous fishes.
4. The potential effects of global climate change on the Klamath basin and its fishes, especially coho, are poorly understood, including the relationship between changing ocean conditions and the abundance of coho and other anadromous fishes. Climate warming would almost certainly be disadvantageous to coho.
5. The thermal consequences of stream and watershed restoration actions, including increasing summer flows down the main-stem Klamath River, are not well documented, especially in relationship to coho salmon.
6. The effects of hatchery operations on wild populations of coho and

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other salmonids in the basin are not understood, including the effects of hatchery steelhead and Chinook on juvenile coho salmon.

7. Strategies for improving tributaries for spawning and rearing of coho and other anadromous fishes are not yet well defined.

8. The lower 30–40 km of the main-stem Klamath seems to be increasingly unfavorable to anadromous fishes, for reasons that are not known. The effect on the lower river of changing flows from the Trinity River needs to be evaluated, as do the potential benefits of comanaging flow releases from the dams on the Trinity and Upper Klamath rivers.

9. Reliable abundance estimates and habitat affinities of juvenile coho and other salmonids are largely lacking.

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8

Facilitating Recovery of Coho Salmon and Other Anadromous Fishes of the Klamath River

Restoration of anadromous fishes to higher abundances in the Klamath basin will require multiple interactive initiatives and will take many years to reach full effectiveness. This chapter emphasizes actions needed for recovery of coho salmon; the same actions likely will benefit other species as well. Remedial actions to be evaluated here include restoration of tributary habitat, restoration of main-stem flows and habitats in the Klamath River, removal of dams, changes in land use and water management, changes in operation of hatcheries, and creation of an institutional framework for fisheries management. Research and monitoring programs are the means by which remedial actions should be evaluated and adjusted.

RESTORATION OF TRIBUTARIES

Coho salmon, spring-run Chinook salmon, and summer steelhead depend heavily on tributaries to complete their life cycles and sustain their populations (Chapter 7). Thus, restoring large, self-sustaining runs of anadromous fishes in the basin requires restoration of the tributaries to conditions that favor spawning and rearing of anadromous fishes. For most of the tributaries, restoring low summer temperatures probably is the most important action (Table 8-1). Removing barriers, improving physical habitat, and increasing minimum flows also are important and are strongly linked to the objective of lowering summer temperatures.

Because the four main tributaries differ from each other, a uniform approach to management and restoration in their watersheds is unlikely to

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TABLE 8-1 Factors Likely to Limit Production of Coho and Other Salmonids in the Shasta, Scott, Salmon, and Trinity Rivers and Their Tributaries

Limiting Factors	Shasta, Main	Shasta, Tributaries	Scott, Main	Scott, Tributaries	Salmon, Main	Salmon, Tributaries	Trinity, Main	Trinity, Tributaries
Migration Barriers								
Dams, weirs, diversion structures	x	x	o	x	–	–	x	o
Low-flow blockage	x	x	x	x	o	o	x	o
Thermal barriers	x	x	x	–	o	–	–	–
Hydrologic Changes								
Low summer and fall flows	x	x	x	x	–	–	–	o
Reduced peak winter flows	o	–	–	–	–	–	x	–
Reduced spring flows due to diversions	o	o	o	o	–	–	x	o
Reduced base-flow support from ground water	x	x	x	x	–	–	–	–
Water Quality								
High temperature	x	x	x	–	o	o	o	o
Low dissolved oxygen (DO)	x	x	o	–	–	–	–	–
pH, alkalinity, dissolved solids	–	–	–	–	–	–	–	–
Suspended solids	–	–	o	o	o	o	o	o
Geomorphology								
Loss of spawning gravel	x	o	x	x	o	–	x	x
Fine sediment deposition	x	x	x	x	o	–	x	x
Channel aggradation and instability	x	o	x	x	–	–	x	x
Reduced in-stream cover	x	o	x	o	–	–	x	x
Loss of riparian cover	x	x	x	o	–	–	o	x
Land Use Constraints								
Timber management practices	–	o	x	x	o	o	x	x
Grazing and pasture in riparian areas	x	x	x	o	–	–	o	o
Grazing in upslope areas	–	o	–	o	–	–	o	o
Management of fuels	–	o	–	x	x	x	o	o
Land conversion for agriculture	x	x	x	o	–	–	–	o
Unscreened diversions	x	x	x	x	–	–	–	o
Tailwater return flows	x	–	x	–	–	–	–	–
Water development	x	x	x	o	–	–	x	o
Urbanization	o	o	o	–	–	–	–	–

Abbreviations: o, common and of moderate concern or significance; x, widespread or important; –, probably not a limiting factor.

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succeed. The following discussion outlines key issues that confront restoration of salmonids in each watershed. This review is not exhaustive; it focuses on the most important factors that appear to limit coho salmon and other anadromous species in the basin.

Shasta River

The Shasta River once was one of the most productive salmon streams in California (Snyder 1931, Wales 1951). It supported large runs of Chinook salmon, coho salmon, and steelhead. Over 80,000 Chinook salmon spawned in the river in the 1930s, by which time the population probably was already in serious decline as a result of habitat changes caused by placer mining and agriculture starting in the 1850s. Snyder (1931, p. 73) referred to it as early as 1931 as a "stream once famous for its trout and salmon." The historical runs of coho salmon and steelhead are not known but were probably large, given the apparent quality of the habitat. An assessment of the river in the 1960s suggested that runs of coho averaged around 1,000 fish per year and runs of steelhead averaged around 6,000 fish per year (CDFG 1965). The productivity of the Shasta River is related to its unusual hydrology and geologic setting (Chapter 4). Unlike the Scott and Salmon rivers, the Shasta River is dominated by groundwater discharge, principally through numerous cold-water springs. The headwaters of the Shasta watershed lie primarily on the northern and western flanks of Mt. Shasta. Rainfall and snowmelt recharge an extensive groundwater system that feeds the Shasta River. Historically, the river flowed at a minimum of about 200 cfs all year. The water was cool in summer and, in comparison with its companion watersheds, warm in winter. The exceptional thermal stability of the Shasta made it one of the most important tributaries for support of salmonids in the Klamath watershed.

Today, agricultural development of the Shasta valley (principally alfalfa and irrigated pasture) and the construction of Dwinnell Dam (which impounds the Shastina Reservoir) have fundamentally changed the hydrology and productivity of the Shasta River. The largest diversion of water is to the Shastina Reservoir, constructed in 1926, which loses a substantial part of its storage each year through seepage and blocks access to about 22% of the historical salmonid habitat. Surface diversions and loss of spring flow to the channel because of groundwater withdrawals have reduced summer flows to about 10% of their historical rates. The low volume of flow, high contribution of warm agricultural return flows, and loss of riparian shading lead to summer water temperatures that consistently exceed acute and chronic thresholds for salmonids. Because of high water temperatures, the Shasta River in summer supports mainly nonsalmonid fishes, such as the brown bullhead and speckled dace. Juvenile fall-run

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Chinook salmon have emigrated by summer, and juvenile steelhead and coho persist mainly in the upper reaches of a few tributaries.

Given its former productivity, the Shasta River has exceptional potential as a restoration site for coho salmon as well as steelhead and Chinook salmon. Although multiple factors limit the abundance of salmonids in the Shasta (Chapter 4), the key to their recovery is to restore enough cold-water flow to keep the daily mean temperatures of the river below 20°C throughout summer. This would allow juvenile salmonids, including coho, to reoccupy the main stem of the Shasta, where they could take advantage of the river's naturally high productivity. Flows must also be restored in several key tributaries (such as Parks Creek and Big Springs) to improve their connectivity with the main river and to provide access to spawning sites.

The restoration of cold-water flows to the Shasta River presents many difficulties. The science behind restoration of the system, however, is relatively simple. Given the magnitude of the groundwater recharge area that is connected to the Shasta River, there appears to be ample potential to restore cool flows (Chapter 4). Additions of cool water to the relatively small volume of current summer flows are likely to have a substantial beneficial effect on temperature and habitat. Modest changes in the timing and magnitude of surface diversions and groundwater pumping, particularly in the upper reaches of the Shasta River and the tributaries between Dwinnell Dam and Big Springs, would have a large beneficial effect on the volume and temperature of water in the river during summer. Because the thermal mass of present flows is small, the benefits of cooling the water may be limited to the upper reaches of the river. If new water-management programs are linked to programs that seek restoration of riparian zones and channels, however, it is very likely that a substantial portion of the Shasta River can be restored to highly productive rearing habitat for coho and other salmonids. It is also appropriate to consider removal of the aging Dwinnell Dam. It loses more water to seepage than it provides for irrigation (Chapter 4), and its removal would restore flows, increase gravel recruitment, and allow access of salmonids to 22% of their historical habitat.

Numerous stakeholder groups and several federal and state agencies are now addressing habitat issues for salmonids in the Shasta watershed. Although not as well funded as the Scott River programs, the Shasta River restoration efforts are making progress, particularly in riparian fencing and management of tailwater return flow. To restore habitat effectively, these groups must develop methods for augmentation of the Shasta River with cool water during summer. Habitat restoration efforts that fail to deal with this issue are unlikely to succeed. A federally organized program promoting technical review of private habitat restoration efforts could make such efforts more successful.

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Scott River

The Scott River originates in forested headwaters of the Marble, Scott, and Trinity mountains, meanders through the broad, agriculturally rich Scott valley, and then passes through the steep Scott River Canyon before joining the Klamath River (Chapter 4). The surrounding mountains are largely national forest, including the Marble Mountains Wilderness Area. The Scott River valley is private agricultural land, and the canyon reach below it is a state Wild and Scenic River (CDFG 1979b). The Scott River exhibits strongly seasonal flows derived from numerous tributaries that drain the western and southern edges of the watershed. The tributaries were and are critical for spawning and rearing of coho and steelhead, and the meandering river on the valley floor was important for spawning of fall-run Chinook and Pacific lamprey. It is likely that in all but the most severe drought years the main stem originally provided important and productive habitat for juvenile salmonids, including coho, throughout the summer, especially in the sloughs and pools of the numerous beaver dams that once were characteristic of the streams on the valley floor (CDFG 1979b).

The Scott River is still an important spawning area for salmonids, as indicated by the annual outmigrant trapping by the California Department of Fish and Game (e.g., Chesney 2002). Numbers of fish are severely diminished, however, and habitat is poor for one or more stages of the life history of all anadromous salmonids (CDFG 1979b). The decline in habitat for salmonids in the watershed has multiple, linked causes (summary in Chapter 4). In the forested western and southern margins of the watershed, intense logging and associated road building on highly erosive soils has produced high sediment yields. Tributaries draining that portion of the watershed have been degraded by deposition of fine sediments. In the lower portion of the tributaries, extensive diversions for irrigation remove water from streams during summer. In the valley, grazing and farming have reduced riparian cover on tributaries and on the main stem. In addition, historical placer mining in the main stem and some tributaries has severely degraded spawning habitat, and has formed migration barriers during low-flow years. The most important effect on salmonid habitat is associated with high water demand for alfalfa and irrigated pasture. Surface diversions and groundwater pumping lead to extensive low-flow and no-flow conditions during summer on the main stem and the lower tributaries. Increased reliance on irrigation wells since the 1970s and changes in cropping patterns appear to be the cause of declining flows between late summer and early fall. Low flows reduce or degrade rearing habitat and limit migration during fall. Low-flow conditions on the Scott also are accompanied by poor water quality (Chapter 4). The low volume of water in the river, coupled with the accrual of tailwater return flows, leads to high summer tempera-

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tures. Typical maximum weekly average temperatures are well above acute or chronic thresholds for salmon from summer into early fall.

Despite widespread decline in suitability of habitat, the Scott River retains high potential for becoming once again a major producer of anadromous fishes, especially coho salmon. The lower reaches of the tributaries on the west side of the basin, and the south and east forks, are still used extensively by coho and steelhead despite considerable degradation of the habitat. In addition to continuing efforts to reduce sedimentation and restore riparian vegetation cover in the streams, the key to restoring coho and other salmonids is to improve access of fish to the upper basin tributaries and to enhance cold-water flows. Improving access will require additional screening of diversions and removal of blockages but also will require more aggressive management of adjudicated surface diversions and groundwater to maintain sufficient flows for fish passage. Restoration of habitat for salmonids on the main stem of the Scott River also remains a considerable challenge. Low flows and associated high temperatures have the greatest effect on fall-run Chinook and lamprey but may also affect coho, particularly during dry falls. High water temperatures and loss of riparian vegetation probably have eliminated holding and rearing habitat for coho in the main stem. Restoring summer and fall conditions suitable for coho in the main stem will require careful and creative management of existing surface-water and groundwater resources in the Scott River valley. Water leasing and conjunctive use of groundwater and surface water may be the only means of reducing diversions and groundwater pumping during critical low-flow periods.

Multiple stakeholder groups and the local Resource Conservation District in the Scott valley have conducted a number of well-funded efforts to restore habitat in the Scott watershed. Cooperation between these groups and the state and federal agencies that support them appears to be the most effective way of restoring habitat in the basin. To date, however, the groups have not attempted to resolve the most important but intractable issue: increasing the amounts of cold water entering the tributaries and the main stem.

Salmon River

The Salmon River has a steep gradient, is largely forested, and lacks broad alluvial valleys. About 98% of the watershed is in federal ownership, and more than 48% is designated as wilderness. The main stem, forks, and Wooley Creek are designated Wild and Scenic Rivers (CDFG 1979a). Wooley Creek is in nearly pristine condition, which is unique in the Klamath watershed. Most strikingly, the Salmon River is free of dams and is not subject to depletion of flow by diversions.

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The Salmon River watershed contains about 140 mi of channel suitable for spawning and rearing of fall-run Chinook salmon and 100 mi of steelhead and coho habitat (CDFG 1979a). Other fishes in the community include spring-run Chinook salmon and summer steelhead, which, like coho salmon, require deep pools and cold water throughout the summer. The principal habitat for spring-run Chinook salmon and summer steelhead in the Salmon River drainage today is Wooley Creek, although small numbers are also found in the forks of the Salmon River as well (Moyle et al. 1995, Moyle 2002).

Despite natural flow conditions and absence of agriculture, salmonid populations in general are low in the Salmon River, and coho salmon in particular are scarce (Olson and Dix 1993, Brown et al. 1994, Elder et al. 2002). Records are poor, but salmonids most likely were considerably more abundant in the past (CDFG 1979a). Olson and Dix (1993) estimated that only about 25% of the available spawning habitat was used by Chinook salmon and steelhead. The causes of decline and the status of current populations are not clear.

A variety of natural and anthropogenic factors may suppress salmonid populations in the Salmon River. Unlike the Shasta and the Scott rivers—which have alluvial valleys that formed favorable habitat for holding, spawning and rearing of salmon—the Salmon River has a bedrock channel of high gradient that limits the total amount of suitable habitat as defined by depth and velocity. The high rates of uplift in the watershed, coupled with unstable rock types, produce naturally high erosion rates that are associated principally with mass movements (CDFG 1979a). High erosion rates, which are accompanied by high sediment yields, have been accelerated by human activity in the last century (Elder et al. 2002).

In addition to naturally high sediment yields, the Salmon River watershed exhibits strong seasonal variations in flow, including large winter floods and low base flow during the last half of the summer. Low-flow conditions in the summer, particularly during drought, and the scarcity of cold springs may have naturally produced sufficiently high summer temperatures (maximums, 20–26°C) in some tributaries and in the main stem to limit production of salmon within the basin. Thus, the Salmon River watershed, although nearly pristine, may have geologic and hydrologic characteristics that are suboptimal for salmon. Under these conditions, human activities that increase sedimentation or raise stream temperature in the basin could have an especially large effect on salmon and steelhead.

The first major anthropogenic disturbance to the Salmon River was placer mining and other forms of gold mining, which peaked in the basin between 1850 and 1900 but continue today on a small scale (CDFG 1979a, Chapter 4). Placer mining disturbs the channel and disrupts sediment transport processes that sustain spawning gravels and maintain pools. A more

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important disturbance in recent years has been a combination of logging and fires. Logging and its associated road-building have greatly increased erosion on the steep and fragile slopes of the watershed and have reduced shading of small tributaries, thus increasing water temperatures. Stream crossings also significantly impair tributary streams in this basin by forming barriers to migration and local sources of erosion. Large fires may have exacerbated the effects of logging in the basin. Almost 30% of the basin has burned in the last 25 yr, and most fires have occurred in the logged portions of the basin (Salmon River Restoration Council 2002). These catastrophic fires, coupled with extensive logging that follows fires ("salvage logging"), have greatly increased the number of logging roads and increased the frequency of landslides (CDFG 1979a, Elder et al. 2002). Elder et al. (2002) estimated that from 1944 to 1988 about 216 mi of stream in the basin were scoured by debris flows caused by landslides. In addition, poaching of the vulnerable adult summer steelhead and spring-run Chinook may be important in reducing their populations (West et al. 1990, Moyle et al. 1995).

Factors outside the basin—including ocean or estuary conditions, harvest, and conditions on the Klamath main stem—may have reduced adult populations of salmonids in the Salmon River. Overall, however, it is likely that land-use activities in the Salmon River watershed have had the largest adverse effects on production of salmon and steelhead in the Salmon River basin.

Because the Salmon River watershed is owned principally by the federal government, there has been comparatively little controversy surrounding management and restoration efforts within the basin. A small but growing stakeholder group is cooperating with state and federal agencies and tribal interests in the Salmon River basin. High priority has been placed on monitoring of salmon and steelhead runs, improvements in riparian habitat, management of fuels, and assessment and rehabilitation of logging roads (Elder et al. 2002). Given proper funding and agency participation, these efforts may be sufficient to improve conditions for coho and other salmon and steelhead in the watershed.

Trinity River

Because the Trinity is the largest tributary of the Klamath River and enters only 43 mi upstream of the estuary, management and investigative efforts by the agencies have regarded it as if it were a separate river system. The creation in 1963 of the Lewiston and Trinity dams combined with the transbasin diversion of a significant proportion of the annual flow further enforces this impression of separation. Even so, the Trinity River flows influence water temperature and quality in the lower Klamath River and its estuary.

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The Klamath River below Iron Gate Dam and the Trinity River have the same fish fauna, including the runs of salmon, which belong to the same ESUs (Moyle 2002). Chinook salmon, for example, have two ESUs: the Upper Klamath and Trinity ESU and the Southern Oregon and California ESU, the latter of which includes salmon in the lower Klamath and Trinity rivers. Both genetic evidence and marked hatchery fish demonstrate that salmon and steelhead from the two systems continuously mix. In addition, both systems have large hatcheries that produce coho salmon, Chinook salmon, and steelhead. Immigrating spawning adults and emigrating smolts from the Trinity River rely on lower Klamath River water temperature and quality to support their success in terms of egg quality, osmoregulatory ability, and survival. Thus, efforts to conserve coho salmon and other declining fishes must take both systems into account.

Data on the numbers of salmon and steelhead returning each year to the Trinity River and its tributaries are fragmentary and incomplete. There is general agreement, however, that populations of the most sensitive salmonids (coho, spring-run Chinook, and summer steelhead) have declined considerably (perhaps 90% or more) to a few hundred individuals of wild origin (Moyle et al. 1995, Moyle 2002, CDFG 2002). Populations of winter steelhead and fall-run Chinook also are much lower than they historically were, but there are few estimates before 1977. Between 1977 and 1999, fall-run Chinook salmon escapement was estimated to range from about 7,000 to 125,000 fish; fewer than 25,000 spawners were present in 12 of 23 years (CDFG 1999). From 1992 through 1996, only about 1,900 adult steelhead were recorded in the river above the confluence with the North Fork River each year; this is only 5% of goals set in 1983, which were based on estimates of historical abundances (USFWS 1999). The Trinity River Hatchery releases large numbers of juvenile coho, steelhead, and fall-run Chinook each year, but its role in maintaining the present runs is not well understood. Although the hatchery has been in operation since 1964, it has failed to prevent the continued decline of salmon and steelhead populations. In years when the numbers of returning Chinook salmon are low, percentages of hatchery Chinook in the run can be as much as 40–50%.

Causes of the decline in coho and other anadromous fishes are similar to those elsewhere in the Klamath basin (USFWS 1999). Some of the most important probable causes of decline specific to the Trinity River include construction of dams and associated regulation, enhancement of erosion associated with logging and grazing practices, placer mining, and hatchery operations. Construction of Lewiston and Trinity dams in the main stem in 1963 blocked access to over 109 mi of salmonid spawning habitat (cold water, good gravels), including 59 mi of spawning habitat for Chinook salmon. The dams and associated water diversion also reduced flows downstream, blocked recruitment of gravel to areas downstream of the dam, and

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reduced rates of channel-forming geomorphic processes. Extensive poorly managed logging and road building on steep slopes with highly unstable soils, followed by large fires, have resulted in a high frequency of landslides and erosion that cause high sediment loads in the river and its tributaries. Massive erosion triggered by the floods of 1964 in particular resulted in large-scale destruction of spawning and rearing habitat. In addition, extensive placer mining for gold in the 19th century, and to some extent into the 20th century, resulted in loss of spawning and rearing habitat that still persists in many places. Finally, the Trinity River Hatchery has a major effect on wild populations of coho salmon, Chinook salmon, and steelhead, given that marked hatchery fish are frequently observed spawning in the wild. It is possible that hatchery production is suppressing populations of wild fish (e.g., Kostow et al. 2003), especially of coho salmon, but this has not been studied in the Trinity basin.

The South Fork Trinity River is one of the largest tributaries within the Klamath basin. Although poorly documented, historical salmon and steelhead runs within the South Fork were very large, and included coho. Poor logging and grazing practices on unstable soils in the South Fork Trinity coupled with highly destructive floods in 1964, destroyed most spawning and rearing habitat within the South Fork. Although habitat conditions appear to be improving, this tributary adds little to the overall salmon and steelhead productivity of the basin.

Recognition that runs of anadromous fish in the Trinity River are declining and in need of recovery has led to many restoration projects throughout the basin. Friends of the Trinity River, for example, estimate that nearly $100 million was spent on restoration projects in the basin from 1983 through 2000 (FOTR 2003). The 1999 EIS/EIR on dam operations indicated that reduced flows below Lewiston Dam, especially in spring, had significantly altered salmonid habitat in the Trinity River. As a result, the Secretary of the Interior in December 2000 issued a Record of Decision (ROD) recognizing that long-term sustainability of the Trinity River's fishery resources requires rehabilitation of the river. The ROD called for specific annual flows designed to vary with water-year type and patterned to mimic natural variability in annual flows. The ROD also specified physical channel rehabilitation, sediment management, and watershed restoration efforts throughout the basin (USFWS 1999, 2000). Additionally, the ROD called for an Adaptive Environmental Assessment and Management (AEAM) program, guided by the Trinity Management Council, to use sound scientific principles in guiding the course for recovery in the Trinity River basin. Because of lawsuits by Central Valley water users challenging the EIS/EIR, however, the new flow regime has not yet been fully implemented.

Poor land-use practices and water diversions have reduced the capacity of the Trinity River to support coho salmon and other anadromous fishes.

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There are no quick fixes for problems that are so severe and pervasive. Some of the measures that could be taken to improve the situation for salmonids both in the Trinity and the lower Klamath River already have been identified in the ROD, and in sediment TMDLs for the main stem and the South Fork (EPA 1998, 2001). The proposed flow schedule for the main-stem Trinity attempts to manage releases in a flexible manner that benefits aspects of the life histories of multiple species while responding to interannual variability in runoff conditions. Coho may benefit less than other species from main-stem flow alterations, however, due to their affinity with smaller tributaries.

Only large-scale restoration projects can reverse the adverse effects of logging, grazing, mining, and fires in the Trinity basin. Effective actions include removal of roads; elimination of logging, grazing, and off-road vehicle use from sensitive areas; planting and protection of trees to reduce erosion and restore riparian zones; and use of any other means to reduce erosion rates. Channel restoration and rehabilitation projects need to focus on restoring key geomorphic attributes of alluvial channels. These actions are called for by the ROD and are to be guided by the Trinity Management Council. Given that 80% of the lands within the Trinity basin are federally managed, large gains could be realized. It is unclear, however, whether these efforts will be restricted only to the areas immediately downstream of Lewiston Dam or, more appropriately, will be applied throughout the entire watershed, including the South Fork. A watershed approach is likely in the long run to be more successful than localized restoration. For coho salmon, physical restoration and protection of cold-water sources in tributaries that were historically important for spawning and rearing are of key importance.

Estimates of numbers of spawners of coho and other salmonids are needed as an index of the effectiveness of restoration efforts. The concept of numerical restoration goals, as set in 1983 and adopted by the 1999 EIR, is valid, but should be reviewed using information from such sources as the Indian fishery and extent of original habitat. The restoration goals must apply to fish spawning in tributaries as well as in the main stem. Goals should include minimum numbers (e.g., following years of poor ocean conditions) as well as numbers for years of average conditions.

The many small restoration projects in the basin should be continued, but should be viewed as experiments in adaptive management that ultimately will demonstrate the most effective treatments for Trinity River problems. Coordination of existing projects with those outlined in the ROD should be expanded.

It is vital that management of the Trinity River, including releases from Lewiston Dam, be viewed in the context of the entire Klamath watershed. The two systems are inextricably linked and are dependent upon each other

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for long-term success. Efforts presently are under way to use enhanced flow releases from the Trinity to reduce the likelihood of fish kills in the lower Klamath. This represents an important step forward in cooperative management for the sake of the entire basin, rather than a single component.

Small Main-Stem Tributaries

About 50 permanent streams, many of which are quite small, flow into the main-stem Klamath between Iron Gate Dam and the mouth of the Klamath. The streams formerly supported substantial runs of steelhead, coho, and other anadromous fishes (Kier Associates 1998). The watersheds of most of the tributaries have been extensively logged, and many roads have been constructed in them. Irrigation diversions in the largest of the tributaries have reduced their summer flows. The status and trends of fish populations in individual tributaries for the most part are not well known, although Blue Creek and other nearby streams are being monitored by the Yurok Tribe (e.g., Gale et al. 1998, Hayden and Gale 1999). Most of these tributaries probably support far fewer adult and juvenile anadromous fish than they once did, because of changes to habitat caused by logging, mining, agriculture, and road construction, and as a result of water diversions. Restoration of habitat, low temperatures, and flows in these small streams would be of major benefit to tributary-spawning species—especially coho salmon, steelhead, and cutthroat trout—and potentially could improve rearing conditions for juvenile salmonids in the Klamath main stem by cooling the pools at the mouths of small tributaries. The emphasis on these restoration efforts should be on those tributaries that have existing or potentially significant sources of cold water.

THE MAIN-STEM KLAMATH RIVER

Modeling of Habitat Availability in Relation to Flow

The National Marine Fisheries Service (NMFS) has sponsored habitat availability monitoring in the Klamath main stem in support of the preparation of its biological opinions (NMFS 2001, 2002). The modeling work was reported by Hardy and Addley (2001) in a document commonly referred to as the Hardy Phase II draft report. The NRC Committee was encouraged to consider the final version of this report, but was cautioned against excessive reliance on the draft report on grounds that the final report would contain more thorough model calibration and possibly other changes that might alter the results.

The NRC committee read and discussed the draft Hardy Phase II report. The committee saw the modeling approach as flawed by heavy reli-

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ance on analogies between habitat requirements for Chinook salmon and habitat requirements for coho salmon. Habitat requirements for Chinook salmon are better known, but the behavior and environmental requirements of Chinook salmon differ substantially from those of coho salmon (Chapter 7). To the extent that this approach is carried forward into the final report, the NRC committee's skepticism about the validity of the analogy would also be carried forward. In addition, the NRC committee, as explained elsewhere in this chapter, concludes that rearing of coho in the Klamath main stem is much less important than rearing of coho in tributaries, which are the preferred rearing habitat of coho. Thus, the importance that can be attached to regulation of flows in the main stem is probably less, in the viewpoint of the committee, for coho than it would be for Chinook, for example. Because the Hardy Phase II draft report does not deal with tributaries, the analysis in the draft Hardy Phase II diverged from the committee's analysis of the critical requirements for coho.

The committee recognizes that main-stem flow may directly affect the coho population at the time of downstream migration of smolts. While it is unclear whether additional water would favor the success of this migration, it is also clear, even in the absence of modeling, that NMFS can argue, given the absence of data to the contrary, that there is some probability of benefit for the smolts to be derived from minimum flows at the time of smolt migration, as expressed in the NMFS biological opinion of 2002. Adaptive management principles could be applied to this issue.

Management of Flow at Iron Gate Dam

In its biological opinions of 2001 and 2002, NMFS (2001, 2002) called for increases in minimum flows from Upper Klamath Lake via Iron Gate Dam for the benefit of coho salmon. NMFS reasoned that increased flows would increase rearing habitat for juvenile coho salmon, thus increasing their growth and survival in the river. For bioenergetic and ecological reasons (Chapter 7), it is unlikely that increased summer flows would benefit juvenile coho salmon. Additional water would likely be too warm for them (Chapter 4), and their principal habitat affinities during rearing are with the tributaries rather than the main stem. Additional flows would probably benefit Chinook salmon, steelhead, Pacific lamprey, and other more thermally tolerant fishes in the river by providing them with additional rearing habitat.

There is limited flexibility for managing the temperature of releases from Iron Gate Dam. Some cool water flows into Iron Gate Reservoir from springs and tributaries, but it is of little value for cooling the river in summer because of the large volume of the reservoir relative to these accretions. Because the deep waters of Iron Gate Reservoir store cool (hypolim-

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netic) water throughout the summer, however, it would seem that the construction of a deep withdrawal, coupled with selective aeration of the hypolimnion during the summer, could make available a pool of water for cooling the Klamath main stem below Iron Gate Dam. Unfortunately, the cool summer water has a volume of only about 15,000–18,000 acre ft (M. Deas, Watercourse Engineering, Inc., personal communication, July 16, 2003), which is sufficient to cool the reservoir release for only seven to ten days. Use of the water for cooling would not provide sustained benefits for the fish, and also would remove the source of cool water for the Iron Gate Hatchery, which relies on the deep water of Iron Gate Reservoir for hatchery operations. Furthermore, information from thermal modeling shows that introduction of cool water would provide benefits only for a relatively short distance downstream of the dam, given that summer thermal loading of the main-stem Klamath is high and that accretion of flow from tributaries consists primarily of warm water in summer.

Higher summer flows from Iron Gate Dam appear to increase minimum temperatures by reducing the effect of nocturnal cooling (Chapter 4). Higher flows also may raise the temperatures of the few cold-water refuges available in the main stem, the pools into which cool tributaries flow. Juvenile salmonids seek these pools during the day but disperse at night as the water cools (M. Deas, Watercourse Engineering, Inc., personal communication, November 25, 2002; unpublished data, USFWS). Even small disturbances to these pools (for example, by anglers) cause the fish to move into unfavorably warm water (M. Deas, Watercourse Engineering, Inc., personal communication, November 25, 2002), potentially harming or killing them. A natural-flow paradigm now commonly referenced in fisheries management is based on the premise that ecosystem functions and processes and the aquatic communities of rivers are affected by deviations from natural flows, including specific seasonal patterns and specific interannual ranges of variability by season (Poff et al. 1997). In the Klamath River, for example, the native fishes evolved with an annual sequence of winter pulse flows (principally from tributaries), high spring flows (from tributaries and the upper basin), and low flows in late summer and fall (principally from the upper basin). Base flows varied with climatic conditions. Some years provided strong winter and spring flooding that connected the channel with the floodplain, redistributed sediment, cleaned gravel, and re-formed the habitat features of the channel; other years had lower flows with much smaller effects. The timing of the flows and the ambient warming of the main-stem Klamath occurred in synchrony with tributary conditions; salmon smolts emigrating from a tributary did not leave a cool, springflow condition to enter a main stem experiencing a warm, summer base-flow condition. Thus, managing stream flows in ways that reflect timing and duration of the unregulated hydrograph is a holistic approach that recog-

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nizes climatological reality but can still be consistent with extensive human use of water resources. Such an approach would not demand high base flows in years of drought but could capitalize on years of high flow to maintain and restore habitat. It is also worth noting that historically the upper Klamath basin supplied only a portion of the flows of the lower Klamath River. Thus, increasing flows from the Scott and Shasta rivers would not only have thermal benefits to the main stem but mimic natural sources of flow more closely. Temperature in the lower basin will likely be increasingly important as global climate change occurs (Parson et al. 2001).

THE LOWERMOST KLAMATH AND OCEAN CONDITIONS

The lowermost Klamath is important to coho as an entry and exit point for the main stem. In addition, any substantial change in the hydrograph at the mouth of the Klamath could be expected to influence conditions in the estuary. While it may be attractive to use Trinity flows to influence conditions in the lower Klamath River, it must not occur at the expense of Trinity River restoration goals. Within the ROD for the Trinity River EIS/EIR, watershed restoration and monitoring that benefits fishery resources below the confluence of the Trinity and the Klamath rivers may be considered for action by the Trinity Management Council.

As explained in Chapter 4, total annual flow in the lower Klamath and its estuary has been altered only to a small degree by water development in the upper basin, even though water development has had drastic effects on hydrographs in a number of headwater areas. Thus, changes in total flow are not sufficiently large to suggest significant biological effects on the estuary strictly related to amount of flow. Furthermore, fall flows, even in years of average or above average moisture, tend to be higher than they were historically at the mouth of the Klamath (USFWS/HVT 1999, Hardy and Addley 2001), which would indicate that fall migrations probably have not been impaired by flow depletion per se. Warming of the water and poor water quality have greater potential significance, particularly near the mouth of the Klamath (see the section in Chapter 7 on fish mortality in 2002).

Estuary and ocean conditions undoubtedly induce variation from year to year in the strength of coho migrations. In part these variations are natural (i.e., they may be related to synoptic changes such as those associated with Pacific decadal oscillation or with shorter-term climate variability affecting ocean conditions). In addition, as mentioned in Chapter 4, the estuary and river mouth have undergone chemical changes because of anthropogenic influences upstream. The extent to which these factors are affecting coho populations is unknown at present, however. While favorable ocean conditions may magnify the strengths of certain year classes, any such favorable effects should not be used as a reason for reducing emphasis

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on improvement of watershed conditions for coho, given that especially good ocean conditions inevitably alternate with poor ocean conditions (NRC 1996).

REMOVAL OF DAMS

Dams often have major adverse effects on native fishes, especially anadromous fishes (Moyle 2002). There is growing national and international recognition that removal of some dams may provide substantial benefits to fish and downstream ecosystems by increasing flows, improving the flow regime, and providing access to upstream habitat (Heinz Center 2002, Hart and Poff 2002). Dams that have been removed so far in the United States primarily have been small and have had low or even negative economic value, although some larger dams have been proposed for removal on grounds that the benefits of removal outweigh the value of the dams and the cost of removal.

All dams (including both large public or corporate dams and small private dams) and diversions in the lower Klamath basin need to be systematically evaluated for their effects on anadromous fishes; those with strong adverse effects should be investigated further for modification or removal. Specifically, Iron Gate Dam should be evaluated for removal in conjunction with recapture of flows in Jenny Creek that are now diverted out of the Klamath basin to the Rogue River. Iron Gate Dam was built in 1962 to reregulate flows from Copco Dam. Copco Dam was built in 1917 to generate power, mostly at times of peak demand. Water released from the dam on demand caused major daily fluctuations in downstream flows that were harmful to the fish and other ecosystem components (Snyder 1931). Iron Gate Dam was intended to allow more uniformity in the release of water. The reservoir behind the dam flooded about 6 mi of the Klamath River. The flooded main-stem reach and its tributaries apparently were excellent spawning habitat for Chinook, coho, and steelhead (Snyder 1931), probably because of cool water in the tributaries. To mitigate this loss, the Iron Gate Hatchery, which uses water from the reservoir, was built to provide a source of young salmon. The hatchery releases several million juvenile Chinook, coho, and steelhead into the river each year (only about 70,000 per year are coho salmon; see Chapter 7). Iron Gate Reservoir supports a recreational fishery mainly for nonnative yellow perch and stocked rainbow trout.

There has been no systematic evaluation of the benefits and costs associated with the removal of Iron Gate Dam, but removal of the dam would recapture about 6 mi of lost habitat in the main stem of the dam and substantial tributary habitat; the 6-mi reach could also have lower summer water temperatures than most of the main stem. Removal of Iron Gate Dam

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would require operation of Copco Dam in a more uniform manner, which would result in loss of power revenues from Copco Dam. An alternative water supply also would be needed for the Iron Gate Hatchery. Opportunities for removal of Iron Gate Dam could be considered in the near future under the Federal Energy Regulatory Commission (FERC) relicensing process. The current license for operation expires in 2006; a draft application is due in 2003 (FERC Relicensing Number 2082).

CHANGES IN OPERATION OF HATCHERIES

The reason for building the hatcheries on the Trinity River and at Iron Gate Dam was to ensure that fisheries could be sustained at levels at least as high as they were before the construction of the dams. Despite the operation of the hatcheries, commercial fisheries for Klamath basin fishes have largely been shut down, and sport fisheries have declined; the principal remaining fishery is the tribal subsistence fishery for salmon and sturgeon. Overall, anadromous fish in the basin now reach only a small fraction of their historical abundance. Abundance has declined despite the release of millions of juvenile Chinook, coho, and steelhead into the rivers each year by the hatcheries (Chapter 7). There is growing evidence from numerous river basins that large-scale releases of hatchery fish have an adverse effect on remaining populations of wild fish and do not contribute as much to fisheries as generally supposed (e.g., Hilborn and Winton 1993, Knudsen et al. 2000, Levin et al. 2001, Moyle 2002). Adverse effects can occur even when hatchery coho are stocked in streams ostensibly to help rebuild wild populations (Nickelson et al. 1986).

The effect of the hatchery fish on populations of wild salmonids in the Klamath basin is not well understood, but it probably is negative. For example, the release of millions of juvenile Chinook salmon every June floods the river with fish that are larger than the wild fish. The hatchery fish are likely to displace or stress wild Chinook and coho salmon (Rhodes and Quinn 1998). If food and space are not limiting factors in the river (that is, if the environment is not saturated with fish), hatchery fish would not make much difference in the growth and survival of wild fish. But this is probably not the case, especially as the water warms and fish seek the cool pools at the mouths of tributary streams. Furthermore, not all hatchery fish emigrate as assumed when stocked. Some of the stocked fish may remain in the river, potentially until the following spring, through the process of residualization. Residualization occurs when the smoltification process stops and a juvenile fish reverts to the parr stage (Viola and Schuck 1995). The smoltification process can stop when fish are exposed to temperatures beyond the physiological tolerance for smoltification. In some instances, large fractions of fish remain and compete with wild fish for limited habitat (Viola and

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Schuck 1995). Residualization has not been studied in the Klamath basin, but its potential for harm to wild fish indicates that it should be studied.

The Klamath and Trinity basins provide an unusual opportunity for large-scale tests of hypotheses relating the effect of hatchery operations to the welfare of wild salmon and steelhead populations. The two basins can be regarded as a paired system in many respects. Because both have production hatcheries for coho, Chinook, and steelhead at the top of the accessible reaches for the species, comparative manipulations of hatchery practices are possible through an adaptive-management framework. For example, the Iron Gate Hatchery could be shut down for 6–8 yr (two Chinook and coho life cycles) while the Trinity River Hatchery remains operational (with the requirement that all fish be marked when released). Such a large-scale experiment would be informative if accompanied by intensive monitoring of juvenile and adult populations. An ecological risk analysis of the costs and benefits of hatchery programs should be conducted (Pearsons and Hopley 1999), especially in relation to coho salmon. If hatchery production results in a net loss of wild coho salmon, hatchery operation should be modified or even terminated.

LAND-MANAGEMENT PRACTICES

Throughout the distribution of coho salmon in the Klamath basin, the effects of land-use practices on the welfare of coho must be closely examined and, where damage to salmon habitat has occurred, restoration must be undertaken. Undesirable practices from the viewpoint of the welfare of coho include augmentation of suspended load through any agricultural practices that enhance erosion, forestry that does not incorporate best management practices, and mining that does not involve strict controls on sediment mobilization or that occurs directly in a stream channel. Coho would almost certainly benefit from regulation of grazing to an extent that involves exclusion of cattle from riparian zones and stream channels. The practice of flash grazing (exposure of riparian zones only for short intervals), while showing the appropriate intent, should be reviewed for actual effectiveness in terms of environmental objectives. Complete exclusion of livestock may be necessary in many instances, at least until woody vegetation is well established, and streambank conditions may never be consistent with the presence of large numbers of cattle, even on a short-term basis. Plans to restore stream channels, while laudable in intent, should be reviewed by federal and state agencies for effectiveness; government should assist landowners in finding the technically most desirable ways of achieving their restoration objectives. Review of channel and riparian conditions and their linkages to land-use practices should be included in a recovery plan for coho salmon (see Chapter 9).

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CREATION OF A FRAMEWORK FOR FISH MANAGEMENT

Management of fish in the lower Klamath basin must deal with both harvest and habitat. For most of the history of the basin, regulation of harvest was the primary management tool, and it was complex in that it involved tradeoffs between ocean and river fisheries and among commercial, sport, and tribal fisheries (Pierce 1991). Despite harvest management, salmon and steelhead populations declined. Today, commercial fisheries are banned, and the sport and tribal subsistence fisheries are restricted. Reduced fishing pressure on wild fish populations, especially of coho salmon, is clearly part of the solution to restoration of the populations, but management of harvest does little good if spawning and rearing habitat is inadequate. The Klamath basin requires habitat restoration.

Numerous state and federal laws provide a basis of aquatic-habitat management and drive the policy of government agencies (Gillilan and Brown 1997). Examples of such legislation relevant to the welfare of fish in the lower Klamath basin are as follows:

- The Fish and Wildlife Coordination Act of 1934, which requires federal agencies to consult with state and federal wildlife agencies before any water development or modification project is undertaken;
- The National Environmental Policy Act of 1970, which requires all federal agencies or holders of federal permits to file reports on the potential environmental effects of their actions;
- The Wild and Scenic Rivers Act of 1968, which identifies rivers with special public values and prohibits construction of new dams on designated rivers;
- The Clean Water Act of 1972, which promotes having the natural waterways of the United States be "drinkable, swimmable, and fishable." Under this act, many streams in the Klamath basin have been declared impaired in water quality;
- The Endangered Species Act of 1973 (ESA), which requires the designation of "critical habitat" for endangered and threatened species (see Chapter 9);
- The National Forest Management Act of 1976 (NFMA), which requires national forests to be managed to provide viable, widely distributed populations of all native vertebrates, including fish;
- The Sustainable Fisheries Act of 1996 (SFA), which requires fisheries agencies to identify "essential fish habitat" (EFH) for managed species;
- The Trinity River Stream Rectification Act (1980), which is intended to control erosion and deposition problems that arise from the Grass Valley Creek watershed;
- The Trinity River Basin Fish and Wildlife Management Act (1984), which directed the Secretary of the Interior to develop a management pro-

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gram to restore fish and wildlife populations in the Trinity basin to levels approximating those that existed immediately before the TRD construction;

- The Central Valley Project Improvement Act (1992), section 3406(b), which called for interim flows until the completion of the 12-yr Trinity River Flow Evaluation Study (USFWS/HVT 1999). The provision Congressionally requires the Secretary to implement recommendations resulting from the study.

Collectively, these laws provide a strong mandate to protect and improve fish habitat in the Klamath basin. Occasionally, they have resulted in major shifts in land use or policy to favor fish. For example, the NFMA resulted in the creation of a process that greatly altered management of public forest lands in the Pacific Northwest (Thomas et al. 1993, FEMAT 1993). A number of Klamath River tributaries have been designated "key watersheds" through this process, indicating their importance to anadromous fishes, and steps needed to enhance their ability to support fish have been outlined. For the most part, however, the laws do not require actions; rather, they provide for consultation and documentation of problems and can stimulate action. Their effect usually is to raise public awareness of problems and thus lead to protection or improvement of habitat through legal and social channels or through changes in agency policies.

An example of the potential of federal legislation to influence remedial action without actually requiring it is the EFH provision of the SFA. Like the ESA for listed species, the EFH provision directs fisheries management agencies to look beyond harvest management to habitat management. The provision recognizes that fisheries can be sustained only if habitat is available to support all life-history stages of the harvested species (Fletcher and O'Shea 2000). It does not mandate habitat management, but it does require the identification, by regional fisheries management councils, of the habitat for each species and of the factors adversely affecting the habitat. The results of the identification process are presented to other federal agencies, which are advised to consider them when they undertake activities that might affect the habitat. Implementation of the EFH is a large task, given that hundreds of species are harvested, but virtually no funding has been provided for it (Fletcher and O'Shea 2000). Even so, the EFH provision has been useful in calling public attention to the importance of habitat to the maintenance of fisheries.

The EFH designations made by the Pacific Fisheries Management Council are generic (PCFFA 2002). In this respect they resemble the critical-habitat designation made by NMFS for Southern Oregon/Northern California Coast coho salmon, which includes all existing and historical habitat (Fed. Reg. 64 (86): 24061–24062 [1999]). For the Klamath basin, there is

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only a general indication that EFH encompasses all anadromous salmonid habitat, present and historical, without regard to species, with a generic description of the habitat requirements of each life-history stage of each species. Despite the lack of enforcement provisions in the EFH requirement of the SFA, it would be worthwhile to designate species-specific EFH in the Klamath basin as a means of assisting decision-making in the many federal, state, and local agencies engaged in land and water management. Ideally, the EFH should be used in setting priorities for conservation and restoration of habitat.

POSSIBLE FUTURE EFFECTS OF CLIMATE CHANGE

Records relevant to the hydrologic cycle in the Klamath watershed are based on about 100 yr of rainfall and runoff records. Probabilistic analyses of the records are used in planning future water-resource management and in designing strategies for restoration of species at risk. Such use of the historical record is based on the assumption that the hydrologic cycle of the past is a general predictor of the hydrologic cycle of the future.

The rapid and substantial rise in atmospheric mixing ratios of carbon dioxide and other greenhouse gas in the industrial era could contribute to a measurable increase in global mean temperatures (IPCC 2001, NRC 2001). Global circulation models (GCMs) indicate that global mean temperatures will rise over the next century and that regional climates will be affected in variable ways (IPCC 2001, Strzepek and Yates 2003).

Regional climate change would probably affect the hydrologic cycle of the Klamath watershed (Snyder et al. 2002, Kim 2001, NAST 2001), but there appears to be no substantial effort on the part of government or private entities to plan for climate change. Planning, if it were to take place, faces two important hurdles. Climate change apparently is assumed to be a distant possibility, to be dealt with after more immediate issues are resolved. It is worthwhile to note, however, that regional climate change could occur over a period considerably shorter than the history of the Klamath Project. A second hurdle is that the current GCMs operate on a spatial scale that cannot resolve regional topographic features, which influence climate in most parts of the West (NAST 2001, Redmond 2003). Multiple efforts are under way to downscale the models so that they project regional climate change more accurately, but current GCMs are not suitable for planning on a watershed scale. Even so, several regional models have sufficient spatial and temporal resolution to allow realistic forecasts of the kinds of changes that are likely in a watershed (e.g., Snyder et al. 2002, Kim 2001, Lettenmaier et al. 1999, Lettenmaier and Hamlet 2003); these models are potentially useful to resource managers even though they might not accurately quantify the magnitude and timing of regional change.

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A detailed model of the Klamath basin region at 25 mi resolution has been developed by Snyder et al. (2002). Use of the model demonstrates three important kinds of changes in the hydrology of the Klamath watershed that could occur over the next century: (1) warming, especially at high elevation in spring (April, May); (2) higher total precipitation, especially in spring; and (3) an increase in the ratio of rainfall to snowfall and large decreases in spring snowpack. The changes modeled by Snyder et al. (2002) and others have strong implications for management of water resources and all aquatic species, but especially salmonids (NAST 2001, O'Neal 2002). For salmonids, the most important potential changes include altered timing of snowmelt, lower base flows, and additional warming of water in summer.

Large reductions in snowpack coupled with higher precipitation would increase winter runoff and decrease spring runoff. Land use and water management already have shifted peak runoff (Figure 4-2), and climate change could increase the shift. Decline in spring runoff would have important implications for spring migration of coho salmon and other salmonids. Base flows during summer and fall would most likely decline in response to climate change because of increased evapotranspiration associated with higher temperatures and the concentration of annual runoff in winter. Base flows, especially in tributaries, already are too low and would decline further.

Increases in water temperature, particularly during summer low-flow periods would probably harm coho salmon and anadromous fishes in general (Chapter 7). Climate change could make temperature an even more urgent issue than it is now for the future of salmonids in the Klamath basin.

The effects of climate change in the Klamath basin would probably vary spatially within the basin. For example, the Wood River and the Shasta River both have headwater and groundwater recharge areas that lie at sufficiently high elevation to be more resilient than most stream reaches in the event of temperature increases and associated changes in precipitation. Conservation of cool-water sources in these and similar tributaries is likely to be even more critical in the future than it is now.

Uncertainty in the magnitude and timing of climate change in the Klamath basin and the uncertainty about its timing have discouraged resource managers from developing comprehensive, specific strategies to cope with it. It is important that climate change be addressed in the framework of adaptive management (Chapter 10) through programs that anticipate changes that would accompany warming.

CONCLUSIONS

Conditions in tributary waters are of paramount importance for rearing of coho salmon, as is also the case for spring-run Chinook salmon and

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summer steelhead, which is in contrast to other stocks of anadromous salmonids, including fall-run Chinook. Tributary waters include both the four main tributaries and numerous small tributaries that enter these main tributaries or enter the Klamath main stem directly. Small tributaries offer exceptional potential for restoration of coho salmon.

Remedial actions intended to promote the welfare of coho salmon are not uniform in type and priority across all tributaries. The Shasta River, which probably has the single largest potential for restoration of coho salmon and anadromous fish in general, shows depression of salmonid stocks caused by extensive diversions and blockage of flows at small dams as well as Dwinnell Dam; diversion of spring flows for agriculture leading to warming of these waters during the critical summer months; loss of riparian vegetation; reduction of base flow through diversions and excessive pumping of groundwater; and possible episodes of low oxygen concentrations. The Shasta River also shows loss of substrate characteristics consistent with successful spawning and has significant channel degradation associated with land-management practices. Practices leading to the degraded state of the Shasta include timber management, grazing, agriculture, and water management.

The Scott River also has high potential for restoration of coho salmon. Groundwater flows from springs are less pronounced than for the Shasta River, but an undesirable degree of cool water diversion occurs through groundwater pumping, as well as from surface diversions. Other problems closely parallel those of the Shasta, but physical degradation of the mainstem channel and lower tributaries may be even more pronounced than in the Shasta.

The Salmon River drains mainly public lands, but nevertheless shows historical reduction of coho and other salmon populations. Degradation of the Salmon River is primarily physical, and is associated with inadequate forest management leading to catastrophic fires and logging practices, especially road construction and maintenance, that lead to high levels of erosion. In addition, there are some flow barriers on the Salmon River.

The Trinity River, which is much larger than the other three tributaries, shows the full complex of problems found in the Scott and Shasta rivers, but is especially affected by loss of habitat caused by installation of dams and by physical damage to channels caused by improper land-management practices. Implementation of actions called for in the Record of Decision will promote restoration and create a framework for adaptive management through a large, comprehensive effort, but this effort must be coordinated with management of the overall Klamath basin.

Small tributaries to the four large tributaries and to the Klamath main stem show a wide array of problems and will require treatment by category or individually for effective restoration. Emphasis on cold

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water bearing tributaries is likely to yield the most benefit for salmonid restoration.

While the Klamath main stem is less important for rearing of coho than to some other anadromous taxa on the Klamath, a number of actions on the main stem might promote the welfare of coho. Additional water during the smolt migration could enhance downstream movement, and could be tested in this respect through adaptive management procedures. In addition, removal of Iron Gate Dam and Dwinnell Dam could open new habitat, especially by making available tributaries that are now completely blocked to coho.

Application of computer modeling to habitat availability on the main stem is not likely to be relevant to coho, but would be relevant to other taxa, such as fall-run Chinook, that use the main stem extensively for rearing. In general, coho restoration requires increased attention to lands and waters beyond the Klamath Project.

Hatchery operations may have a suppressive effect on coho salmon through predation and competition; it should not be assumed that hatchery operations are beneficial to salmonids in general or to coho in particular. Hatchery operations could be viewed as adjustable rather than static and thus explored through adaptive management principles.

Because land-management practices are broadly responsible for degradation of habitat that is critical to the coho, improvement of land-management practices and restoration activities in tributary waters are the key to restoration of coho populations. Restoration will require extensive work with private parties and with agencies that are not now strongly involved in ESA actions. Restoration can succeed only through substantial technical assistance in support of the considerable private efforts that are now under way. Constant evaluation of the success of specific strategies will be important to their ultimate success.

A framework for overall management of fisheries exists already through interlocking federal statutes that require conservation and protection of habitat and fishes. The Sustainable Fisheries Act of 1996 in particular seems well suited as a model for management of environmental remediation in the Klamath basin.

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9

Regulatory Context: The Endangered Species Act

Although the federal Endangered Species Act (ESA) is not alone in providing a legal framework for resolving issues related to endangered and threatened fishes in the Klamath River basin, it is the dominant legal feature now affecting federal water management in the basin. As the nation's principal federal law to protect species, the ESA's express purpose is "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved" (16 U.S.C. 1531(b) [2002]). Further explanation is provided in the statute's definition of "conserve," which is "to use . . . all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary" (16 U.S.C. 1532 [2002]). It is also a policy of the ESA, however, that "Federal agencies shall cooperate with State and Local agencies to resolve water resource issues in concert with the conservation of endangered species" (16 U.S.C. 1531(c) [2002]). The difficulty of satisfying those two central objectives is well illustrated by the Klamath River basin, as attested by the U.S. Bureau of Reclamation's (USBR) Klamath Project and other public and private water-management practices. Accordingly, this chapter provides an overview of the ESA and discusses the structure and implementation of its provisions that are relevant to the Klamath River basin generally and the Klamath Project in particular. The chapter provides conclusions as to how the ESA could be implemented more productively for the benefit of species and ecosystems in the Klamath River basin.

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OVERVIEW OF THE ESA IN THE KLAMATH CONTEXT

In 1988, pursuant to its authority under Section 4 of the ESA, the U.S. Fish and Wildlife Service (USFWS) listed the shortnose sucker and Lost River sucker as endangered species (53 Fed. Reg. 27130, July 18, 1988). Almost a decade after the sucker listings, in 1997, the National Marine Fisheries Service (NMFS) listed the Southern Oregon/Northern California Coast (SONCC) coho salmon, an evolutionarily significant unit (ESU) of coho salmon found in the Klamath River basin, as a threatened species (62 Fed. Reg. 24588, May 6, 1997). These listings triggered a suite of ESA regulatory responsibilities that have since had substantial influence in Klamath River basin water issues:

- Section 4 of the ESA requires the listing agency to designate "critical habitat" for endangered and threatened species unless exceptions, which are narrow, apply.
- Section 4(f) of the ESA requires the listing agency to develop and implement a "recovery plan" for endangered and threatened species.
- Section 7(a)(1) of the ESA requires all federal agencies, through consultation with the listing agency, to use their authorities to carry out programs for the "conservation" of endangered and threatened species.
- Section 7(a)(2) of the ESA requires all federal agencies, through consultation with the listing agency, to ensure that actions they carry out, fund, or authorize do not "jeopardize" the continued existence of endangered and threatened species and do not result in "adverse modification" of their critical habitat.
- Section 9(a)(1) of the ESA prohibits all persons subject to U.S. jurisdiction (including federal, state, tribal, and local governments) from "taking" endangered wildlife species—and Section 4(d) allows the listing agency to extend the same level of protection to threatened wildlife species—unless authorized by the listing agency pursuant to appropriate "incidental take authorization" provisions of the ESA.

For reasons described more fully below, some of these responsibilities have not been implemented to their full potential in the Klamath River basin. USFWS and NMFS have used ESA's authority primarily through Section 7(a)(2), which prohibits federal agencies from causing "jeopardy" to listed species. Thus, the listing agencies have focused primarily on USBR's operation of the Klamath Project.

Before proceeding to a section-by-section comparison of ESA implementation in the Klamath River basin, it is important to recognize the pervasive influence of three general principles of ESA law and policy: the "best available evidence" standard, the burden of proof applicable to the relevant decision-makers, and the species-specific orientation of the ESA.

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As a package, these principles substantially affect the agencies' implementation of ESA duties and authorities under specific ESA provisions and their approach to the larger challenge of ecosystem-level management of resources in the Klamath River basin. Emphasizing the general principles also helps to clarify the distinctions between the framework within which the agencies operate under the ESA and the framework within which the NRC committee evaluated the relevant agency decisions as defined by its charge.

The "Best Available Evidence" Standard

USFWS and NMFS have ESA decision-making duties, such as listing of species under Section 4 and issuance of biological opinions under Section 7, for which they must use the "best scientific and commercial data available" as prescribed in 16 USC 1533(b) [2002] and 50 CFR 424.11(b) [2002] (listing decisions) and 16 USC 1536(b) [2002] and 50 CFR 402.14(g)(8) [2002] (consultations). Section 7 thus requires that NMFS and USFWS consult the existing body of the "best scientific and commercial data available" to determine whether USBR's proposed operation of the Klamath Project is "likely to jeopardize the continued existence of any endangered species or threatened species."

Although the statute leaves the standard for "best evidence" undefined, the courts have interpreted it to mean several things:

- The agencies may not manipulate their decisions by unreasonably relying on some sources to the exclusion of others.
- The agencies may not disregard scientifically superior evidence.
- Relatively minor flaws in scientific data do not render the data unreliable.
- The agencies must use the best data *available*, not the best data *possible*.
- The agencies must rely on even inconclusive or uncertain information if that is the best available at the time of the decision.
- The agencies cannot insist on conclusive data to make a decision.
- The agencies are not required to conduct independent research to improve the pool of available data.

A summary of the existing body of case law appears in Southwest Center for Biological Diversity v. Norton, 2002 WL 1733618 (D.D.C. 2002).

Similarly, in 1994, USFWS and NMFS issued a joint policy providing guidelines for ESA decisions (59 Fed. Reg. 34271 [1994]). The policy shows how the "best evidence" standard would apply in the context of the jeopardy consultation; it directs the agencies to follow six guidelines:

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- Require that all biologists evaluate all scientific and other information that will be used to make any consultation decision.
- Gather and impartially evaluate biological, ecological, and other information that disputes official positions taken by USFWS or NMFS.
- Ensure that biologists document their evaluation of information that supports or does not support a position being proposed by the agency.
- Use primary and original sources of information, when possible, as the basis of consultation decisions or recommendations.
- Adhere to schedules established by the ESA.
- Conduct management-level review of documents developed by the agency to verify and ensure the quality of the science used to established official positions.

Appropriately, therefore, the charge of the NRC committee included a determination as to "whether the biological opinions are consistent with the *available* scientific information" (emphasis added).

The Decision-Making Burden of Proof

The NRC committee's charge to assess "whether the [agencies'] biological opinions are consistent with the available scientific information" requires the committee to adopt the burden of proof that would apply in the scientific community rather than the legal burden of proof that applies under the ESA. Scientific burden of proof may differ from legal burden of proof; this issue pervades the ESA, where science and law intersect. Keeping scientific and legal burdens of proof separate is important for proper execution of the committee's charge. The committee believes that in its interim report and in this final report it has applied an accepted scientific framework for its assessment.

Some parties to the Klamath River basin ESA actions have advocated use of a "precautionary principle," according to which a special burden of proof lies with users of resources (e.g., G. H. Spain, Pacific Coast Federation of Fisherman's Associations, personal communication, August 26, 2002). The precautionary principle, however, is a decision-making policy instrument, not a scientific standard of proof or a requirement of the ESA. Although many versions of the precautionary principle exist in the laws of many nations and in the text of many international treaties, the prototype is found in Principle 15 of the 1992 Rio Declaration of the United Nations Conference on Environment and Development (Rio Declaration on Environment and Development, UNCED, U.N. Doc. A/CONF.151/Rev. 1, 31 I.L.M. 874 [1992]):

> In order to protect the environment, the precautionary approach shall be widely applied by the States according to their capabilities. Where there

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> are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

In other words, ignorance should not justify the decision either to move forward with a proposed action that might threaten the environment or to not regulate an activity for purposes of protecting the environment.

Application of the precautionary principle in the ESA context is discussed in the National Research Council's report *Science and the Endangered Species Act* (NRC 1995), which outlines the benefits of applying such an approach to decisions about conservation of species under the ESA. As that discussion demonstrates, however, whether to apply the precautionary principle is a policy decision and as such is outside the present committee's scope of work, which pertains to "whether the biological opinions are consistent with the available scientific information."

Indeed, even when a policy decision is made to apply the precautionary principle, the question of whether the decision is consistent with the available scientific information is important. As discussed above, the ESA and the agencies' implementing regulations unequivocally require that NMFS and USFWS base their decisions, as given in their biological opinions, on the *best available* scientific evidence and that NMFS and USFWS use that evidence to decide whether Klamath Project operations are *likely* to jeopardize the listed species. These are the only explicit evidentiary standards and burdens of proof that the ESA and the agency regulations impose on the two agencies in the consultation process. In the decision-making context, relevant principles of administrative law and the ESA leave application of the precautionary principle to the discretion of USFWS and NMFS when they are confronted with substantial but inconclusive or conflicting data, especially as to whether a species deserves listing or whether a proposed action is likely to cause jeopardy (see *Conner v. Burford*, 848 F.2d 1441, 1454 9th Cir. [1988]). At some point, however, erring on the side of protection in decision-making ceases to be precautionary and becomes arbitrary. One indication that policy-based precaution has given way to bias or political forces is a major inconsistency of a presumed precautionary action with the available scientific information. Hence, the precautionary principle could not guide the NRC committee's scientific evaluation; rather, the committee evaluated the way in which NMFS and USFWS considered the best available scientific information and how they used this information to decide whether USBR's proposed operation of the Klamath Project is likely to jeopardize the continued existence of the endangered suckers and threatened coho salmon. In making this evaluation, the NRC committee recognized that scientists of federal agencies who are responsible for judging jeopardy to listed species inevitably face difficulties that derive from incom-

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plete information even under the best of circumstances, and certainly so in the case of the Klamath basin.

The Species-Specific Orientation of the ESA

The portion of the committee's charge requiring it to evaluate "whether the biological opinions are consistent with the available scientific information" implicates one of the inherent limiting features of the ESA: it is species-specific. The biological opinions under study, therefore, are opinions about listed species and not directly about the effects of the Klamath Project on resources in the Klamath River basin that have no known linkage to listed species. Notwithstanding its stated purpose of conserving the ecosystems on which listed species depend, the ESA is strikingly short on ecosystem-focused rationale. The ESA authorizes USFWS and NMFS to list species, to designate critical habitat for species, to prepare recovery plans for species, to use authorities for conservation of species, and to issue incidental-take authorizations for species. The ESA prohibits federal agencies from jeopardizing species, and it prohibits all others (including individuals and private organizations) from taking species. Indeed, the NRC committee's charge has been conditioned by the ESA's species-specific focus, with the ultimate objective of providing "an assessment of scientific considerations relevant to strategies for promoting the recovery of listed species in the Klamath River Basin" (Appendix A).

As shown in previous chapters of this report, the listed species do not define all there is to manage in the basin; their needs encompass only a portion of the Klamath basin's combined environmental resources. In fact, a species-specific focus and an ecosystem-level focus may lead to different management policies and decisions (NRC 1995, p. 111–121). Often, actions that restore ecosystem functions are beneficial to listed species, but not always. Conversely, what is good for the listed species is not necessarily good for other ecosystem attributes or, for that matter, equally beneficial for all the listed species themselves. The dichotomy between the listed species and ecosystems limits the extent to which USFWS and NMFS can use the ESA for ecosystem management (Ruhl 2000). The ESA's species-specific focus is in itself an inadequate basis of ecosystem-wide decision-making in the Klamath River basin.

SPECIES LISTING AND DESIGNATION OF CRITICAL HABITAT

None of the conservation measures of the ESA that bear on the Klamath River basin apply unless a species is listed as endangered or threatened according to procedures specified in Section 4 of the statute. A related

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decision, although not necessarily made at the time of listing (or, in some cases, at all), is whether the species has "critical habitat" that should receive special protection. Listing of species and critical-habitat designations thus are the events that trigger the ESA's recovery-planning efforts and regulatory programs. A review of the background of the Klamath River basin species listings and critical-habitat determinations shows the potential and realized scope of the recovery-planning efforts and regulatory programs that have followed.

Listing of Endangered and Threatened Species

Section 4 of the ESA governs listing of species as endangered or threatened. A species is endangered if it "is in danger of extinction throughout all or a significant portion of its range" and is threatened if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (16 U.S.C. 1532 [2002]). The agencies must consider five criteria in listing a species: the present or threatened destruction, modification, or curtailment of its habitat or range; its overuse for commercial, recreational, scientific, or educational purposes; disease or predation; the inadequacy of existing regulatory mechanisms; and other natural or anthropogenic factors affecting its continued existence (16 U.S.C. 1533(a)(1)(A)–(E) [2002]). As noted above, the agencies must evaluate these criteria for the species in question and make the listing determination "solely on the basis of the best scientific and commercial data available . . . after conducting a review of the status of the species." This limitation keeps USFWS or NMFS from considering economic factors in deciding whether to list a species.

USFWS listed the two sucker species as endangered in 1988, noting that "dams, draining of marshes, diversion of rivers and dredging of lakes have reduced the range and numbers of both species by more than 95 percent. . . . Both species are jeopardized by continued loss of habitat, hybridization with more common closely related species, competition and predation by exotic species, and insularization of remaining habitats" (53 Fed. Reg. 27130 [1988]). The agency explained some of the principal factors causing decline in amount of habitat, as given in Chapters 5 and 6.

NMFS, in listing the coho salmon as a threatened ESU in 1997, found that "threats to this ESU are numerous and varied. Several human caused factors, including habitat degradation, harvest, and artificial propagation, exacerbate the effects of natural environmental variability brought about by drought, floods, and poor ocean conditions" (62 Fed. Reg. 24588 [1997]). The agency also explained in more detail the major factors responsible for the decline of coho salmon in Oregon and California (Chapters 7 and 8).

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Designation of Critical Habitat

Section 4 of the ESA also requires USFWS and NMFS, subject to specified exceptions, to designate the critical habitat of a listed species. Critical habitat consists of "the areas within the geographical area occupied by the species, at the time it is listed . . . on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection" (16 U.S.C 1531 [2002]). Areas outside the occupied area can be included if they are essential to the conservation of the species. USFWS and NMFS, in making the critical-habitat determination, consider space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal; and habitats that are protected from disturbance or are representative of the historic geographic and ecological distributions of a species (50 C.F.R. 424.12(b)(1)–(5) [2002]). In weighing these factors, the agencies focus on "primary constituent elements," which are "roost sites, nesting grounds, spawning sites, feeding sites, seasonal wetland or dryland, water quality or quantity, host species or plant pollinator, geological formation, vegetation type, tide, and specific soil types." The agencies must consider the factors "on the basis of the best scientific and commercial data available" but must also take "into consideration the economic impact, and any other relevant impact, of specifying any particular area as critical habitat" (16 U.S.C. 1533(b)(2) [2002]). Areas that otherwise satisfy the criteria for critical habitat must be excluded from designation if the costs of designation outweigh the benefits of including the area, unless failure to designate such an area would result in the extinction of the species.

The agencies are required to designate critical habitat, to the greatest extent prudent and determinable, concurrently with the listing decision (16 U.S.C. 1533(a)(3) [2002]). The time period for a designation may be extended up to 1 yr if the agency finds either that publishing the listing rule has high priority for conservation of the species or that critical habitat is not determinable at the time of listing. In such a case the agency must designate critical habitat within the 1-yr extension period "to the maximum extent prudent" (16 U.S.C. 1533(b)(6)(C) [2002]). Accordingly, the agency can find that designating critical habit is "not prudent" and thus decline to do so.

Treatment of the "economic impacts" and the "not prudent" components of critical-habitat requirement by the agencies has been the subject of intense litigation in recent years; several judicial opinions have found the agencies' approaches flawed. For the analysis of economic impacts, the agencies have taken the position that the combined legal (and thus eco-

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nomic) effects of jeopardy consultations under Section 7(a)(2) and of the take prohibition under Section 9(a)(1), both of which apply when a species is listed and do not require designation of critical habitat to take effect, subsume any regulatory effects that critical-habitat designation might impose. Thus the incremental economic impact of designating critical habitat is, according to the agencies, essentially nil. Adopting this position as an assumption for purposes of analyzing economic impacts has allowed the agencies to truncate the process: although economic effects were never actually quantified, the agencies took the baseline effects imposed under the jeopardy consultation and the take prohibition as the starting point for economic analysis of the effects of critical-habitat designation. The agencies thus avoided having to describe the baseline effects and routinely found—with relatively little analytic exercise, given their operating assumptions—that the incremental effects of critical-habitat designation were zero. In 2001, however, a court ruled that the agencies' approach subverted congressional intent; the court required the agency in question to quantify both the baseline effects and any incremental effects (see *New Mexico Cattle Growers Association v. USFWS*, 248 F.3d 1277, 10th Cir. [2001]).

Similarly, on the "not prudent" question, the agencies had taken the position that because designation of critical habitat triggers only the prohibition against federal agencies' adversely modifying critical habitat, it adds relatively little protection, if any, to what is already available to listed species under the jeopardy consultation and prohibition against take. Designation of critical habitat, the agencies also argued, could be detrimental to species by identifying places where unscrupulous collectors might find the species. On balance, the agencies often found that detriments associated with designation of critical habitat outweighed benefits and that a designation of critical habitat was "not prudent." This set of assumptions also has been rejected by courts in recent years on the grounds that designation of critical habitat has important educational effects at least and that Congress did not intend it to be avoided through the blanket assumptions that the agencies have adopted (see *Sierra Club v. USFWS*, 245 F.3d 434, 5th Cir. [2001]). Notwithstanding the assumptions that have prevailed in the agencies' implementation of critical-habitat rules, USFWS has proposed critical habitat for the suckers, and NMFS has done the same for the coho salmon (Chapters 5–8).

In its 1988 rule listing the suckers, USFWS declined to designate critical habitat, because "little additional benefits of notification of the species presence would be achieved through critical habitat designation" (53 Fed. Reg. 27132 [1988]). Later, however, USFWS proposed critical habitat for the species (Chapter 6; 59 Fed. Reg. 61744, December 1, 1994), but it has not promulgated a final ruling on critical habitat for the suckers, probably because of general litigation over the manner in which USFWS has imple-

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mented decisions on critical habitat. It is not clear what effect some of the recent judicial opinions on critical habitat would have on the designation of critical habitat for the listed suckers, because the analysis of economic impacts has not been developed, contrary to some judicial requirements.

In its 1997 rule listing the salmon, NMFS found that "critical habitat is not determinable at this time" and that the species should be listed before the decision on critical habitat was finalized (62 Fed. Reg. 24608 [1997]). The agency did, however, designate critical habitat for the species in 1999 (64 Fed. Reg. 24049, May 5, 1999). It adopted a watershed-based approach to the designation (64 Fed. Reg. 24052 [1999]), explaining that

> a more inclusive, watershed-based description of critical habitat is appropriate because it (1) recognizes the species' use of diverse habitats and underscores the need to account for all of the habitat types supporting the species' freshwater and estuarine life stages, from small headwater streams to migration corridors and estuarine rearing areas; (2) takes into account the natural variability in habitat use that makes precise mapping problematic (e.g., some streams may have fish present only in years of plentiful rainfall); and (3) reinforces the important linkage between aquatic areas and adjacent riparian/upland areas. While unoccupied streams are excluded from critical habitat, NMFS reiterates the proposed rule language that "it is important to note that habitat quality in this current range is intrinsically related to the quality of upland areas and of inaccessible headwater or intermittent elements (e.g., large woody debris, gravel, water quality) crucial for coho in downstream reaches."

Significantly, NMFS included riparian zones in the designation because "streams and stream functioning are inextricably linked to adjacent riparian and upland (or upslope) areas" (64 Fed. Reg. 24053 [1999]). NMFS also explained (64 Fed. Reg. 24059 [1999]) that

> activities that may require special management considerations for freshwater and estuarine life stages of listed coho salmon include, but are not limited to (1) land management; (2) timber harvest; (3) point and nonpoint water pollution; (4) livestock grazing; (5) habitat restoration; (6) beaver removal; (7) irrigation water withdrawals and returns; (8) mining; (9) road construction; (10) dam operation and maintenance; (11) diking and streambank stabilization; and (12) dredge and fill activities.

It is not clear what effect some of the recent judicial opinions on critical habitat would have on the NMFS ruling for coho salmon, because the analysis of economic impacts has not been developed.

Recovery Planning

Section 4(f) of the ESA provides that, on listing a species, USFWS or NMFS "shall develop and implement plans (hereinafter in this subsection

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referred to as 'recovery plans') for the conservation and survival of endangered species and threatened species listed pursuant to this section, unless [the agency] finds that such a plan will not promote the conservation of the species" (16 U.S.C. 1533(f) [2002]). Recovery plans are to include a description of site-specific management actions that may be necessary for the conservation and survival of the species and objective, measurable criteria that, when met, would result in a determination that the species be removed from the list.

Despite the requirements of Section 4(f), recovery plans do not constitute mandatory directives to USFWS, NMFS, other federal agencies, or others. USFWS and NMFS portray them as guidelines and useful menus of recovery-oriented actions that they and other parties can take voluntarily. The courts have rejected efforts to instill more legal effect into the recovery-plan program (Cheever 2001).

NMFS has prepared no formal recovery plan for the coho salmon. In contrast, USFWS finalized a formal recovery plan for the endangered sucker species on March 17, 1993. As explained in Chapter 6, the NRC committee believes that the sucker recovery plan contains many constructive recommendations but may need revision in view of extensive research efforts since 1993.

REGULATORY CONSEQUENCES

Only when a species is listed do the regulatory programs of the ESA come into play. Two of them apply directly only to federal agencies: the so-called conservation duty under Section 7(a)(1), and the duty under Section 7(a)(2) to avoid jeopardizing species or adversely modifying critical habitat. Section 7(a)(2), however, can have substantial indirect effects on state, tribal, and local governments and private entities that receive federal funding or approvals or that benefit from federal actions. The third major regulatory program, the take prohibition of Section 9(a)(1), applies directly to all entities—federal, state, tribal, and local governments and all private entities.

Federal Agency Conservation Duty

Section 7(a)(1) of the ESA states that "all federal agencies shall, in consultation and with the assistance of [USFWS and NMFS], utilize their authorities in furtherance of the purposes of this chapter by carrying out programs for the conservation of endangered species and threatened species" (16 U.S.C. 1536(a)(1) [2002]). This duty, however, is poorly defined. No procedures are specified in the ESA, nor have USFWS and NMFS provided any in their regulations.

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The courts generally have construed the provision to require federal agencies to take affirmative action or to restrain from negative action to advance the purpose of conservation (Ruhl 1995). In addition, courts have confirmed that Section 7(a)(1) is a source of authority for an agency to take action in support of species conservation where no other provision of the ESA requires it, as long as the action is within the scope of and not in conflict with the agency's authority under its enabling statutes. As explained below, Sections 7(a)(2) and 9(a)(1) are prohibitions: Section 7(a)(2) prohibits federal agencies from jeopardizing species or adversely modifying critical habitat, whereas Section 9(a)(1) prohibits federal agencies from causing take (mortality or impairment). Failure of an agency to undertake actions that would promote conservation of species often would be consistent with these prohibitions. In contrast, Section 7(a)(1) is an affirmatively stated duty to promote conservation of species, and thus can serve as authority for taking actions that neither Section 7(a)(2) nor Section 9(a)(1) would require (see *Carson-Truckee Water Conservancy District v. Watt*, 549 F. Supp. 704, D. Nev. 1982, aff'd 741 F.2d 257, 9th Cir. [1984]). For example, USBR could restrict water deliveries to protect endangered fish, even though it is not required to do so under Section 7(a)(2) or 9(a)(1), because of Section 7(a)(1).

USFWS, NMFS, and other federal agencies carrying out their responsibilities in the Klamath River basin have not taken full advantage of their authority under Section 7(a)(1). For example, USBR explained in its 2002 biological assessment for the Klamath Project that Section 7(a)(1) does not expand the agency's authority beyond its enabling laws. On the basis of that principle, USBR made no additional effort to exercise its authority under Section 7(a)(1). As described above, however, Section 7(a)(1) essentially states that actions by agencies that are consistent with enabling laws and that are intended to provide for the conservation of species cannot be challenged just because they are not required by Sections 7(a)(2) or 9(a)(1). Hence, the provision creates an opportunity for conservation-promoting actions under the ESA beyond the mandates of Sections 7(a)(2) and 9(a)(1). Many of the actions outlined in this report for conservation of the listed suckers and coho salmon would be supported by Section 7(a)(1), even though they might not be required by Sections 7(a)(2) or 9(a)(1). In other words, USFWS, NMFS, and all other federal agencies carrying out actions in the Klamath River basin have substantial discretion to act on behalf of the listed species even where they do not have the duty to do so.

Section 7(a)(1) clearly does require that all relevant federal agencies at the very least consult with USFWS and NMFS about the exercise of discretionary authority (see *Sierra Club v. Glickman*, 156 F.3d 606, 5th Cir. [1998]). Unlike consultation under Section 7(a)(2), which has been the context for most ESA implementation measures in the Klamath River basin,

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consultation under Section 7(a)(1) is not governed by formal procedures. Working together, the agencies could establish and implement a comprehensive, flexible, multiagency consultation process that is directed specifically at the Klamath River basin and is designed to specify actions that each agency could take, under and consistent with its general authorities, to promote conservation of the listed species. In implementing such actions, agencies would be protected from legal challenge by their authority under Section 7(a)(1).

A substantial effort, justified under Section 7(a)(1), should be made to enlist all federal agencies operating in the Klamath River basin in recovery efforts. In fact, the relevant agencies—which include USFWS, NMFS, USBR, the U.S. Environmental Protection Agency, the U.S. Forest Service, and the U.S. Army Corps of Engineers—in 1994 jointly affirmed their Section 7(a)(1) authority and agreed to "identify opportunities to conserve Federally listed species and the ecosystems upon which those species depend" (Memorandum of Agreement 1994). Each of these agencies also agreed to "determine whether its respective planning processes effectively help conserve threatened and endangered species and the ecosystems upon which those species depend" and to "use existing programs, or establish a program if one does not currently exist, to evaluate, recognize, and reward the performance and achievements of personnel who are responsible for planning or implementing programs to conserve or recover listed species or the ecosystems upon which they depend." Yet there is little evidence that any federal agency operating in the Klamath River basin has been successful in fulfilling these agreements in the context of the ESA.

In summary, a multiagency consultation process under Section 7(a)(1) could expand recovery efforts beyond USBR and its Klamath Project, as needed ultimately for recovery. Section 7(a)(1) does not require any agency participating in the consultation to implement particular measures; only institutional will can bring that about. But if ever a case existed for motivating institutional will in this direction, the Klamath River basin fits the description.

Prohibition Against Jeopardy and Adverse Modification Caused by Federal Agencies

Section 7(a)(2) of the ESA requires (16 U.S.C. 1536(a)(2) 2002) that

> each federal agency shall, in consultation with and with the assistance of [USFWS and NMFS], insure that any action authorized, funded, or carried out by such agency (hereinafter in this section referred to as an "agency action") is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined . . . to be critical.

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The Klamath Project is subject to this requirement (see *Klamath Water Users Protection Ass'n v. Patterson*, 191 F.3d 1115, 9th Cir. 1999; *O'Neil v. United States*, 50 F.3d 667, 9th Cir. [1995]). The ESA provides an elaborate set of procedures and criteria for carrying out the jeopardy and adverse modification consultations (16 U.S.C. 1536(b)–(d) [2002]). USFWS and NMFS also have issued an extensive set of regulations covering the process (50 C.F.R. part 402 [2002]). Generally, the action agency must prepare a "biological assessment" detailing the effects that it believes its actions will have on listed species, and the consulting agency (USFWS or NMFS) must in response provide a "biological opinion" declaring whether jeopardy and adverse modification are likely to occur. If the consulting agency finds that jeopardy will occur, it must suggest "reasonable and prudent alternatives" (RPA) by which the action agency can avoid such an outcome. The RPAs, technically within the discretion of the action agency to accept or reject (see *Southwest Center for Biological Diversity v. Bureau of Reclamation*, 143 F.3d 515, 9th Cir. [1998]), carry considerable weight and are viewed as essentially mandatory in the absence of some compelling basis that the action agency might have for using different alternatives (see *Bennett v. Spear*, 520 U.S. 154 [1997]).

All agencies must fulfill all the duties by using "the best scientific and commercial data available" (50 C.F.R. 402.14(d) and 402.14(g)(8) [2002]). Action agencies also must ensure that they and their license or permit applicants "shall not make any irreversible or irretrievable commitment of resources with respect to the agency action which has the effect of foreclosing the formulation or implementation of any reasonable and prudent alternatives" (16 U.S.C. 1536(d) [2002]). A procedure established in the ESA—but rarely used, given its narrow criteria—allows an action agency to appeal a jeopardy or adverse modification finding to a committee of cabinet-level and other federal agency officials and thereby seek to carry out the action regardless of jeopardy or adverse modification (16 U.S.C. 1536(e)–(n) [2002]; 50 C.F.R. part 450 [2002]). Irrigation districts sought to initiate that procedure with respect to the 2001 jeopardy opinions that USFWS and NMFS issued for the Klamath Project, but in July 2001 the Department of the Interior declined to pursue the exemption process further. In addition to the jeopardy standards of Section 7(a)(2), the criteria for exemption involve policy matters outside the scope of this report.

The procedural details of the consultation process are not relevant to the NRC committee's charge. Rather, the key aspects of the consultation program for the committee's purposes are the meanings of *jeopardy* and *reasonable and prudent alternative*, because both USFWS and NMFS made jeopardy findings in their 2001 biological opinions and because the RPAs that they presented led USBR to suspend water deliveries in 2001. The statute defines neither term. Under USFWS and NMFS regulations, *jeopar-*

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dize the continued existence means "to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 C.F.R. 402.02 [2002]). *Reasonable and prudent alternative* means "alternative actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the Federal agency's legal authority, that is economically and technologically feasible, and that [USFWS or NMFS] believes would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat" (50 C.F.R. 402.02 [2002]). Judgments of jeopardy are inherently difficult in a technical sense. Site-specific evidence must be used as extensively as possible in making such judgments, but use of professional judgment where site-specific evidence is inadequate or absent is inevitable and desirable for rational judgments of jeopardy (see Chapter 1).

As described in Chapter 1, USFWS has consulted with USBR regarding the Klamath Project's effects on the listed sucker species, and NMFS has done so for the coho salmon. The history of the consultations is long and has at times been controversial (see, e.g., *Bennett v. Spear*, 5 F.Supp.2d 882 D. Or. [1998]; *Pacific Coast Federation of Fishermen v. Bureau of Reclamation*, 138 F.Supp.2d 1228 N.D. Cal. [2001]). For consistency with its charge, the NRC committee's principal focus has been on the 2001 and 2002 consultation documents.

In addition to the Klamath Project, numerous other actions in the Klamath River basin are carried out, funded, or authorized by federal agencies (Chapter 2). USFWS and NMFS do not appear to maintain comprehensive inventories of actions for which consultation is necessary and for which each action agency's consultation is satisfied or deficient, nor is there any basinwide strategy for conservation of the species through coordinated Section 7(a)(2) consultations. The agencies should prepare and implement such an inventory and strategy.

The Authorities to Prohibit Take and Incidental Take

Section 9(a)(1) of the ESA provides that "with respect to any endangered species of fish or wildlife . . . it is unlawful for any person subject to the jurisdiction of the United States to . . . take any such species within the United States or the territorial sea of the United States" (16 U.S.C. 1538(a)(1) [2002]). Although threatened species, such as the coho salmon, are not covered directly in this provision, Section 4(d) of the ESA provides that USFWS and NMFS "may by regulation prohibit with respect to any threat-

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ened species any act prohibited under section 1538(a)(1) of this title . . . with respect to endangered species" (16 U.S.C. 1533(d) [2002]).

Under the statute, to *take* is to "harass, harm, pursue, hunt, shoot, wound, trap, capture, or collect, or to attempt to engage in any such action" (16 U.S.C. 1532 [2002]). USFWS and NMFS have further defined *harm* to mean "an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering" (50 C.F.R. 17.3 [2002]). The U.S. Supreme Court has upheld the latter definition as consistent with the congressional intent of the ESA but in so ruling construed the regulation to limit findings of harm to cases in which actual death or injury to identifiable members of a protected species is the proximate and foreseeable result of a habitat modification (*Babbitt v. Sweet Home Chapter of Communities for a Great Oregon*, 515 U.S. 687 [1995]).

When USFWS and NMFS prepare biological opinions in connection with consultations under Section 7(a)(2) of the ESA, they most often find that no jeopardy or adverse modification will occur. Even in such cases, however, incidental take of a species might be a foreseeable consequence of the action. In such instances the consulting agency must (16 U.S.C. 1536(b)(4) [2002])

> provide the Federal agency and the applicant concerned, if any, with a written statement that (i) specifies the impact of such incidental take on the species, (ii) specifies those reasonable and prudent measures that the Secretary considers necessary or appropriate to minimize such impact, (iii) in the case of marine mammals, specifies those measures that are necessary to comply with section 1371(a)(5) of this title with regard to such taking, and (iv) sets forth the terms and conditions (including, but not limited to, reporting requirements) that must be complied with by the Federal agency or applicant (if any), or both, to implement the measures specified under clauses (ii) and (iii).

A similar procedure for authorization of incidental take is available under Section 10(a)(1)(B) of the ESA for projects and actions not carried out, funded, or authorized by a federal agency and thus not subject to the consultation requirement of Section 7(a)(2). Under the procedure, the entity carrying out an action that will cause take of a listed species must submit a habitat conservation plan (HCP) to USFWS or NMFS on which the agency bases its decision of whether to grant a permit for the incidental take (16 U.S.C. 1539(a)(1)(B) [2002]).

USFWS and NMFS consistently have found in their biological opinions for the Klamath Project that USBR's actions will result in take of the species in question and have prepared incidental-take statements with reasonable and prudent measures and terms and conditions for implementing them.

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Some take of the listed species is an undisputed consequence of USBR's operation of the Klamath Project (see Chapters 6 and 8), and the reasonable and prudent measures for avoiding this take are well founded. One concern of the NRC committee, however, is the lack of attention that USFWS and NMFS appear to have given to take of the listed species by actions other than USBR's operation of the Klamath Project. Throughout the Klamath River basin, actions by public and private entities are causing take of the listed species. Many of these actions are outside the control of the USBR and thus not susceptible to correction though the Klamath Project consultations. Such sources of take, which the committee believes may be substantial, should not be ignored simply because USBR and the Klamath Project present a bigger and easier target for consultation. Indeed, doing so leads inevitably to the potential for overregulation of the Klamath Project and, indirectly, its beneficiaries and thus an inequitable distribution of the social and economic costs of the conservation of species. The Klamath Project is a valid target for scrutiny and regulation, but not the only one.

Examples of take outside the reach of the Klamath Project are given in the listing documents and in Chapters 5–8 of this report. For example, Chiloquin Dam causes take of endangered suckers but is not under the control of USBR in connection with the Klamath Project. Even so, there is no organized effort by USFWS to enforce the take prohibition at Chiloquin Dam or elsewhere outside the Klamath Project where persons causing take must modify their behavior so as to avoid take or submit HCPs under Section 10(a)(1)(B). NMFS has a similar record in relation to coho salmon. In other parts of the nation, however, such as Austin, Portland, Tucson, and southern California, USFWS and NMFS have expended considerable resources to limit incidental take of listed species caused by dispersed actions, including those of private parties. It is not clear why the agencies have not initiated similar enforcement actions in the Klamath River basin.

There is ample basis for each agency to extend its authority to prohibit take, and doing so is likely to benefit the listed species. For example, NMFS listed the coho salmon ESU as threatened, requiring the agency to adopt conservation regulations under Section 4(d) of the ESA, and thus to regulate take of the species. In July 1997, the agency published an interim Section 4(d) rule extending the full extent of Section 9(a) take prohibitions to the species, except for specified benign and beneficial actions, including aspects of habitat restoration programs that the states had initiated (62 Fed. Reg. 38479 July 18, 1997). In July 2000, the agency included the coho salmon in a rule establishing general take authorizations for specified activities, subject to limits, covering 14 salmonid ESUs (65 Fed. Reg. 42421 July 10, 2000).

When describing the activities that would be affected by the take prohibition in its July 1999 interim Section 4(d) rule for the coho salmon ESU,

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NMFS explained that "agricultural activities that might result in take of SONCC coho are . . . sediment from cultivation or livestock movements on the banks or in the beds of streams; unscreened water diversions and reductions of flow through irrigation could also result in take; and NMFS . . . would expect the 4(d) rule to result in some curtailment of [timber] harvest on lands owned by small entities over and above the impacts of state regulation" (62 Fed. Reg. 38481-38483 [1997]). In the July 2000 rule, NMFS explained that the general take authorizations cover "properly screened water diversion devices" (62 Fed. Reg. 42423 [1997]). Other agricultural, logging, and land-use activities were not covered in any general or specific way by the general take authorizations.

As is the case for the listed sucker species, there clearly are numerous common activities outside the control of USBR that are recognized by NMFS as causing unauthorized take of coho salmon in the Klamath basin. NMFS recognized this in its 2002 biological opinion on the Klamath Project, for example, when it acknowledged that USBR accounts for 57% rather than 100% of the total irrigation-related depletions of flow at Iron Gate Dam. If, as NMFS has concluded, USBR's flow-depletion component has triggered jeopardy of the species, the other irrigation flow depletions most likely are also causing take of the species. Yet there is little evidence that NMFS has actively enforced the take prohibition in these contexts in the Klamath River basin (as it recently did, in contrast, against the Grants Pass Irrigation District for its take of salmon at its Savage Rapids Dam diversion structure). The NRC committee has not examined the full extent of the potential measures that NMFS might take in enforcing the take prohibition in the Klamath basin beyond USBR's operation of the Klamath Project, but there is ample basis for the agency to do so, and doing so is likely to benefit the species (Chapter 8).

For take caused by the Klamath Project, USBR obtains approval through the procedure on incidental-take statements given in Section 7(b)(4). If USFWS and NMFS were faithfully to enforce the take prohibition, there would be many more additional nonproject actions that, if not modified to discontinue the take, also would require authorization of incidental take. Take of listed suckers and salmon caused by actions other than the Klamath Project may even be associated with some federal agency funding or approval, in which case Section 7(b)(4) also would apply. For take caused by actions not carried out, funded, or authorized by a federal agency, Section 10(a)(1) supplies the applicable procedure.

Given the multiplicity of actions that may be causing take of the listed suckers and salmon, it may be productive for representatives of various interests to consider organizing an effort to explore a regional HCP that would form the basis for USFWS and NMFS to issue an "umbrella" authorization of incidental take for several actions in the Klamath River basin.

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Regional HCPs have been used or explored in a number of urban and rural settings as a means of avoiding piecemeal administration of incidental take permitting and to enhance opportunities for more efficient and effective habitat conservation and mitigation measures (Thornton 2001). Moreover, like the Section 7(a)(1) multiagency consultation proposed above, the regional HCP process involves coordination of numerous diverse interests and thus has the potential to produce more sustainable decisions than would incremental, action-specific permitting. As an earlier National Research Council committee found (NRC 1995, p. 92, 198–199), "habitat conservation planning . . . has the potential to be effective in protecting ecosystems and has realized that potential in a few cases," leading it to "endorse regionally based, negotiated approaches to the development of habitat conservation plans."

NMFS appears to have recognized the benefits of such interest planning processes in its 2002 biological opinion when it recommended creation of a "task force" to address the 43% of irrigation-related flow depletion at Iron Gate Dam that is not attributable to USBR. The NRC committee sees no reason why a Section 7(a)(1) process and a regional HCP process cannot be undertaken simultaneously and in coordination to fulfill the objectives of such a task force and of related species-conservation goals in the Klamath River basin.

CONCLUSIONS

The ESA is not a panacea for the challenges of ecosystem management and species conservation posed in the Klamath River basin. However, ESA authorities could be implemented more effectively, more extensively, and more creatively than they are now. Specifically, the relevant federal agencies have failed in several ways to exercise their full ESA authorities.

- USFWS and NMFS recovery planning for listed species under Section 4(f) has stalled.
- Federal agencies operating in the Klamath River basin have not been successful in the full use of discretionary conservation authority given in Section 7(a)(1).
- USFWS and NMFS appear to have focused jeopardy consultation under Section 7(a)(2) narrowly on USBR's operation of the Klamath Project, notwithstanding the many other federal agency actions carried out, funded, or authorized in or affecting the Klamath River basin. Neither agency has made any basinwide inventory of or strategy for federal actions and consultations a prominent part of its public discourse on the Klamath basin.
- USFWS and NMFS have not actively enforced the ESA Section 9 take prohibition outside the context of the Klamath Project itself, notwith-

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standing ample evidence that numerous other actions are causing take of the species.

Those problems in large part could be remedied as follows:

- NMFS could prepare and promulgate a recovery plan for the coho salmon, and USFWS could revise, update, and repromulgate the sucker recovery plan. In each case, the recovery plan could be designed with the specific purpose of enabling federal agency consultations under Sections 7(a)(1) and 7(a)(2) and individual or regional habitat-conservation planning under Section 10(a)(1), and it ideally would be capable of being carried out more comprehensively—that is, across the full spectrum of issues in the Klamath River basin and not just the Klamath Project—and through adaptive-management principles.
- NMFS and USFWS could inventory all federal agencies that are exercising any authority in or affecting the Klamath River basin and could initiate a multiagency consultation process with them under Section 7(a)(1). The consultation process would be most effective if centered on adaptive-management principles. Each federal agency engaging in the process could direct its institutional will toward fulfilling the agreements it made in the 1994 interagency agreement regarding the exercise of discretionary authority under Section 7(a)(1), with the Klamath River basin specifically in mind.
- If they have not already done so, NMFS and USFWS could inventory all active and potential federal agency consultations that are or could be carried out in the Klamath River basin under Section 7(a)(2), and develop a more coordinated basin-wide approach to the entire package of consultations. If these instruments already exist, the agencies could use them more overtly and provide the public more information about them.
- NMFS and USFWS could identify the inventory of federal, state, local, tribal, and private actions that are causing unauthorized take of the suckers and coho salmon. NMFS and USFWS could work with the agencies and persons causing the takes to help them either to modify their behavior to avoid the takes or to obtain incidental-take authorization under Sections 7(b)(4) or 10(a)(1). NMFS and USFWS could explore with those interests, which include private-sector and government actors, the possibility of a regional habitat-conservation planning approach.

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10

Adaptive Management for Ecosystem Restoration in the Klamath Basin

This report has described many ways in which the status of Klamath basin ecosystems can be improved for the benefit of endangered or threatened species and other fish and wildlife resources. The report also shows that geographic expansion of restoration efforts beyond the lakes and the main stem of the Klamath River is necessary for recovery of listed species. Recovery efforts will require adjustments in policies of agencies, in cooperation between institutions, and human use of resources in the basin.

Ecosystem management in the Klamath basin today is disjointed, occasionally dysfunctional, and commonly adversarial. Thus, it often is inefficient or ineffective in dealing with issues related to restoration of listed species in the basin. Cooperation among agencies has been poor; potential restoration activities have been generally restricted to actions or operations of the Klamath Project; and local communities, stakeholders, and individuals that control resources critical to long-term solutions often have been alienated, uninterested, or simply left out. Changes that occurred during consultations leading to the biological assessment and opinions of 2002 appear to show some movement toward remedies for these deficiencies, but much remains to be done, and an overall integrated strategy still is missing.

This chapter discusses alternative or modified management frameworks that might allow resources for recovery to be used more effectively than in the past. First, the potential value of adaptive management is explored. The chapter then presents specific examples of policy instruments, approaches, and activities that may facilitate environmental restoration. The last section suggests specific changes in management that probably would improve the

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efficacy of public and private investments in habitat or minimize the costs to private landowners as they adjust to the needs of listed species.

ADAPTIVE MANAGEMENT AS AN ORGANIZING FRAMEWORK

Regional restoration programs—which typically are large, complex, and fraught with uncertainties and competing interests—must include a process for implementing restoration activities and a means of measuring their effectiveness. The concepts of adaptive assessment (analysis leading to adaptations) and adaptive management (adjustment of management in light of new information) are often suitable for those purposes; for brevity, they are referred to here collectively as adaptive management.

Adaptive management is a formal, systematic, and rigorous program of learning from the outcomes of management actions, accommodating change, and improving management (Holling 1978). Its primary purpose is to establish a continuous, iterative process for increasing the probability that a plan for environmental restoration will be successful. In practice, adaptive management uses conceptual and numerical models and the scientific method to develop and test management options. It requires the explicit recognition that management policies can, with appropriate precautions, be applied as experimental treatments (Walters 1997). Decision makers use the results as a basis for improving knowledge of the system and adjusting management accordingly (Haley 1990, McLain and Lee 1996).

Adaptive management is being applied to major ecosystem restoration projects in the Florida Everglades, Chesapeake Bay, and California's Sacramento and San Joaquin River system (CERP 2002, CALFED 2002), and it recently has been used in an evaluation of flow regimes for the Grand Canyon (NRC 1999) and the Trinity River component of the Klamath River system (USFWS/HVT 1999). The following description of the adaptive management process is drawn from the CALFED Sacramento-San Joaquin Comprehensive Study working paper (2002), the appendix to USFWS/HVT (1999), Nagle and Ruhl (2002), and other sources. Not all features of adaptive management will be applicable to the Klamath basin, given legal constraints arising from the federal Endangered Species Act (ESA; Chapter 9). The general principles of adaptive management do, however, provide useful guidance as managers consider development and implementation of recovery plans. Adaptive management on the Trinity River could serve as a useful model for the rest of the basin.

Ecosystem Management and Adaptive Management

Ecosystem management refers to policy goals directed at ensuring the sustainability of natural resources in ecologically functional units (Grumbine

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1994). Grumbine defines *adaptive management* as a set of policy tools intended to move decision-making from a process of incremental trial and error to one of experimentation that uses continuous monitoring, assessment, and recalibration. Ecosystem management and adaptive management are not interchangeable, but they are nearly inseparable (Nagle and Ruhl 2002). Successful ecosystem management usually requires some form of adaptive management, and use of adaptive management in the context of natural-resources conservation generally requires that goals be expressed in terms of ecosystem management.

Through research already completed, scientists and managers have come to understand much about Klamath basin ecosystems and the species that depend on them, but many of the important ecological and human processes and interactions that animate the ecosystem remain unknown. Furthermore, ecosystem processes, habitats, and species are modified continually by changing environmental conditions and human activities. Presently and in the future, uncertainty is inevitable. Adaptive management provides an iterative process for continually reducing uncertainty by refining the implementation of environmental restoration projects in response to information from monitoring and scientific analysis.

Extreme events such as drought, flood, and unexpected human actions are anticipated by a properly designed adaptive-management program. Adaptive management incorporates processes for early detection and interpretation of the unexpected and for maximizing the learning opportunities associated with these events. Adaptive management is valuable in that it treats all responses, expected or not, as learning opportunities.

An example of an incidental experiment from the Klamath basin is the variation of water levels of Upper Klamath Lake over the last 15 yr. Drought and human management have caused the water level of the lake to fluctuate over a range of about 6 ft (Chapter 3). Changes in water levels now can be compared with changes in water quality (Chapter 3) or in sucker populations (Chapter 6). A number of other experiments, planned or inadvertent, have occurred in the basin, such as changes in seasonal and annual flows at Iron Gate Dam; they provide useful information about recovery, but in many cases monitoring programs have been inadequate to support analysis and interpretation that would lead to adaptation of management based on the new information.

Key Components of Adaptive Management

The key components of adaptive management are as follows:

- *Definition of the problem.* Examples are loss of critical habitat for species and the need for protection and restoration of habitat for species, such as those listed under the ESA.

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• *Determination of goals and objectives for management of ecosystems*. Examples are restoration of habitat protection and recovery of endangered species and other fish and wildlife resources at minimum social or economic cost.

• *Determination of the ecosystem baseline*. The ecosystem baseline includes all relevant information, past and present, such as physical, chemical, and biological features and benchmark indicators of the abundance of critical species. The baseline is the reference condition against which progress toward management goals is measured.

• *Development of conceptual models*. The analytical basis of adaptive management typically is a set of conceptual and numerical models. For example, conceptual ecological models convert broad, policy-level objectives into specific, measurable indicators of the status of natural and human systems. Conceptual modeling requires knowledge of ecosystem functions, of alteration or degradation, and of potential improvements. This information is framed in terms of major stressors and indicators (ecological attributes) that provide the most useful measures of ecological and social response to change. The conceptual model can be used to identify a small number of representative biological, chemical, and physical indicators of system-wide responses to restoration on various spatial and temporal scales. The indicators then can be used in developing models or protocols for monitoring and testing the efficiency of the restoration efforts. Performance measures are developed for each of the elements (ideally for both stressors and indicators) and are used as the standards for evaluating the restoration program.

• *Selection of future restoration actions*. The conceptual models shape the character of restoration actions by identifying key kinds of uncertainty or by revealing the extent of confidence that a particular action will achieve a given objective. On the basis of past and current conditions of the ecosystem, and insights from the conceptual models about the ecological and social consequences of management actions, managers apply two processes for changing management activities: identification of alternative-management procedures to achieve objectives and selection of alternatives that appear to move the system toward management objectives. One aspect of the selection process should be the social and economic costs of achieving an objective. When two alternatives are effective, lower cost is preferred. If alternative actions are proposed for the same purpose, comparison (perhaps in consecutive years) leads to selection of the action that most efficiently achieves the objectives.

• *Implementation of management actions*. A group of scientists and agency managers collectively is responsible for determining the criteria and procedures for management actions. This work requires coordination, organization, and accountability among the agencies, which can be difficult if

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the agencies have conflicting missions, as is the case in the Klamath basin. Experts in modeling, simulation, experimental design, and prediction forecast responses to managerial actions. Each iteration of simulation is tested through post-audit comparisons of observed and expected results. As part of an evaluation program, agency managers may support short-term and long-term experiments, such as alternative water levels or stream flows, habitat restoration efforts in selected areas, or other ecosystem changes. Experiments often involve major change, as would be the case for closure of the Iron Gate or Trinity Hatchery or removal of major dams (Chapter 8).

- *Monitoring of the ecosystem response.* "It is critical to monitor the implementation of restoration actions to gage how the ecosystem responds to management interventions. Monitoring provides the information necessary for tracking ecosystem health, for evaluating progress toward restoration goals and objectives, and for evaluating and updating problems, goals and objectives, conceptual models, and restoration actions. Monitoring requires measuring the baseline condition, abundance, distribution, change or status of ecological indicators" (CALFED Bay-Delta Program 2000).
- *Evaluation of restoration efforts and proposals for remedial actions.* After implementation of specific restoration activities and procedures, the status of the ecosystem is regularly and systematically reassessed and described. Comparison of the new state with the baseline state is a measure of progress toward objectives. The evaluation process feeds directly into adaptive management by informing the implementation team and leading to testing of management hypotheses, new simulations, and proposals for adjustments in management experiments or development of wholly new experiments or management strategies.

Status of Adaptive Management in the Klamath Basin

There has been little effort to implement adaptive-management strategies in the Klamath basin, except through the Trinity River Restoration Program, which deals only with the Trinity River. Even the 2002 biological assessment of the U.S. Bureau of Reclamation (USBR), which prescribes Klamath Project operations for the next 10 yr, gives only weak indications of mechanisms for adapting to new information. One exception is the proposed water bank, which if properly structured will provide annual information on the quantities of water available for voluntary transfer across uses and locations, and on the economic and social value of such water. This information can then be used by USBR to manage the water bank and to develop more accurate estimates of water availability for both agricultural and environmental uses in the basin, and to establish a long-term mechanism to address demands for water.

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Ecosystem management in the Klamath basin typically has pursued the widely recognized alternatives to adaptive management: deferred action and trial and error involving crisis management In the deferred-action approach, management methods are not changed until ecosystems are fully understood (Walters and Hillborn 1978, Walters and Holling 1990, Wilhere 2002). This approach is cautious but has two notable drawbacks: deferral of management changes may magnify losses, and knowledge acquired by deferred action may reveal little about the response of ecosystems to changes in management. Stakeholder groups or agencies that are opposed to changes in management often are strong proponents of deferred action.

Crisis management is common throughout the Klamath basin and permeates most restoration efforts, particularly on the tributaries. The approach often involves restoration actions, but neglects assessment (Wilhere 2002). Thus, management becomes based principally on casual observations and anecdotal reports. Trial and error without assessment and adaptation undervalues information, which is the most critical need in restoration, and overvalues action for its own sake. The trial and error without assessment and adaptation may cause more harm than good, but its benefits typically cannot be determined.

The legislative potential for watershed planning and restoration based on an adaptive-management framework already exists through the Klamath Act (Public Law 99-552), which was passed by Congress in 1986. The act led to formation of the Klamath River Basin Conservation Area Restoration Program, which includes the Klamath Basin Restoration Task Force. The task force is comprised of federal, state, and local officials and representatives of several tribes and other stakeholders, including the private sector. In addition, other committees, organizations and ad hoc working groups, such as the Upper Klamath Basin Working Group, the Klamath Basin Ecosystem Foundation, and several watershed councils have been created for improvement of dialogue among parties in the basin, and for development of solutions to water issues within the basin. The task force and other groups have facilitated discussion, but it is not clear that any group has contemplated extensive use of adaptive management. Considerable public and private funds have been invested in restoration and management of the ecosystems of the Klamath basin. It is not clear what benefits have been derived from the investments, or how management will be improved as a result. Adaptive management as applied to the Klamath basin would need to function within the legal framework of the ESA (Chapter 9), but the key point of the process is to set goals, develop a plan, determine whether it is achieving specific goals, and make adjustments as needed to be effective. This approach is both ecologically and socially responsible, given that ultimately all agencies and other stakeholders have

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limited resources with which to operate. As specific goals are achieved, resources become available for other socially desirable purposes within and outside the basin.

POLICY OPTIONS AND RESTORATION ACTIVITIES

Federal legislation and regulations, including the ESA and Federal Tribal Trust responsibilities, supercede state laws, including state water law. Thus, water demands for ESA purposes or to meet treaty obligations to Indian tribes have generally been upheld by federal courts (see, for example, the Winters Doctrine). Since such federal rulings reinforcing the ESA or tribal water needs typically do not apply to all waters in a basin or watershed, the Prior Appropriation Doctrine is still the major allocation device for waters in much of the West, including the Klamath basin. The prior appropriation system requires that the first individual to divert water for a beneficial use shall have the right to do so into perpetuity ("first in time, first in right"). The right of use generally is defined in terms of a given amount of water at a particular point of diversion. The rights of later diverters are junior (subordinate) to the right of the first diverter (senior right); in times of shortage, those holding water rights with earlier diversion dates are the last to be denied water. These water rights are established and protected by the states in which the diversions occur, usually by a state department of water resources.

The prior appropriation system of rights provides an efficient mechanism for allocating water during times of shortage, but has many limitations (Getches 2003). One is that the use of water by the holders of senior rights (seniors) may in some cases be of lower economic or social value than that of holders of junior rights (juniors). For example, a senior may divert water onto pastureland, of low economic value while a junior has the opportunity to use water to produce crops of high value. In a time of drought, there may not be sufficient water for both users, and only the crop of lower value would receive water. A related issue is that the most senior water rights are for diversions, primarily to agriculture. Values of flow in the stream itself have only recently been recognized as beneficial. As a result, seniors have the potential to divert all usable flow, thus dewatering portions of streams, even if the marginal value of water in the stream could produce substantially higher benefits than the diversion.

Another shortcoming of the prior-appropriation doctrine as applied by most states is that water rights are defined for a specific location. Thus, water rights are tied to a particular parcel of land unless a change is approved by a state authority. Defining water rights as appurtenant to land creates inflexibilities in the use of the water (for example, it restricts water trading), which leads to substantial economic and social costs with respect

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to maximizing the value of water to society, as demonstrated in the example of the preceding paragraph.

Because of problems with the prior-appropriation doctrine, states began using water markets about 30 yr ago (Colby Saliba and Bush 1987, National Research Council 1992, Getches 2003). The idea of a water market is that willing buyers and sellers should engage in transfers of water, thereby increasing the value of water to society. To use the preceding example, the junior may be willing to pay more for water than the senior can realize from using it. In such a case, both parties would gain and society would have realized greater value through the transfer.

To facilitate creation of a water market, states have changed laws and rules to allow a water right to be separated from the land to which it was originally applied. In such cases, the right is redefined as a particular flow or volume of water instead of a diversion at a particular location. Thus, a downstream user can purchase water from an upstream user. The magnitude of the gain from such a transaction is determined by the seller's increase in returns (over the value of the water on site) plus the additional increase in income or averted loss realized by the downstream purchaser. Obviously, trades will not occur unless they are of mutual benefit to buyer and seller. The existence of a market also allows other prospective water users to obtain water that was previously unavailable. For example, conservation groups or fisheries agencies may purchase water for maintenance of stream flows that benefit fish and wildlife (Colby 1990, Adams et al. 1993). In some western states (such as, Colorado and Arizona) municipalities purchase agricultural water rights through water markets to meet rising water demand due to residential growth.

Water markets create their own problems. They include so-called third-party effects by which someone who is not party to the sale may be harmed. For example, harm could come to an irrigator who has been using return flows from an upstream irrigator. If the upstream irrigator ceases irrigation, there would be no return flows for the neighboring irrigator. In addition, some return flows create wetlands or supplement groundwater supplies; if the water is moved to a new location as a result of a water transfer, these local benefits may be lost.

Water markets also may affect rural communities. If large amounts of water are diverted from agriculture to other uses, rural communities, including Indian tribal groups, who depend on the economic activity generated by irrigated agriculture will suffer. Thus, although the traders gain from the existence of markets and society gains from water transfers to use of higher value, rural communities may lose economic viability.

Despite the problems created by water markets, their use is increasing throughout the West. Many of the western states allow water to be sold or

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leased. Permanent transfer of water rights occurs in the case of a true water market, but a water bank typically involves the temporary transfer (lease) of a water right. Water banks are particularly useful during drought. Water banks also reduce some of the adverse effects of a permanent transfer of a water right. Farmers and rural communities often are more supportive of the water-bank concept than of sales of water rights (Keenan et al. 1999).

Water banks hold promise for water problems such as those of the Klamath basin. As noted earlier, Indian tribal claims to waters of the upper Klamath basin must be addressed as part of the adjudication process. Remaining water rights then will be assigned based on demonstrated proof of the initiation of beneficial use. Indeed, the recent USBR biological assessment (2002) contains a 10-yr plan that calls for creation of a water bank of 100,000 acre-ft of water per yr (see Table 1-1 for comparison with total annual flows). The water would come from groundwater and from surface water within and outside the Klamath Project. USBR would purchase the water, which would be used for environmental purposes.

The Klamath basin shows one of the necessary conditions for a water market or bank to be successful: a pronounced difference in the value of water across crops and other uses. For example, crops of both low and high value are grown in the Klamath Project and in the basin. In addition to providing a mechanism by which USBR could purchase water for environmental uses, a properly structured water bank would allow irrigators to trade among themselves. In a hypothetical analysis of the events of the 2001 water year in the Klamath basin, Jaeger (2002) has shown that a fully functioning water bank would have reduced losses to agriculture by over 50%. A water bank also could allow irrigation water to be shifted to nonagricultural uses. For example, the California water bank, which is administered by the California Department of Water Resources, reserves a small portion of each exchange between farmers to be used for environmental purposes in the Sacramento-San Joaquin delta.

The necessary economic conditions exist for a water bank in the Klamath basin, but institutional conditions do not. Specifically, before water can be traded, water rights must be clearly defined. In California, such rights have been established by the state. Oregon, however, has not finished the adjudication process for water rights in its portion of the Klamath basin. In the short term, water banking will need to rely on water sales from the California portion of the basin or among farmers in the Klamath Project who have water available for transfer, such as from wells. Even a limited water bank that is based on adjudicated surface water in California or from groundwater in the Klamath Project has the potential to improve water allocation in the basin.

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IMPROVEMENT OF RESOURCE MANAGEMENT IN THE KLAMATH BASIN

The present management structure for restoring the two sucker species and coho salmon in the Klamath basin consists of the federal agencies involved in the ESA Section 7 (a)(2) consultations—USBR, the U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS)—and, less directly, a number of other federal and state agencies, such as the U.S. Forest Service, Bureau of Land Management, U.S. Fish and Wildlife Service National Wildlife Refuges, the Natural Resource Conservation Service, the Bureau of Indian Affairs, the Environmental Protection Agency, the Army Corps of Engineers, the California and Oregon Departments of Environmental Quality, and state water-resources departments. Because the ESA is federal legislation, USBR, USFWS, and NMFS are the primary agencies that respond to ESA rules and procedures for the Klamath Project. Given the conflicting objectives and missions of these agencies, however, tensions among them are inevitable. ESA processes also have been joined by a number of advocacy groups that oppose or support actions of the various federal agencies. For example, the National Research Council staff has identified at least 29 environmental advocacy groups that have joined in litigation or taken positions against USBR and at least seven water-user advocacy groups that have brought suit against or opposed actions of USFWS. In addition, stakeholders in and outside the Klamath Project and local communities have not been adequately included in actions implemented under the ESA (Chapter 9). Entities outside the federal agencies feel disempowered by the present process (Lach et al. 2002). Their sense of powerlessness may contribute to the litigious nature of interaction among parties in the Klamath basin.

The current management structure includes the Klamath Basin Ecosystem Restoration Office (ERO), which fills two important functions in implementing the ESA in the Klamath basin: it provides money for research on the status of suckers in the upper basin, and it reviews USBR's biological assessments and prepares the USFWS biological opinions for the Section 7(a)(2) consultations. In fulfilling these functions, it operates essentially as a regulatory agency and could be viewed as an adversary to regulated parties (in this case, USBR and the irrigators in the Klamath Project). It also funds "restoration activities and practices" as part of the recovery program for the listed species. The activities and practices may lead to changes in land-use patterns on private lands in support of the sucker-recovery efforts.

The ERO serves as both a regulator and a funding agency; it is staffed primarily by USFWS personnel. It apparently does not effectively monitor and evaluate the success of its restoration actions. As noted earlier in this chapter, monitoring and evaluation are the most critical components of

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adaptive management for measuring the success of any ecosystem-restoration effort and incorporating new knowledge into the management process. In fact, USFWS and the ERO do not appear to have an operational recovery plan for the two sucker species (Chapter 9).

The underlying presumption of ERO managers appears to be that expenditure of money by the ERO on selected restoration actions is an acceptable measure of performance. In this regard, the ERO functions in a manner similar to that of many federal and state agencies in the basin that mistake input for output when evaluating their performance.

Federal and state emergency funding to assist farmers and agencies in 2001 was well intended but only exacerbated the problem of accountability. Similarly, the recent farm bill legislation that earmarked $50 million specifically for the Environmental Quality Incentives Program (NRCS 2003) and similar U.S. Department of Agriculture programs in the basin raises the issue of accountability in the absence of any central plan for recovery of the suckers. It is clear that the present level of emergency and supplemental funding for the basin may not be sustainable. Managers, therefore, need to have mechanisms in place to ensure that such funds, when available, are achieving the goals of the ESA recovery plans or, where appropriate, are being spent effectively in assisting stakeholders as they adjust to the consequences of the ESA.

Management of species in the Klamath basin should have two goals: maintenance and recovery of listed species and, among the actions that meet this objective, minimization of cost to society. The first goal is mandated by the ESA; the second is not the main objective of the ESA but is consistent with it (Chapter 9). The present management system in the Klamath basin is not ideal for reaching either goal.

If institutional deficiencies in the Klamath basin could be remedied, the likelihood of achieving the recovery of species and minimizing costs would increase. The design of research should begin with a broad set of objectives and scientific hypotheses; such breadth may require information from sources beyond local agencies and their supporting scientists and staff. The strong focus on water levels in Upper Klamath Lake and flows in the main stem, although driven by a desire to deal with issues over which the federal agencies have immediate control (through USBR operations), is indicative of an excessively narrow consideration of possibilities for restoration at the expense of other activities and solutions that may be effective over the long term. Furthermore, locations of restoration activities and their effects on water quality and habitat should be considered in the acquisition of land or other major investments. The assignment of priorities should recognize budgetary limitations of the agencies and others. Estimation of the cost effectiveness of restoration efforts is needed, as are the integrated monitoring and assessment programs to evaluate them.

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Management requires external oversight by a committee or group capable of resolving conflicts between federal agencies. There appears to have been closer collaboration between USBR, USFWS, and NMFS in developing their most recent biological assessment and biological opinions than in previous years (Chapter 1), perhaps in response to external review. There is no guarantee, however, that such collaboration will continue and some mechanism should be in place for coordination of federal management efforts. For example, such a management role could be played by the Committee on Environment and Natural Resources of the National Science and Technology Council; this committee of the executive branch was founded for such purposes. At the same time that there is need for oversight of federal agencies, the management structure for ecosystem restoration needs to involve local groups and private landowners as well in the design of restoration activities and investments. As a part of these efforts, federal management agencies should recognize the nature of incentives in the ESA for private landowners to participate in ecosystem recovery. Specifically, the ESA may prohibit taking of endangered species by private landowners; it does not contain provisions that encourage landowners to increase the abundance of fish populations. Indeed, landowners who increase populations of endangered species on their land may face increased government regulation. Thus, although the ESA does not prohibit the use of incentives that would encourage landowners to promote the welfare of endangered species, it is often viewed by landowners as more stick than carrot. This perception could be changed by cooperative arrangements that promote the welfare of the listed species without threatening landowners.

Third, the management structure should, through monitoring and evaluation, improve the efficiency of expenditures for both research and restoration activities. That requires better mechanisms for setting spending priorities. Research demonstrates that cumulative effects are typical of stream restoration and that thresholds for recovery require implementation of corrective measures on a geographically broad scale (Adams et al. 1993, Li et al. 1994, Wu et al. 2000). The present pattern of federal, state, and private land acquisition for restoration in the upper Klamath basin shows little evidence of being guided by any systematic plan.

The process-oriented issues described above can be addressed by use of the adaptive-management framework, subject to the limitations imposed by the ESA. The Klamath River Basin Restoration Task Force (KRBRTF) or some other broadly constituted group may be a logical starting point in developing and implementing a set of basinwide restoration activities. At a minimum, an adaptive management approach, whether through an existing group or through a new entity, would address current shortcomings that arise from a lack of clearly defined benchmarks and a failure to monitor the biological and economic efficiency of current expenditures. The use of

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external advisory groups or panels for oversight would also provide fresh perspective and perhaps reduce some of the tensions and distrust inherent in the current system.

CONCLUSIONS

The listing agencies for endangered and threatened species in the Klamath basin accept adaptive management as a principle for pursuing restoration of these species, as does USBR. Even so, working examples of adaptive management in the upper Klamath basin are virtually absent. Erratic funding, lack of recovery plans, absence of systematic external review of research, and other deficiencies having to do with lack of continuity have been the direct cause of deficiencies in adaptive management.

Adaptive management is an ideal approach for the Klamath basin insofar as the effects of specific actions intended to benefit the endangered and threatened species cannot be evaluated fully except on a conditional trial basis. Conditional trials require thoughtful design and organized monitoring that will reveal responses to management actions. Efforts to implement ESA requirements for the benefit of fishes in the Klamath basin cannot succeed without aggressive pursuit of adaptive management principles, which in turn require continuity, master planning, flexibility, and conscientious evaluation of the outcomes of management.

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11

Recommendations

BASINWIDE ISSUES

Scope of ESA Actions

Recovery of endangered suckers and threatened coho salmon in the Klamath basin cannot be achieved by actions that are exclusively or primarily focused on operation of USBR's Klamath Project. While continuing consultation between the listing agencies and USBR is important, distribution of the listed species well beyond the boundaries of the Klamath Project and the impairment of these species through land- and water-management practices that are not under control of USBR require that the agencies use their authority under the ESA much more broadly than they have in the past.

Recommendation 1. The scope of ESA actions by NMFS and USFWS should be expanded in several ways, as follows (Chapters 6, 8, 9).

- NMFS and USFWS should inventory all governmental, tribal, and private actions that are causing unauthorized take of endangered suckers and threatened coho salmon in the Klamath basin and seek either to authorize this take with appropriate mitigative measures or to eliminate it.
- NMFS and USFWS should consult not only with USBR, but also with other federal agencies (e.g., U.S. Forest Service) under Section 7(a)(1); the federal agencies collectively should show a will to fulfill the interagency agreements that were made in 1994.

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• NMFS and USFWS should use their full authority to control the actions of federal agencies that impair habitat on federally managed lands, not only within but also beyond the Klamath Project.

• Within 2 yr, NMFS should prepare and promulgate a recovery plan for coho salmon, and USFWS should do the same for shortnose and Lost River suckers. The new recovery plans should facilitate consultations under ESA Sections 7(a)(1), 7(a)(2), and 10(a)(1) across the entire geographic ranges of the listed species.

• NMFS and USFWS should more aggressively pursue opportunities for non-regulatory stimulation of recovery actions through the creation of demonstration projects, technical guidance, and extension activities that are intended to encourage and maximize the effectiveness of non-governmental recovery efforts.

Planning and External Review

For all three of the listed fish species, monitoring, research, and remediation have been handicapped by lack of effective central planning, by insufficient external review, and by poor connections between research and remediation (Chapters 6, 8, 10).

Recommendation 2. Planning and organization of research and monitoring for listed species should be implemented as follows.

• Research and monitoring programs for endangered suckers should be guided by a master plan for collection of information in direct support of the recovery plan; the same should be true of coho salmon.

• A recovery team for suckers and a second recovery team for coho salmon should administer research and monitoring on the listed species. The recovery team should use an adaptive management framework that serves as a direct link between research and remediation by testing the effectiveness and feasibility of specific remediation strategies.

• Research and monitoring should be reviewed comprehensively by an external panel of experts every 3 yr.

• Scientists participating in research should be required to publish key findings in peer-reviewed journals or in synthesis volumes subjected to external review; administrators should allow researchers sufficient time to do this important aspect of their work.

• Separately or jointly for the upper and lower basins, a broadly based, diverse committee of cooperators should be established for the purpose of pursuing ecosystem-based environmental improvements throughout the basin for the benefit of all fish species as a means of preventing future listings while also preserving economically beneficial uses of water that are compatible with high environmental quality. Where possible, existing fed-

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eral and state legislation should be used as a framework for organization of this effort.

ENDANGERED LOST RIVER AND SHORTNOSE SUCKERS

Needs for New Information

The endangered suckers have been extensively studied, particularly in Upper Klamath Lake, in ways that have proven very useful to the diagnosis of causes for decline in the abundance of suckers. Research and monitoring programs will continue to be valuable in revealing mechanisms that cause decline of the listed species, in developing a scientific basis for recovery actions, and in evaluating trial remediation measures through adaptive management. Research that is focused on gaps in knowledge or on mechanisms that appear to be particularly important to the recovery of the suckers will be most useful in support of the recovery effort.

Recommendation 3. Research and monitoring on the endangered suckers should be continued. Topics for research should be adjusted annually to reflect recent findings and to address questions for which lack of knowledge is a handicap to the development or implementation of the recovery plan. Gaps in knowledge that require research in the near future are as follows (Chapters 5, 6).

- Efforts should be expanded to estimate annually the abundance or relative abundance of all life stages of the two endangered sucker species in Upper Klamath Lake.
- At intervals of 3 yr, biotic as well as physical and chemical surveys should be conducted throughout the geographic range of the endangered suckers. Suckers should be sampled for indications of age distribution, qualitative measures of abundance, and condition factors. Sampling should include fish other than suckers on grounds that the presence of other fish is an indicator of the spread of nonnative species, of changing environmental conditions, or of changes in abundance of other endemic species that may be approaching the status at which listing is needed. Habitat conditions and water-quality information potentially relevant to the welfare of the suckers should be recorded in a manner that allows comparison across years. The resulting survey information, along with the more detailed information available from annual monitoring of populations in Upper Klamath Lake, should be synthesized as an overview of status.
- Detailed comparisons of the Upper Klamath Lake populations (which are suppressed) and the Clear Lake and Gerber Reservoir populations (which are apparently stable), in combination with studies of the environmental factors that may affect welfare of the fish, should be con-

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ducted as a means of diagnosing specific life-history bottlenecks that are affecting the Upper Klamath Lake populations.

- Multifactorial studies under conditions as realistic as practicable should be made of tolerance and stress for the listed suckers relevant to poor water-quality conditions in Upper Klamath Lake and elsewhere.
- Factors affecting spawning success and larval survival in the Williamson River system should be studied more intensively in support of recovery efforts that are focused on improvements in physical habitat protection for spawners and larvae in rivers.
- An analysis should be conducted of the hydraulic transport of larvae in Upper Klamath Lake.
- Relevant to the water quality of Upper Klamath Lake, more intensive studies should be made of water-column stability and mixing, especially in relation to physiological status of *Aphanizomenon* and the occurrence of mass mortality; of mechanisms for internal loading of phosphorus; of winter oxygen concentrations; and of the effects of limnohumic acids on *Aphanizomenon*.
- A demographic model of the populations in Upper Klamath Lake should be prepared and used in integrating information on factors that affect individual life-history stages.
- Studies should be done on the degree and importance of predation on young fish by nonnative species.
- Additional studies should be done on the genetic identities of subpopulations.

Remedial Actions

Because the suckers currently are not showing evidence of recovery, new types of actions intended to promote recovery are essential. The main focus of action in the recent past has been maintenance of specific minimum water levels in Upper Klamath Lake. Current evidence suggests that these manipulations will not be effective in causing restoration of suckers in Upper Klamath Lake, despite evidence that higher water levels maximize certain habitat features that are known to be important to the suckers. Additional harm to the suckers might result, however, from changes in the Klamath Project operations that would allow greater degrees of mean or maximum drawdown than those observed in the 1990s. USFWS may continue to investigate the effects of lake level in a more directed way by collaborating with USBR in experiments involving water-level manipulations. Some new types of manipulations not produced by past operating procedures might be especially informative. In planning experiments USFWS should consider the possibility that sustained high water levels could be detrimental to the suckers by increasing the severity of mass mortality

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through maintenance of high water-column stability, thus exacerbating surface oxygen depletion at times of mixing during the late growing season. Water levels in Clear Lake and Gerber Reservoir appear to have been adequate to sustain stable populations except at extreme drawdown, the occurrence of which is a risk to the suckers.

Current evidence indicates that attempts to intercept nutrients from the watershed will not improve the quality of water of Upper Klamath Lake, and thus cannot be taken as a likely way to achieve recovery of suckers.

Recovery actions for suckers of Upper Klamath Lake at present should emphasize measures that maximize production and survival of young fish on the basis that additional recruitment into the subadult and adult stages could partially or fully offset mass mortality of adults. In addition, experiments should be done on artificial oxygenated refugia that may be used by large fish. Recovery planning should assume that, because mass mortality of adults will likely continue in Upper Klamath Lake, significant efforts should be made to establish self-sustaining populations elsewhere in the Klamath basin.

Recommendation 4. Recovery actions of highest priority based on current knowledge of endangered suckers are as follows (Chapter 6):

- Removal of Chiloquin Dam to increase the extent of spawning habitat in the upper Sprague River and expand the range of and conditions under which larvae enter Upper Klamath Lake.
- Removal or facilitation of passage at all small blockages, dams, diversions, and tributaries where suckers are or could be present.
- Screening of water intakes at Link River Dam.
- Modification of screening and intake procedures at the A Canal as recommended by USFWS (2002).
- Protection of known spawning areas within Upper Klamath Lake from disturbance (including hydrologic manipulation, in the case of springs), except for restoration activities.
- For river spawning suckers of Upper Klamath Lake, protection and restoration of riparian conditions, channel geomorphology, and sediment transport; elimination of disturbance at locations where suckers do spawn or could spawn. These actions will require changes in grazing and agricultural practices, land management, riparian corridors, and public education.
- Seeding of abandoned spawning areas in Upper Klamath Lake with new spawners and physical improvement of selected spawning areas.
- Restoration of wetland vegetation in the Williamson River estuary and northern portions of Upper Klamath Lake.
- Use of oxygenation on a trial basis to provide refugia for large suckers in Upper Klamath Lake.

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- Rigorous protection of tributary spawning areas on Clear Lake and Gerber Reservoir, where populations are apparently stable.
- Reintroduction of endangered suckers to Lake of the Woods after elimination of its nonnative fish populations.
- Reestablishment of spawning and recruitment capability for endangered suckers in Tule Lake and Lower Klamath Lake, even if the attempts require alterations in water management, provided that preliminary studies indicate feasibility; increased control of sedimentation in Tule Lake.
- All proposed changes in Klamath Project operations should be reviewed for potential adverse effects on suckers; water level limits for the near future should be maintained as proposed by USBR in 2002 but with modifications as required by USFWS in its most recent biological opinion (2002).

THREATENED COHO SALMON

Needs for New Information

While the biology of coho salmon is well known in general, studies of coho salmon specific to the Klamath River basin have been few and do not provide the requisite amount of information to support quantitative assessments of population strength and distribution, environmental correlates of successful spawning and rearing, overwintering losses and associated habitat deficiencies, water temperatures at critical points in tributary waters, and effects of hatchery-reared fish on wild coho. Main-stem conditions are primarily of interest with respect to the spawning run and the downstream migration of smolts. Tributary conditions, which have been much less studied than main-stem conditions, are critical to both spawning and rearing; habitat includes but extends beyond the main stems of the large tributaries and into the small tributaries and headwaters that strongly favor spawning and rearing of coho.

Recommendation 5. Needs for new information on coho salmon are as follows (Chapters 7, 8).

- Annual monitoring of adults and juveniles should be conducted at the mouths of major tributaries and the main stem as a means of establishing a record of year-class strength for coho. Every 3 yr, synoptic studies of the presence and status of coho should be made of coho in the Klamath basin. Physical and chemical conditions should be documented in a manner that allows interannual comparisons. Not only coho but other fish species present in coho habitats should be sampled simultaneously on grounds that changes in the relative abundance of species are relevant to the welfare of coho and may serve as an early warning of declines in the abundance of

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other species. Results of synoptic studies, along with the annual monitoring at tributary mouths, should be synthesized as an overview of population status at 3-yr intervals.

- Detailed comparisons should be made of the success of coho in specific small tributaries that are chosen so as to represent gradients in potential stressors. The objective of the study should be to identify thresholds for specific stressors or combinations of stressors and thus to establish more specifically the tolerance thresholds for coho salmon in the Klamath basin.
- The effect on wild coho of fish released in quantity from hatcheries should be determined by manipulation of hatchery operations according to adaptive-management principles. As an initial step, release of hatchery fish from Iron Gate Hatchery (all species) should be eliminated for 3 yr, and indicators of coho response should be devised. Complementary manipulations at the Trinity River Hatchery would be desirable as well.
- Selected small tributaries that have been impaired should be experimentally restored, and the success of various restoration strategies should be determined.
- Success of specific livestock-management practices in improving channel conditions and promoting development of riparian vegetation should be evaluated systematically.
- Relationships between flow and temperature at the junctions of tributaries with the main stem and the estuary should be quantified; possible benefits of coordinating flow management in the Trinity and Klamath main stem should be studied.

Remediation

Actions intended to improve environmental conditions for the threatened coho salmon to date primarily have involved hydrologic manipulation of the main stem at Iron Gate Dam. Continual focus on hydrologic conditions in the main stem is an excessively narrow basis for recovery actions or for a recovery plan in that coho salmon are strongly oriented toward tributaries for all phases of the freshwater phase of their life cycle except migration at the adult and smolt stages. Changes required by NMFS in the flow of the main stem include additional water specifically for smolt migration; it is unknown whether this will be a major benefit to coho, but in the absence of information to the contrary it is a reasonable requirement. Establishment of more stringent minimum flows for the other parts of the year, as compared to the operations during the 1990s, are of uncertain benefit to coho salmon, although they may be of substantial benefit to other species that use the main stem more extensively. In apportioning responsibility to USBR for providing minimum flows according to its proportional

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use of water, NMFS is recognizing in a realistic way the need for all consumptive uses to be factored into any minimum-flow regime.

Major tributaries as well as small tributaries must benefit from remediation if recovery is to occur. Although more detailed information would be desirable as a basis for remediation, beginning points for remediation are obvious in locations where tributaries have been critically dewatered or warmed to the lethal threshold for coho salmon (a problem that could be exacerbated by climate change), or where appropriate substrate has been eliminated and cover is absent. Thus, there is ample justification for beginning remediation immediately. This will require extensive work on private lands, and also the establishment of improved management practices for mining and forestry, some of which is under the direct control of other agencies that are subject to ESA authority through NMFS. Blockage of coho migration, which occurs in dozens of locations at various scales within the Klamath basin, is inconsistent with ESA regulations on take and must be dealt with by NMFS.

Recommendation 6. Remediation measures that can be justified from current knowledge include the following (Chapter 8).

- Reestablishment of cool summer flows in the Shasta and Scott rivers in particular but also in small tributaries that reach the Klamath main stem or the Trinity main stem where water has been anthropogenically warmed. Reestablishment of cool flows should be pursued through purchase, trading, or leasing of groundwater flows (including springs) for direct delivery to streams; by extensive restoration of woody riparian vegetation capable of providing shade; and by increase of annual or seasonal low flows.
- Removal or provision for effective passage at all small dams and diversions throughout the distribution of the coho salmon, to be completed within 3 yr. In addition, serious evaluation should be made of the benefits to coho salmon from elimination of Dwinnell Dam and Iron Gate Dam on grounds that these structures block substantial amounts of coho habitat and, in the case of Dwinnell Dam, degrade downstream habitat as well.
- Prescription of land-use practices for timber management, road construction, and grazing that are sufficiently stringent to prevent physical degradation of tributary habitat for coho, especially in the Scott, Salmon, and Trinity river basins as well as small tributaries affected by erosion.
- Facilitation through cooperative efforts or, if necessary, use of ESA authority to reduce impairment of spawning gravels and other critical habitat features by livestock, fine sediments derived from agricultural practice, timber management, or other human activities.
- Changes in hatchery operations to the extent necessary, including possible closure of hatcheries, for the benefit of coho salmon as determined through research by way of adaptive management of the hatcheries.

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COSTS

The costs of remediation actions are difficult to estimate without more detail on their mode of implementation by the agencies. Based on general knowledge of costs of research and monitoring at other locations, an approximate figure for the recommendations on endangered suckers over a 5-yr period is $15–20 million, including research, monitoring, and remedial actions of minor scope. Excluded are administrative costs and the costs of remedial actions of major scope (e.g., removal of Chiloquin Dam), which would need to be evaluated individually for cost. For coho salmon, research, monitoring, and remedial projects of small scope over 5 yr is estimated at $10–15 million. Thus, the total for all three species over 5 yr is $25–35 million, excluding major projects such as removal of dams. These costs are high relative to past expenditures on research and remediation in the basin, but the costs of further deterioration of sucker and coho populations, along with crisis management and disruptions of human activities, may be far more costly. A hopeful vision is that increased knowledge, improved management, and cohesive community action will promote recovery of the fishes. This outcome, which would be of great benefit to the Klamath basin, could provide a model for the nation.

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Appendix A

Statement of Task

The committee will review the government's biological opinions regarding the effects of Klamath Project operations on species in the Klamath River Basin listed under the Endangered Species Act, including coho salmon and shortnose and Lost River suckers. The committee will assess whether the biological opinions are consistent with the available scientific information. It will consider hydrologic and other environmental parameters (including water quality and habitat availability) affecting those species at critical times in their life cycles, the probable consequences to them of not realizing those environmental parameters, and the inter-relationship of these environmental conditions necessary to recover and sustain the listed species.

To complete its charge, the committee will:

1. Review and evaluate the science underlying the Biological Assessments (USBR 2001a,b) and Biological Opinions (USFWS 2001; NMFS 2001).
2. Review and evaluate environmental parameters critical to the survival and recovery of listed species.
3. Identify scientific information relevant to evaluating the effects of project operations that has become available since USFWS and NMFS prepared the biological opinions.
4. Identify gaps in the knowledge and scientific information that are needed to develop comprehensive strategies for recovering listed species and provide an estimate of the time and funding it would require.

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A brief interim report will be provided by January 31, 2002. The interim report will focus on the February 2001 biological assessments of the Bureau of Reclamation and the April 2001 biological opinions of the U.S. Fish and Wildlife Service and National Marine Fisheries Service regarding the effects of operations of the Bureau of Reclamation's Klamath Project on listed species. The committee will provide a preliminary assessment of the scientific information used by the Bureau of Reclamation, the Fish and Wildlife Service, and the National Marine Fisheries Service, as cited in those documents, and will consider to what degree the analysis of effects in the biological opinions of the Fish and Wildlife Service and National Marine Fisheries Service is consistent with that scientific information. The committee will identify any relevant scientific information it is aware of that has become available since the Fish and Wildlife Service and National Marine Fisheries Service prepared the biological opinions. The committee will also consider any other relevant scientific information of which it is aware.

The final report will thoroughly address the scientific aspects related to the continued survival of coho salmon and shortnose and Lost River suckers in the Klamath River Basin. The committee will identify gaps in the knowledge and scientific information that are needed and provide approximate estimates of the time and funding needed to fill those gaps, if such estimates are possible. The committee will also provide an assessment of scientific considerations relevant to strategies for promoting the recovery of listed species in the Klamath Basin.

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Appendix B

Committee on Endangered and Threatened Fishes in the Klamath River Basin

WILLIAM M. LEWIS JR. (Chair) is professor and director of the Center for Limnology, Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado. Dr. Lewis earned his PhD from Indiana University (1973) with emphasis on limnology. His research interests, as reflected by over 160 journal articles and books, include productivity and other metabolic aspects of aquatic ecosystems, aquatic food webs, composition of biotic communities, nutrient cycling, and the quality of inland waters. The geographic extent of Dr. Lewis's work encompasses not only the montane and plains areas of Colorado but also Latin America and southeast Asia, where he has conducted extensive studies of tropical aquatic systems. Dr. Lewis has served on many National Research Council committees. He was a member of the National Research Council's Water Science and Technology Board. His current research projects include the use of stable isotopes to define carbon flux in the Orinoco River floodplain, biogeochemistry of the waters of the Orinoco River, metabolic adaptations in planktonic algae, and nutrient regulation in montane waters of the central Rockies.

RICHARD M. ADAMS is professor of agricultural and resource economics at the Oregon State University. Dr. Adams has served as editor of the *American Journal of Agricultural Economic*s and associate editor of *Water Resources Research* and the *Journal of Environmental Economics and Management*. He is a member of various government committees dealing with climate change, water resources, and other environmental issues, including service on three National Research Council panels addressing

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water-resource issues. Dr. Adams's current research interests include the economic effects of air and water pollution, global climate change, and the valuation of nonmarket commodities. He is a Distinguished Fellow of the American Agricultural Economics Association and has published over 150 books, book chapters, and refereed journal articles. Dr. Adams earned his PhD at the University of California Davis (1975).

ELLIS B. COWLING is University Distinguished Professor At-Large of North Carolina State University. He is a forest biologist who became a world leader in air-pollution research and policy. He is director of the Southern Oxidants Study, in which he leads a team of nearly 300 scientists and engineers in a research and assessment program on ozone and particulate-matter pollution in the southeastern states. From 1975 to 1983, he helped to establish the National Atmospheric Deposition Program—the first permanent precipitation-chemistry monitoring program in the United States. Since 1992, he has taught a graduate course and lectured widely on the role of scientists and engineers in public decision-making. Dr. Cowling was elected to membership in the National Academy of Sciences in 1973 and has served on several National Research Council committees and boards.

GENE S. HELFMAN is professor of ecology and a faculty member in the Conservation Ecology and Sustainable Development program at the University of Georgia. He received a BA in zoology from the University of California (1967), an MS in zoology from the University of Hawaii (1973), and a PhD in ecology and systematics from Cornell University (1978). He is on the editorial boards of *COPEIA* and *Environmental Biology of Fishes*. His current projects focus on the conservation of fishes, the effects of land use on fishes, invasive species, homogenization of fish faunas, and behavioral and ecological interactions and their impact on fish conservation.

CHARLES D. D. HOWARD has been an independent consulting engineer since 1969 in water-resources systems analysis. He has provided advice on operations and planning to water and power utilities; provincial, state, and federal governments in Canada and the United States; the United Nations Development Program; and the World Bank. Mr. Howard is the author of many engineering reports and articles in technical journals. In 1998, he received the Julian Hinds Award of the American Society of Civil Engineers. He has participated in a number of National Research Council committees and boards, including the Water Science and Technology Board, 1996–1999. Mr. Howard earned a BS (1960) and an MS (1962) from the University of Alberta and an MS (1966) from the Massachusetts Institute of Technology.

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ROBERT J. HUGGETT is professor of zoology and vice president for research and graduate studies at Michigan State University and professor emeritus of marine science at the College of William and Mary. His aquatic-biochemistry research has involved the fate and effects of hazardous substances in aquatic systems with a focus on hydrophobic chemicals and their partitioning in sediment and pore water. From 1994 to 1997, Dr. Huggett was the assistant administrator for research and development for the U.S. Environmental Protection Agency. Dr. Huggett earned his PhD at the College of William and Mary (1977).

NANCY E. LANGSTON is associate professor of environmental studies/forest ecology and management at the University of Wisconsin-Madison. Dr. Langston earned an MPhil at Oxford (1986) and a PhD from the University of Washington (1994). Her research emphasis is on the historical and ecological processes that shape landscape change in western ecosystems. Recent projects include analysis of forest change in fire-adapted ecosystems and restoration alternatives in ponderosa pine forests. Her current projects examine riparian change in the inland West—focusing on the interplay between ranching, irrigation, and wildlife refuge management—and analyses of the potential for adaptive management. She serves on the Board of Directors of the Forest History Society and on the editorial board for *Environmental History*. Her first book, *Forest Dreams, Forest Nightmares: the Paradox of Old Growth in the Inland West*, won the Charles Weyerhaeuser Prize for best book in conservation history (1997), and her forthcoming book is *Where Land and Water Meet: A Western Landscape Transformed*.

JEFFREY F. MOUNT is professor of geology at the University of California, Davis. Dr. Mount's research emphasis is on the geomorphic response of lowland river systems to changes in land use and land cover and the links between hydrogeomorphology and riverine ecology. Current projects include analysis of geomorphology of flood plains, flood-plain response to nonstructural flood-management measures, development of new flood-plain restoration methods, role of hydrologic and sedimentologic residence time in riverine ecosystems, and development of coupled hydrogeomorphic and ecosystem models for environmental monitoring. He earned his PhD from the University of California, Santa Cruz (1980).

PETER B. MOYLE is a professor in the Department of Wildlife, Fish and Conservation Biology at the University of California, Davis. Dr. Moyle earned a BA in zoology from the University of Minnesota (1964), an MS in conservation biology from Cornell University (1966), and a PhD in zoology from the University of Minnesota (1969). His research interests include conservation of aquatic species, habitats, and ecosystems, including salmon;

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ecology of fishes of the Sacramento-San Joaquin estuary; ecology of California stream fishes; the impact of introduced aquatic organisms; and the use of flood plains by fish. Dr. Moyle is the author or coauthor of over 170 publications (mostly related to fish in California). His most recent book, *Inland Fishes of California*, was published in 2002.

TAMMY J. NEWCOMB is the Lake Huron Basin coordinator for the Michigan Department of Natural Resources Fisheries Division. In that position, she coordinates ecosystem and watershed management for the Lake Huron drainages and the Lake Huron sport, tribal, and commercial fisheries. Dr. Newcomb is also an adjunct faculty member of the Virginia Polytechnic Institute and State University with a research focus on salmonid population dynamics, watershed and stream habitat management, and stream-temperature modeling. Dr. Newcomb earned her PhD at Michigan State University (1998).

MICHAEL L. PACE is assistant director of the Institute of Ecosystem Studies in Milbrook, New York. Dr. Pace earned his PhD in ecology from the University of Georgia (1981). He has served as chair of the Scientific Advisory Board of the National Center for Ecological Analysis and Synthesis from 2000 to 2001. His research interests focus on aquatic ecosystems. Based on projects conducted in lakes, estuarine mesocosms, and the Hudson River, Dr. Pace's work illustrates that particular species can modify trophic interactions and have enormous influence on the structure and function of ecosystems.

J. B. RUHL teaches law at Florida State University. Professor Ruhl is recognized as a leading authority on endangered-species law and one of the country's most prolific environmental-law scholars. He is coauthor of *The Law of Biodiversity and Ecosystem Management* (Foundation Press 2002). He teaches classes in property, land-use regulation, endangered species, and environmental-business transactions, and he serves as faculty adviser to *The Journal of Land Use & Environmental Law*. He earned his BA (1979) and JD (1982) from the University of Virginia and his LLM from the George Washington University (1986). Professor Ruhl has served as a visiting professor at The George Washington University Law School and a professor at Southern Illinois University School of Law. A member of the American Law Institute and former executive editor of *Natural Resources and the Environment*, he is a former partner in the Austin, Texas, office of Fulbright & Jaworski and is currently of counsel to Smith, Roberts, Elliott & Glen of Austin, Texas.

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RECOVERY PLAN

FOR THE EVOLUTIONARILY SIGNIFICANT UNITS OF

SACRAMENTO RIVER WINTER-RUN CHINOOK SALMON
AND
CENTRAL VALLEY SPRING-RUN CHINOOK SALMON

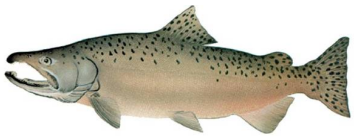
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THE DISTINCT POPULATION SEGMENT OF

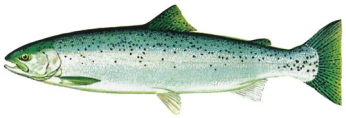
CALIFORNIA CENTRAL VALLEY STEELHEAD



Winter-run



Spring-run



Steelhead

National Marine Fisheries Service

West Coast Region

Sacramento, California

July 2014

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List of Acronyms

AFRP	Anadromous Fish Restoration Program
Bay/Delta	San Francisco Bay/Sacramento-San Joaquin Delta
BRT	Biological Review Team
CALFED	CALFED Bay-Delta Program
CAMP	Comprehensive Assessment and Monitoring Program
CBDA	California Bay/Delta Authority
CCWD	Contra Costa Water District
CCWMG	Cow Creek Watershed Management Group
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
CMARP	Comprehensive Monitoring Assessment and Research Program
cm	centimeters
cm/sec	centimeters per second
CNFH	Coleman National Fish Hatchery
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVSEPWT	Central Valley Salmonid Escapement Project Work Team
CWT	Coded Wire Tag
Delta	Sacramento-San Joaquin Delta
DPS	Distinct Population Segment
DWR	Department of Water Resources
ERP	Ecosystem Restoration Program
ESA	Federal Endangered Species Act
ESU	Evolutionarily Significant Unit
EWA	Environmental Water Account
FERC	Federal Energy Regulatory Commission
FL	fork length
FRFH	Feather River Fish Hatchery
ft/sec	feet per second
HGMPs	Hatchery and Genetic Management Plans
IEP	Interagency Ecological Program
LSNFH	Livingston Stone National Fish Hatchery
m	meters
mi^2	square miles
m/sec	millimeters per second
mm	millimeters
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PCSRF	Pacific Coastal Salmon Recovery Fund
PRD	Protected Resources Division
PVA	Population Viability Analyses
QC	Quality Control
RBDD	Red Bluff Diversion Dam
Reclamation	Bureau of Reclamation
RM	River Mile
RST	Rotary Screw Trap
SWP	State Water Project
TRT	Technical Recovery Team
USACOE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
VSP	Viable Salmonid Population

EXECUTIVE SUMMARY

Introduction: Recovery is the process by which listed species and their ecosystems are restored and their future is safeguarded to the point that protections under the Endangered Species Act (ESA) are no longer needed. The goal of this Recovery Plan is to recover the endangered Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU), the threatened Central Valley spring-run Chinook salmon ESU, and the threatened California Central Valley steelhead Distinct Population Segment (DPS). Recovering these species and the Central Valley, San Francisco Bay-Delta Estuary, and Pacific Ocean ecosystems that support them will be challenging and will require shifts in societal values. Californians must work together towards a conservation ethic and practice that ensures wild salmon and steelhead are an important part of coastal California and Central Valley culture for many generations to come.

Background: The rivers draining the Great Central Valley of California ("Central Valley") and adjacent Sierra Nevada and Cascade Range once were renowned for their production of large numbers of Pacific salmon (Clark 1929; Skinner 1962 *in* Yoshiyama *et al.* 1998). The Central Valley rivers and creeks historically have been the source of most of the Pacific salmon produced in California waters (CDFW 1950, 1955; Fry and Hughes 1951; Skinner 1962; CDWR 1984 *in* Yoshiyama *et al.* 1998). Chinook salmon *(Oncorhynchus tshawytscha)* historically were, and remain today, the only abundant salmon species in the Central Valley (Eigenmann 1890; Rutter 1908 *in* Yoshiyama *et al.* 1998), although small numbers of other salmon species also have occurred occasionally in its rivers (Collins 1892; Rutter 1904a, 1908; Hallock and Fry 1967; Moyle *et al.* 1995 *in* Yoshiyama *et al.* 1998). Steelhead (anadromous *O. mykiss)* were common in Central Valley tributaries (USFC 1876; Clark 1973; Latta 1977; Reynolds *et al.* 1993 *in* Yoshiyama *et al.* 1998), but records for them are few and fragmented, partly because they did not support commercial fisheries (Yoshiyama *et al.* 1998).

Populations of native Chinook salmon and steelhead have declined dramatically since European settlement of the Central Valley in the mid-1800s. California's salmon resources began to decline in the late 1800s, and continued to decline in the early 1900s, as reflected in the decline of Chinook salmon commercial harvest. The total commercial catch of Chinook salmon in 1880 was 11 million pounds; by 1922 it had dropped to seven million pounds, and it reached a low of less than three million pounds in 1939 (Lufkin 1996).

Another major factor affecting anadromous salmonids during this period was hydraulic gold mining, which began in the 1850s. By 1859, an estimated 5,000 miles of mining flumes and canals diverted streams used by salmonids for spawning and nursery habitat. Habitat alteration and destruction also resulted from the use of hydraulic cannons, and from hydraulic and gravel mining, which leveled hillsides and sluiced an estimated 1.5 billion cubic yards of debris into the streams and rivers of the Central Valley (Lufkin 1996).

Despite the prohibition of hydraulic mining in 1894, habitat degradation continued. Habitat quantity and quality have declined due to: construction of levees and barriers to migration, modification of natural hydrologic regimes by dams and water diversions, elevated water temperatures, and

water pollution from agriculture and industry (Lufkin 1996).

Although the effects of habitat degradation on fish populations were evident by the 1930s, rates of decline for most anadromous fish species increased following construction of major water project facilities (USFWS 2001), which primarily occurred around the mid- 1900s. Many of these water development projects completely blocked the upstream migration of Chinook salmon and steelhead to spawning and rearing habitats, and altered flow and water temperature regimes downstream from terminal dams. As urban and agricultural development of the Central Valley continued, numerous other stressors to anadromous salmonids emerged and continue to affect the viability of these fish today. Some of the more important stressors include: the high demand for limited water supply resulting in reduced instream flows, increased water temperatures, and highly altered hydrology in the Sacramento-San Joaquin Delta, barriers to historic habitat, widespread loss of tidal marsh, riparian and floodplain habitat, poor water quality, commercial and/or recreational harvest, and predation from introduced species such as striped bass.

Recovery Strategy: Recovery of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead across such a vast and altered ecosystem as the Central Valley will require a broadly focused, science-based strategy. The scientific rationale for the strategy in this plan focuses on two key salmonid conservation principles. The first is that functioning, diverse, and interconnected habitats are necessary for a species to be viable. That is, salmon and steelhead recovery cannot be achieved without providing sufficient habitat. Anadromous salmonids persisted in the Central Valley for thousands of years because the available habitat capacity and diversity allowed species to withstand and adapt to environmental changes including catastrophes such as prolonged droughts, large wildfires, and volcanic eruptions.

To help return the habitat capacity and diversity in the Central Valley to a level that will support viable salmon and steelhead, we have identified and prioritized recovery actions based on a comprehensive life stage-specific threats assessment. Minimizing or eliminating stressors to the fish and their habitat in an efficient and structured way is a key aspect of the recovery strategy.

The second salmonid conservation principle guiding the recovery strategy is that a species' viability is determined by its spatial structure, diversity, productivity, and abundance (McElhany *et al*. 2000). Abundance and population growth rate are self-explanatory parameters that are clearly important to species and population viability, while spatial structure and diversity are just as important, but less intuitive. Spatial structure refers to the arrangement of populations across the landscape, the distribution of spawners within a population, and the processes that produce these patterns. Species with a restricted spatial distribution and few spawning areas are at a higher risk of extinction from catastrophic environmental events (e.g., a single landslide) than are species with more widespread and complex spatial structure. Species or population diversity concerns the phenotypic (morphology, behavior, and life-history traits) and genetic characteristics of populations. Phenotypic diversity allows more populations to use a wider array of environments and protects populations against short-term temporal and spatial environmental changes. Genetic diversity,

on the other hand, provides populations with the ability to survive long-term changes in the environment. It is the combination of phenotypic and genetic diversity expressed in a natural setting that provides populations with the ability to adapt to long-term changes (McElhany *et al.* 2000).

Bridging the gap between the species and population levels are population groups or salmonid ecoregions, which are delineated based on climatological, hydrological, and geological characteristics. The Central Valley Technical Recovery Team (TRT) identified four population groups (hereafter referred to as diversity groups) that Chinook salmon historically inhabited in the Central Valley:

- The basalt and porous lava diversity group composed of the upper Sacramento River, McCloud River, Pit River and Battle Creek watersheds;
- The northwestern California diversity group composed of streams that enter the mainstem Sacramento River from the northwest;
- The northern Sierra Nevada diversity group composed of streams tributary to the Sacramento River from the east, and including the Mokelumne River; and
- The southern Sierra Nevada diversity group composed of streams tributary to the San Joaquin River from the east.

Based on the two scientific principles described above and on a comparison of current species viability, relative to historic viability, the basic strategy put forth in this recovery plan is to secure all extant populations and to reintroduce populations to historic habitat such that each salmonid diversity group in the Central Valley supports viable populations. The TRT concluded that recovery of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead would require that no more populations are allowed to become extirpated and that habitat must be expanded to allow for the establishment of additional populations (Lindley *et al.* 2007).

The primary means of securing existing populations is to reduce or eliminate threats to those populations and their habitats. To help guide threat abatement efforts, watersheds and recovery actions have been prioritized. Watersheds that are currently occupied by at least one of the listed Chinook salmon and steelhead species have been prioritized among three levels. Of highest priority are core 1 populations, which have been identified, based on their known ability or potential to support independent viable populations. Core 1 populations form the foundation of the recovery strategy and must meet the population-level biological recovery criteria for low risk of extinction set out in Table 5-1. NMFS believes that core 1 populations should be the first focus of an overall recovery effort. Core 2 populations are assumed to have the potential to meet the moderate risk of extinction criteria set out in Table 5-1. These dependent populations are of secondary importance for recovery efforts. Core 3 populations are present on an intermittent basis and are characterized as being dependent on other nearby populations for their existence. The presence of these populations provides increased life history diversity to the ESU/DPS and is likely to buffer against local catastrophic occurrences that could affect other nearby populations. Connectivity between populations and genetic diversity may be enhanced by

working to recover smaller core 3 populations that serve as stepping stones for dispersal. General guidance for how this watershed prioritization should be applied is that if a core 1 watershed and a core 2 (or 3) watershed had a similar problem affecting salmon and/or steelhead, then efforts should be directed at fixing the problem in the core 1 watershed first.

Unoccupied habitats that historically supported winter-run Chinook salmon, spring-run Chinook salmon, or steelhead have been prioritized regarding fish reintroductions. These unoccupied habitats have been prioritized as primary areas, candidates, or have been ruled out as places to reintroduce one or more of the species. Primary areas for reintroductions are areas where there is a known high likelihood of success based on species-specific life history needs, and available habitat quality and quantity. Specific primary reintroduction areas include the McCloud River, Battle Creek, the Yuba River, and the San Joaquin River. Candidate areas for reintroduction are unoccupied habitats that require further study of their potential for successful reintroductions. Some areas that were historically accessible to anadromous salmonids, but are no longer because of dams, have been excluded from consideration for reintroductions because they are so critically impaired by hydroelectric development and channel inundation that we felt efforts should be focused on areas with a higher potential for success.

Because recovery of winter- and spring-run Chinook salmon and steelhead will require implementation over a large landscape and over an extended period of time, a stepwise strategy has been adopted, based on the prioritization of watersheds and recovery actions. As this Recovery Plan is implemented over time, additional information will become available to help determine the degree to which the threats have been abated, to further develop understanding of the linkages between threats and population responses, to identify any additional threats, and to evaluate the viability of Chinook salmon and steelhead in the Central Valley.

Recovery Goals, Objectives, and Criteria: The overarching goal of this Recovery Plan is the removal of the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead DPS from the Federal List of Endangered and Threatened Wildlife (50 C.F.R. 17.11). The objectives and criteria to accomplish this goal builds upon the technical input and guidance provided by the TRT, and much of the following discussion is taken directly from information developed by the TRT (Lindley *et al.* 2004; 2006; 2007).

In order for the Chinook salmon ESUs and the steelhead DPS to achieve recovery, each diversity group must be represented, and population redundancy within the groups must be met to achieve diversity group recovery. Therefore, ESU-level recovery criteria include the following:

Winter-run Chinook salmon ESU:

- Three populations in the Basalt and Porous Lava Diversity Group at low risk of extinction

Spring-run Chinook salmon ESU and **Central Valley steelhead DPS**:

- One population in the Northwestern California Diversity Group at low risk of extinction

- Two populations in the Basalt and Porous Lava Diversity Group at low risk of extinction
- Four populations in the Northern Sierra Nevada Diversity Group at low risk of extinction
- Two populations in the Southern Sierra Nevada Diversity Group at low risk of extinction
- Maintain all Core 2 populations at moderate risk of extinction.

Recovery criteria at the population level were established by the Central Valley TRT and are included in this recovery plan (and apply to all three species), as described in Lindley *et al*. (2007). The TRT incorporated the four viable salmonid population parameters (McElhany *et al*. 2000) into assessments of population viability, and two sets of population viability criteria were developed, expressed in terms of extinction risk. The first set of criteria deal with direct estimates of extinction risk from population viability models. If data are available and such analyses exist and are deemed reasonable for individual populations, such assessments may be efficient for assessing extinction risk. In addition, the TRT also provided simpler criteria. The simpler criteria include population size (and effective population size), population decline, catastrophic rate and effect, and hatchery influence. For a population to be considered at low risk of extinction (i.e., < 5 percent chance of extinction within 100 years), the population viability assessment must demonstrate that risk level or all of the following criteria must be met:

- Census population size is >2,500 adults -or- Effective population size is >500
- No productivity decline is apparent
- No catastrophic events occurring or apparent within the past 10 years
- Hatchery influence is low (see Figure 4-1).

Additionally, threat abatement criteria must be met demonstrating that specific threats have been alleviated. The following threat abatement criteria have been established to ensure that each of the five ESA listing factors are addressed before a species can be delisted:

- Populations have unobstructed access to Core 1, 2, and 3 watersheds and assisted access to primary watersheds for reintroduction that are obstructed. Man-made structures (e.g., bridges and water diversions) affecting these watersheds and in migratory habitat must meet NMFS salmonid passage guidelines for stream crossings and screening criteria for anadromous salmonids (Listing Factors 1, 4, and 5)
- Utilization for commercial, recreational, scientific, and educational purposes is managed, such that all Core 1 populations meet the low extinction risk category for abundance (see Table 5-1) (Listing Factor 2)
- Hatchery programs are operated so that all Core 1 populations meet the low extinction risk criteria for hatchery influence (see Table 5-1) (Listing Factors 3 and 5)
- Migration and rearing corridors meet the life-history, water quality and habitat requirements of the listed species, such that the corridor

supports multiple viable populations (Listing Factors 1, 3, 4, and 5)

Recovery Actions: This Recovery Plan establishes a strategic approach to recovery, which identifies and prioritizes recovery actions at the Statewide, Central Valley wide, and site-specific levels. Three steps were taken to prioritize recovery actions as they are presented in this plan. First, results from the threats assessment and prioritization process (described in Appendix B) were used to guide the identification of watershed- and site-specific recovery actions for each diversity group and population. This step prioritized recovery actions separately for each species. The second step to prioritize recovery actions was undertaken through consideration of specific actions that benefit multiple species and populations. Results from the second step included tables of recovery actions listed in descending order of priority by geographic region (e.g., Delta, mainstem Sacramento River, Diversity Group) based on multiple species benefits. These first two steps were the only steps taken to prioritize recovery actions that were presented in the Co-Manager Review Draft Recovery Plan. Based on feedback from co-managers, it was apparent that the priority with which recovery actions should be undertaken was not clear. To address this, we implemented a third step and prioritized each of the region-specific recovery actions according to three categories. Priority 1 actions are those critical actions that address threats that generally ranked among the most important threats to one or more of the species; priority 2 actions address threats of moderate importance, and priority 3 actions are among the least important to implement. Actions were identified as priority 1, 2, or 3 based on the first two prioritization steps and on the best professional judgment of agency co-managers, including biologists from CDFW, USFWS, USFS, and NMFS.

Prioritized recovery actions for each of the following scales or regions are described in chapter 6 in the form of implementation tables: California-wide, Central Valley-wide, Pacific Ocean, San Francisco Bay, Delta, mainstem Sacramento River, mainstem San Joaquin River, and each of the four diversity groups. These implementation tables describe each action, the time frames and, if possible, the costs associated with it. Cost estimates have been provided wherever practicable, but in some cases where the uncertainties regarding the exact nature or extent of the recovery actions is unknown, these costs estimates can only be provided after site-specific investigations are completed.

Investment in recovery of salmon and steelhead will result in economic, societal and ecosystem benefits. Monetary investments in watershed restoration projects can promote the economy in a myriad of ways. These include stimulating the economy directly through the employment of workers, contractors and consultants, and the expenditure of wages and restoration dollars for the purchase of goods and services. Habitat restoration projects have been found to stimulate job creation at a level comparable to traditional infrastructure investments such as mass transit, roads, or water projects (Oregon Watershed Enhancement Board 2010). In addition, viable salmonid populations provide ongoing direct and indirect economic benefits as a resource for fish, recreation, and tourist related activities. Dollars spent on salmon and steelhead recovery will promote local, state, Federal and tribal economies, and should be viewed as an investment with both societal (clean

rivers, healthy ecosystems) and economic returns.

The largest direct economic returns resulting from recovered salmon and steelhead are associated with sport and commercial fishing. On average 1.6 million anglers fish the Pacific region annually (Oregon, Washington and California) and 6 million fishing trips were taken annually between 2004 and 2006 (NMFS 2010a). Most of these trips were taken in California and most of the anglers lived in California. The California salmon fishery is estimated to generate $118 to $279 million in income annually, and provide roughly two to three thousand jobs (Michael 2010). With a revived sport and commercial fishery, these substantial economic gains and the creation of jobs would be realized across California, but most notably for river communities and rural coastal counties.

Many of the actions identified in this Recovery Plan are designed to improve watershed-wide processes which will benefit many native species of plants and animals (including other state and federally listed species) by restoring natural ecosystem functions. In addition, restoration of habitat in watersheds will provide substantial benefits for human communities. Some of these benefits are: improving and protecting the quality of important surface and ground water supplies; reducing damage from flooding resulting from floodplain development; and controlling invasive exotic animal and plant species which can threaten water supplies and increase flooding risk. Restoring and maintaining healthy watersheds also enhances important human uses of aquatic habitats, including outdoor recreation, ecological education, field based research, aesthetic benefits, and the preservation of tribal and cultural heritage.

The final category of benefits accruing to recovered salmon and steelhead populations are even more difficult to quantify and are related to the ongoing costs associated with maintaining populations that are at risk of extinction. Significant funding is spent annually by entities (Federal, State, local, private) in order to comply with the regulatory obligations that accompany populations that are listed under the ESA.

Important activities, such as water management for agriculture and urban use, are now constrained to protect ESA listed populations of salmon and steelhead. Examples of these types of obligations include such requirements as: ESA section 7 consultations, development and implementation of Habitat Conservation Plans, the provision of fish passage at impassible barriers, and a high degree of uncertainty for the regulated entities. Recovering the salmonid populations so the protections of the ESA are no longer necessary will also result in elimination of the regulatory requirements imposed by the ESA, and allow greater flexibility for land and water managers to optimize their activities and reduce costs related to ESA protections. Salmon recovery is best viewed as an opportunity to diversify and strengthen the economy while enhancing the quality of life for present and future generations.

Implementation: It is a challenging undertaking to facilitate a change in practice and policy that reverses the path towards extinction of a species to one of recovery. This change can only be accomplished with effective outreach and education, strong partnerships, focused recovery strategies and solution-oriented thinking that can shift agency and societal attitudes, practices and understanding. Implementation of the recovery plan by NMFS will take many forms and is described in the NMFS

Protected Resources Division (PRD) Strategic Plan 2006 (NMFS 2006). The Recovery Planning Guidance (NMFS 2010b) also outlines how NMFS shall cooperate with other agencies regarding plan implementation. These documents, in addition to the ESA, shall be used by NMFS to set the framework and environment for plan implementation. The PRD Strategic Plan asserts that species conservation (in implementing recovery plans) by NMFS will be more strategic and proactive, rather than reactive. To maximize existing resources with workload issues and limited budgets, the PRD Strategic Plan champions organizational changes and shifts in workload priorities to focus efforts towards "*…those activities or areas that have biologically significant beneficial or adverse impacts on species and ecosystem recovery* (NMFS 2006)." The resultant shift will reduce NMFS engagement on those activities or projects not significant to species and ecosystem recovery.

NMFS actions to promote and implement recovery planning shall include:

- Coordinating priorities and actions with the Anadromous Fish Restoration Program, the Ecosystem Restoration Program, and other key funding sources.
- Creating and maintaining partnerships with fish and water stakeholder groups, including Federal, State, and local governments, water agencies, fishing groups, and watershed conservation groups.
- Formalizing recovery planning goals on a program-wide basis to prioritize work load allocation and decision-making (to include developing the mechanisms to make implementation (e.g., restoration) possible).
- Supporting outreach and education programs.
- Facilitating a consistent framework for research, monitoring, and adaptive management that can directly inform recovery objectives and goals.
- Establishing an implementation tracking system that is adaptive, web-based, and pertinent to support the annual reporting for the Government Performance and Results Act, Biennial Recovery Reports to Congress and the 5-Year Status Reviews.

NMFS' efforts must be as far-reaching (beyond those under the direct regulatory jurisdiction of NMFS) as the issues adversely affecting the species. Thus, to achieve recovery, NMFS will need to promote the recovery plan and provide needed technical information and assistance to other entities that implement actions that may impact the species' recovery. For example, NMFS will work with key partners on high priorities such as facilitating passage assessment and working with Counties to ensure protective measures consistent with recovery objectives are included in their General Plans.

Many complex and inter-related biological, economic, social, and technological issues must be addressed in order to recover anadromous salmonids in the Central Valley. Policy changes at the Federal, State and local levels will be necessary to implement many of the recovery actions identified in this Recovery Plan. For example, without substantial strides in

habitat restoration, fish passage, and changes in water use, recovery will be difficult if not impossible. In some cases, conflicting regulatory mandates that influence water and aquatic resources management will need to be resolved. Most importantly, recovering winter-run Chinook salmon, spring-run Chinook salmon, and steelhead will require a focused effort that secures existing populations, re-establishes populations in watersheds that historically supported them, and restores the ecological function of the habitats upon which the species depend for their long-term survival.

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1.0 Introduction

"Salmon was now abundant in the Sacramento. Those which we obtained were generally between three and four feet in length, and appeared to be of two distinct kinds. It is said that as many as four different kinds ascend the river at different periods. The great abundance in which this fish is found gives it an important place among the resources of the country."

- Captain John C. Frémont, memoirs for 30 March-5 April 1846 *in* Yoshiyama et al. 1998

The rivers draining the Great Central Valley of California ("Central Valley") and adjacent Sierra Nevada and Cascade Range once were renowned for their production of large numbers of Pacific salmon (Clark 1929; Skinner 1962 *in* Yoshiyama *et al.* 1998). The Central Valley system historically has been the source of most of the Pacific salmon produced in California waters (CDFW 1950, 1955; Fry and Hughes 1951; Skinner 1962; CDWR 1984 *in* Yoshiyama *et al.* 1998).

Chinook salmon *(Oncorhynchus tshawytscha)* historically were, and remain today, the only abundant salmon species in the Central Valley system (Eigenmann 1890; Rutter 1908 *in* Yoshiyama *et al.* 1998), although small numbers of other salmon species also have occurred occasionally in its rivers (Collins 1892; Rutter 1904a, 1908; Hallock and Fry 1967; Moyle *et al.* 1995 *in* Yoshiyama *et al.* 1998). Steelhead (anadromous *O. mykiss)* apparently were common in Central Valley tributaries (USFC 1876; Clark 1973; Latta 1977; Reynolds *et al.* 1993 *in* Yoshiyama *et al.* 1998), but records for them are few and fragmented, partly because they did not support commercial fisheries (Yoshiyama *et al.* 1998).

Anadromous salmonids, in particular Chinook salmon, have and continue to be an important resource, both revered and harvested by humans. The Native American people depended upon these fishes for subsistence, ceremonial, and trade purposes. Prior to Euro-American settlement, Native Americans within the Central Valley drainage harvested Chinook salmon at estimated levels that reached 8.5 million pounds or more annually (Yoshiyama *et al.* 1998). With the advent of the California gold rush in the mid-1800s, a commercial Chinook salmon fishery developed in the San Francisco Bay and Sacramento-San Joaquin Delta ("Delta") region. Annual catches by the early in-river fisheries commonly reached 4-10 million pounds. The first west coast salmon cannery opened on a scow moored near Sacramento in 1864. Within 20 years, 19 canneries were operating in the Delta region, and processed a peak of 200,000 cases (each case comprised of 48, 1-pound cans) in 1882 (Lufkin 1996). The salmon fishery remained centered in the Delta region until the early 1900s, when ocean salmon fishing began to expand and eventually came to dominate the fishery.

1.1 The Great Central Valley of California

The northern half of the Central Valley is comprised of the Sacramento River Basin (covering approximately 24,000 square miles [mi^2]), with the southern half (covering approximately 13,540 mi^2) primarily composed of the San Joaquin River Basin (**Figure 1-1**). The broad expanse of the Central Valley region of California once encompassed numerous salmon-producing streams that drained the Sierra Nevada and Cascade mountains on the east and north and, to a lesser degree, the lower-elevation Coast Range on the west. The large areal extent of the Sierra Nevada and Cascades watersheds, coupled with regular, heavy snowfalls in those regions, provided year-round streamflows for a number of large rivers which supported substantial runs of Chinook salmon (Yoshiyama *et al.* 1998).



Figure 1-1. Central Valley Region of California

In the Sacramento River Basin, most Coast Range streams historically supported regular salmon runs, although their runs were limited by the volume and seasonal availability of streamflows due to the lesser amount of snowfall west of the valley (Yoshiyama *et al.* 1998). In the San Joaquin River Basin, a number of major streams (e.g., the Merced, Tuolumne, and upper San Joaquin rivers) sustained very large salmon populations, while other streams with less regular streamflows had intermittent salmon runs in years when rainfall provided sufficient flows. All of the west side San Joaquin River Basin streams flowing from the Coast Range were highly intermittent (Elliott 1882) and none are known to have supported anadromous salmonids (Yoshiyama *et al.* 1998).

1.2 Salmon & Steelhead at Risk

Since settlement of the Central Valley in the mid-1800s, populations of native Chinook salmon and steelhead have declined dramatically. California's salmon resources began to decline in the late 1800s, and continued to decline in the early 1900s, as reflected in the decline of commercial harvest. The total commercial catch of Chinook salmon in 1880 was 11 million pounds, by 1922 it had dropped to 7 million pounds, and reached a low of less than 3 million pounds in 1939 (Lufkin 1996).

History and Current Status of Commercial Harvest

Although Chinook salmon remain an important resource, fishing for salmon has changed, most notably, in the last 20 years. 28 evolutionarily significant units (ESU'S) and distinct population segments (DPS's) of salmonids have been listed under the List of Endangered and Threatened Wildlife by the National Marine Fisheries Service (NMFS) on

the West Coast of the United States since 1989. This is significant because commercial ocean harvest and sport fishing for salmon has undergone dramatic management and regulatory implementations in order to continue with the commercial fishery while at the same time finding and implementing an exploitation rate that enables sustained Chinook populations into the future. It is also now possible for the ocean fishery to be managed for specific river fisheries through genetic sampling of the ocean harvest along the Pacific Coast. This change has altered the way ocean harvest is regulated, and further protects critical species in that life stage.

New matrixes developed by the National Oceanic and Atmospheric Administration (NOAA) Pacific Northwest Region emphasize that commercial fishing or ocean harvest is a critical parameter in the decisions used to manage sustainable fisheries or to reestablish adequate escapement levels.

Commercial and recreational ocean salmon fisheries in the U.S. Exclusive Economic Zone off the coasts of Washington, Oregon, and California are authorized by NMFS under the Magnuson-Stevens Fishery Conservation and Management Act (MSA). Specifically, these fisheries are managed under the Federal Pacific Coast Salmon Fishery Management Plan (FMP) (PFMC 2003). Consistent with the FMP, detailed management regulations are developed annually, designed to respond to new information and the current status of each salmon stock. Pursuant to the MSA, the Pacific Fishery Management Council (PFMC) develops recommendations for the development of the FMP, FMP amendments, and annual management measures and provides those recommendations to the Secretary of Commerce, through NMFS, for review and approval. The Secretary may approve the PFMC's recommendations for implementation as federal regulation if found to be consistent with the MSA and other applicable law, including the ESA.

The number of Chinook salmon harvested in the California commercial salmon fishery dramatically declined starting in 2006. From 1978 to 2005, the annual salmon harvest for the California commercial fishery exceeded 300,000 in all but one year (2001). In 2006 the fishery collapsed resulting in complete fishery closures in 2008 and 2009, and a heavily restricted fishery in 2010. The average Chinook salmon harvest in the fishery in 2006, 2007, and 2011 was approximately 85,000 (PFMC 2012).

Sources of Habitat Decline

A major factor affecting Chinook salmon and steelhead was hydraulic gold mining, which began in the 1850s. By 1859, an estimated 5,000 miles of mining flumes and canals diverted streams used by salmonids for spawning and nursery habitat. Habitat alteration and destruction also resulted from the use of hydraulic cannons, which leveled hillsides and sluiced an estimated 1.5 billion cubic yards of debris into the streams and rivers of the Central Valley (Lufkin 1996).

Evan though hydraulic mining was prohibited in 1894, other habitat degradation continued. Habitat quantity and quality have declined due to construction of levees and barriers to migration, modification of natural hydrologic regimes by dams and water diversions, elevated water temperatures, and water pollution (Lufkin 1996). Although the effects of habitat degradation on fish populations were evident by the 1930s, rates of decline for most anadromous fish species increased following completion of major water project facilities (USFWS 2001) which primarily occurred around the mid- 1900s.

Numerous water development projects blocked the upstream migration of Chinook salmon and steelhead, and altered flow and water temperature regimes downstream from terminal dams. An extensive network of reservoirs and aqueducts has been developed throughout much of California to provide water to major urban and agricultural areas. The two largest water projects in California are the State Water Project (SWP) and the Federal Central Valley Project (CVP). The CVP delivers on average over 7 million acre-feet per year. CVP water is used to irrigate 3 million acres of farmland in the San Joaquin Valley, as well as provide water for urban use in Contra Costa, Santa Clara, and Sacramento counties. The largest state-built water and power project in the United States, the SWP spans 600 miles from Northern California to Southern California, providing drinking water for 23 million people and irrigation water for 750,000 acres of farmland (see www.aquafornia.com for more information about California water management).

An estimated 1,126 miles of stream remain of the more than 2,183 miles of Central Valley streams that were historically accessible by Chinook salmon – indicating an overall loss of at least 1,057 miles (48 percent) of the original total (Yoshiyama *et al.* 2001). The estimated habitat loss includes the lengths of stream used by salmon mainly as migration corridors, in addition to holding and spawning habitat. This estimated loss of habitat does not include the Delta, comprising about 700 miles of river channels and sloughs (USFWS 1995), available to various degrees as migration corridors or rearing areas for Chinook salmon and steelhead.

It is likely that the lower reaches of the Sacramento and San Joaquin rivers historically were used as rearing areas (at least during some flow regimes) as the juveniles moved downstream, but recently they have been less suitable for rearing due to alterations in channel morphology and other degraded environmental conditions. In terms of only spawning and holding habitat, the proportionate loss of historically available habitat far exceeds 48 percent, much of which was located in upper stream reaches that have been rendered inaccessible by terminal dams (Yoshiyama *et al.* 2001). Excluding the lower stream reaches that were used as adult migration corridors (and, to a lesser degree, for juvenile rearing), it has been estimated that at least 72 percent of the original Chinook salmon spawning and holding habitat in the Central Valley drainage is no longer available (Yoshiyama *et al.* 2001).

The amount of steelhead habitat lost most likely is much higher than that for Chinook salmon, because steelhead were undoubtedly more extensively distributed. Due to their superior leaping and swimming ability and the timing of their upstream migration, which coincided with the winter rainy season, steelhead likely used at least hundreds of miles of smaller tributaries not accessible to even the highest migrating winter-run and spring-run Chinook salmon (Yoshiyama *et al.* 2001).

In addition to commercial exploitation, large-scale habitat degradation, blockage of historically available habitat and altered flow and water temperature regimes, other factors that may have adversely affected natural stocks of Chinook salmon and steelhead include overharvest, illegal harvest, hatchery production, entrainment, and introduction of competitors, predators and diseases. Fish populations also vary due to natural events, such as droughts and poor ocean conditions (e.g., El Niño). However, populations in healthy habitats typically recover within a few years after natural events. In the Central Valley, the decline of fish populations has continued through cycles of beneficial and adverse natural conditions, indicating the need to improve habitat (USFWS 2001).

1.3 The Recovery Planning Process

The Federal Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 *et seq*.) mandates the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) to develop and implement plans (i.e., recovery plans) for the conservation and survival of NMFS listed species. Winter-run Chinook salmon are listed as endangered under the Federal ESA, and spring-run Chinook salmon and steelhead are listed as threatened. Implementation of the Recovery Plan for the Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU), Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead Distinct Population Segment[1] (DPS) is vital to the continued persistence and recovery of these populations.

The recovery plan is a comprehensive plan that serves as a road map for species recovery – it lays out where we need to go and how best to get there. A recovery plan is one of the most important tools to ensure sound scientific and logistical decision-making throughout the recovery process. Primarily, a recovery plan should do the following:

- Delineate those aspects of the species' biology, life history, and threats that are pertinent to its endangerment and recovery;
- Outline and justify a strategy to achieve recovery;
- Identify the actions necessary to achieve recovery of the species; and
- Identify goals and criteria by which to measure the species' achievement of recovery (NMFS 2010b).

Although recovery plans provide guidance, they do not have the force of law. The success of this Recovery Plan depends upon the cooperation of all stakeholders and regulatory entities to ensure appropriate implementation.

Pursuant to Section 4(f) of the ESA, a recovery plan must be developed and implemented for the conservation and survival of species listed as threatened or endangered unless it finds that a recovery plan will not promote the conservation of the species. A recovery plan must, to the maximum extent practicable, include the following:

- A description of site-specific management actions necessary for recovery;
- Objective, measurable criteria, which when met, will allow delisting of the species; and
- Estimates of the time and cost to carry out the recovery measures.

The purpose of this Recovery Plan is to guide implementation of recovery of the species by resolving the threats to the species and thereby ensuring viable Chinook salmon ESUs and the steelhead DPS. This Recovery Plan may be used to inform all stakeholders including Federal, State, Tribal, and local agencies and land use actions, but it does not place regulatory requirements on such entities.

Past recovery plans generally have focused on the abundance, productivity, habitat and other life history characteristics of a species. While knowledge of these characteristics is certainly important for making sound conservation management decisions, the long-term

[1] On January 5, 2006, NMFS departed from their previous practice of applying the ESU policy to steelhead. NMFS concluded that within a discrete group of steelhead populations, the resident and anadromous life forms of steelhead remain "markedly separated" as a consequence of physical, ecological and behavioral factors, and may therefore warrant delineation as a separate DPS (71 FR 834).

sustainability of a species in need of recovery can only be ensured by alleviating the threats that are contributing to the status of the species as threatened or endangered. Therefore, the identification of the threats to the species is a key component of this Recovery Plan.

To be most useful for recovery planning, a threats assessment should be used to determine the relative importance of various threats to a species. A threats assessment includes: (1) identifying threats and their sources; (2) evaluating the effects of threats; and (3) ranking each threat based on relative effects. The Interim Endangered and Threatened Species Recovery Planning Guidance (NMFS 2010b) recommends "*…using a threats assessment for species with multiple threats to help identify the relative importance of each threat to the species' status, and, therefore, to prioritize recovery actions in a manner most likely to be effective for the species' recovery*." This Recovery Plan uses this recommended approach to identify and prioritize threats to the Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon ESUs, and the California Central Valley steelhead DPS. The prioritized threats are then used to guide the identification of specific recovery actions.

The methodology used in the threats assessment for this Recovery Plan is generally described in the next chapter (Background) and is fully described in Appendix B.

1.3.1 A Collaborative Effort

Central Valley Technical Recovery Team

As part of its recovery planning efforts, the NMFS Southwest Region (now part of the West Coast Region) designated the Central Valley as a "Recovery Domain." The NMFS Southwest Region established the Central Valley Technical Recovery Team (TRT) to provide technical assistance to the recovery planning process for the Central Valley Domain. The NMFS' intent in establishing the Central Valley TRT was to seek unique geographic and species expertise, and to develop a solid scientific foundation for the Recovery Plan. The Central Valley TRT identified unique habitat and biological characteristics of the three species, made technical findings regarding limiting factors and stressors for each ESU and DPS and its component populations, recommended biological viability criteria at the ESU/DPS- and population-level, and provided scientific review of local and regional recovery planning efforts.

The Central Valley TRT, a collaborative body of biologists that were selected based on their expertise and local knowledge, produced three documents heavily relied upon in preparation of the Recovery Plan: (1) *Population Structure of Threatened and Endangered Chinook Salmon ESUs in California's Central Valley Basin* (Lindley *et al.* 2004); (2) *Historical Population Structure of Central Valley Steelhead and its Alteration by Dams* (Lindley *et al.* 2006); and (3) *Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin* (Lindley *et al.* 2007).

Public Participation

NMFS conducted a series of Recovery Planning Workshops, designed as round-table discussions, to solicit information and promote dialogue as part of the development of the Federal Recovery Plan for winter-run Chinook salmon, spring-run Chinook salmon and steelhead in the Central Valley Domain. Public workshops were held in Sacramento, California on July 20, 2006, in Redding, California on August 15, 2006, and in

Stockton, California on August 17, 2006. At these workshops, NMFS provided a general overview of: (1) the Federal recovery planning process; (2) the timeline for NMFS recovery plan development; (3) the current understanding of Chinook salmon and steelhead populations and their habitats; and (4) threats identified in original ESA listing documents.

Following the overviews, workshop participants were separated into smaller facilitated discussion groups to generate more in-depth dialogue and identify threats to specific Chinook salmon and steelhead populations and their habitats.

Information obtained at the initial series of workshops also was used in additional workshops to develop recovery actions that reduce or eliminate identified threats. These additional workshops were held in Sacramento, California on May 22, 2007 and in Redding, California on May 24, 2007.

In October of 2009, NMFS released a Public Draft Recovery Plan for Central Valley salmon and steelhead, commencing a 60-day public review and comment period (74 FR 51553; October 7, 2009). Based on requests from the public for additional review time, this comment period was extended an additional 60 days (74 FR 61329; November 24, 2009). NMFS received 78 written comment submissions from the public as well as several verbal comments. Many of the public comments and suggested edits have strengthened this Recovery Plan. Following release of the Public Draft Recovery Plan, a total of eight public workshops were held in Sacramento (three workshops), Chico (three workshops), Salida, and Mt. Shasta to help establish working relationships with local communities and to obtain stakeholder input.

Existing Efforts

Local water agencies and irrigation districts, municipal and county governmental agencies, watershed groups, and State and Federal agencies have undertaken major habitat restoration efforts in many parts of the Central Valley and Delta. These actions include the addition of gravel below dams, removal of small dams, screening water diversions, fish passage improvements, riparian revegetation, bank protection, structural habitat enhancement, restoration of floodplain and tidal wetlands, development and implementation of new flow and water temperature requirements below dams, and operational constraints in the Delta. Major restoration efforts that impact salmon and steelhead recovery throughout the Central Valley include the programs established under the Anadromous Fish Restoration Program (AFRP) of the Central Valley Project Improvement Act (CVPIA) and the Ecosystem Restoration Program (ERP). Shared purposes of the AFRP and the ERP are to protect and restore diversity within and among the various naturally-producing populations of Chinook salmon and steelhead in the Central Valley, and to restore the habitats upon which the populations depend.

The AFRP promotes collaboration between the Department of Interior (USFWS and the Bureau of Reclamation [Reclamation]) with other agencies, organizations and the public to increase natural production of anadromous fish in the Central Valley by augmenting and assisting restoration efforts presently conducted by local watershed workgroups, the California Department of Fish and Wildlife (CDFW), and others. Purposes of the CVPIA (Section 3402) relevant to the AFRP are: (1) to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley; (2) to address impacts of the CVP on fish, wildlife, and associated habitats; (3) to improve the operational flexibility of the

CVP; (4) to contribute to the State of California's interim and long-term efforts to protect the San Francisco Bay and Sacramento-San Joaquin Delta Estuary; and (5) to achieve a reasonable balance among competing demands for the use of CVP water, including the requirements of fish and wildlife, agricultural, municipal and industrial, and power contractors (USFWS 2001).

The ERP is CDFW's principal program designed to restore the ecological health of the Bay/Delta ecosystem. The ERP includes actions throughout the Bay/Delta watershed and focuses on the restoration of ecological processes and important habitats. In addition, the ERP aims to reduce the effects of stressors that inhibit ecological processes, habitats and species (CALFED 1999b).

Another major effort that could impact Central Valley salmon and steelhead recovery, if implemented, is the Bay Delta Conservation Plan (BDCP). The dual goals of the BDCP are to provide a comprehensive ecosystem restoration program for the delta and a reliable water supply. Further information is available at the BDCP website: http://baydeltaconservationplan.com/.

1.4 Recovery Plan Content

This introductory chapter provides an overview of many important facets of this Recovery Plan, and in particular describes the collaborative processes of the plan. The remainder of this Recovery Plan for the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU and the California Central Valley steelhead DPS is presented in several chapters.

The second chapter provides background including the current regulatory status, a description of the population trends and distribution of each species, and a description of the life history and habitat requirements for each species. A brief description of the reasons for listing and a current threats assessment is then presented (a detailed threats assessment is presented in Appendix B). Finally, current conservation efforts and biological constraints are discussed, including limiting factors that should be considered for the species recovery.

Next, the Recovery Strategy Chapter presents and justifies the recommended recovery program for each species. This chapter also describes the key facts, concepts and assumptions upon which the recovery program is based.

The following chapter describes the recovery goals, objectives, and criteria. The ultimate goal of the Recovery Plan is delisting of the Chinook salmon ESUs and the steelhead DPS. The recovery objectives basically subdivide the goal into discrete components which collectively describe the conditions necessary for delisting. Recovery criteria are the objective and measurable standards upon which decisions to delist the ESUs and DPS are based.

Next, the specific actions that should be implemented to achieve recovery are presented in the Recovery Actions Chapter. That chapter is intended to satisfy the requirement under the ESA (Section 4 (f)(1)(B)(iii)) that Recovery Plans must contain to the maximum extent practicable "*…estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal*." Recovery actions are linked to the identified threats (or stressors) individually for specific populations of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead within the Central Valley Domain, and are prioritized according to the priority of threats addressed.

This Recovery Plan includes a chapter discussing the impacts of climate change on Central Valley salmonids, including how those impacts are expected to affect recovery efforts in the coming decades.

Lastly, a chapter on how this plan will be implemented is provided. The chapter discusses the time and cost to recovery, the benefits of recovery, and the various tools under the ESA that can be used to implement anadromous salmonid recovery in the Central Valley.

2.0 Background

"The requirement for determining that a species no longer requires the protection of the ESA is that the species no longer be in danger of extinction or likely to become endangered in the foreseeable future based on evaluation of the listing factors specified in ESA Section 4(a)(1). Any new factors identified since listing must also be addressed in this analysis to ensure that the species no longer requires protection."

- NMFS Supplement to the Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan 2005

The Central Valley Domain encompasses the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead DPS. Following are descriptions of the current regulatory status, life histories, population trends and distribution, and the habitat requirements for winter- and spring-run Chinook salmon, and steelhead in the Central Valley. A brief description of the reasons for listing and a current threats assessment is then presented (a detailed threats assessment is presented in Appendix B). Finally, current conservation efforts and biological constraints are discussed, including limiting factors that should be considered for recovery of winter-run and spring-run Chinook salmon, and steelhead within the Central Valley Domain.

2.1 Winter-run Chinook Salmon

2.1.1 ESA Listing Status

The Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) ESU, currently listed as endangered, was listed as a threatened species under emergency provisions of the ESA in August 1989 (54 FR 32085: August 4, 1989) and listed as a threatened species in a final rule in November 1990 (55 FR 46515; November 5, 1990). In June 1992, NMFS proposed that winter-run Chinook salmon be reclassified as an "endangered"[2] species (57 FR 27416; June 19, 1992). NMFS finalized its proposed rule and re-classified winter-run Chinook salmon as an endangered species on January 4, 1994 (59 FR 440). NMFS concluded that winter-run Chinook salmon in the Sacramento River warranted listing as an endangered species due to several factors, including: (1) the continued decline and increased variability of run sizes since its first listing as a threatened species in 1989; (2) the expectation of weak returns in future years as the result of two small year classes (1991 and 1993); and (3) continued threats to the winter-run Chinook salmon.

[2] Under the ESA, an "endangered species" is, with the exception of insects determined to be pests, "…any species which is in danger of extinction throughout all or a significant portion of its range…" (16 USC § 1532(6)).

On June 14, 2004, NMFS issued a proposed rule to reclassify the listing status of winter-run Chinook salmon from endangered to threatened (69 FR 33102). To prevent further decline of the ESU by preventing take of this species from activities that harm fish and fish habitat, NMFS proposed to apply the ESA Section 9(a) take prohibitions with specific limitations to winter-run Chinook salmon under ESA Section 4(d) (69 FR 33102).

Following a series of extensions to the public comment period on the proposed listing determinations, the public comment period closed during November 2004 (69 FR 61348; October 18, 2004). On June 28, 2005, NMFS issued a final listing determination for the Sacramento River winter-run Chinook salmon ESU, which concluded that the Sacramento River winter-run Chinook salmon ESU is "in danger of extinction" due to risks to the ESU's diversity and spatial structure and, therefore, continues to warrant listing as an endangered species under the ESA (70 FR 37160). Additionally, the Sacramento River Winter-run Chinook salmon was listed as endangered under the California ESA in 1989.

The Sacramento River winter-run Chinook salmon ESU includes winter-run Chinook salmon spawning naturally in the Sacramento River and its tributaries, as well as winter-run Chinook salmon that are part of the conservation hatchery program at the Livingston Stone National Fish Hatchery (LSNFH) (70 FR 37160). The Sacramento River winter-run Chinook salmon ESU is depicted in **Figure 2-1**.

2.1.2 Species Description and Taxonomy

Chinook salmon, also referred to as king salmon in California, are the largest of the Pacific salmon. The following physical description of the species is provided by Moyle (2002). Spawning adults are olive to dark maroon in color, without conspicuous streaking or blotches on the sides. Spawning males are darker than females, and have a hooked jaw and slightly humped back. There are numerous small black spots in both sexes on the back, dorsal fins, and both lobes of the tail. They can be distinguished from other spawning salmon by the color pattern, particularly the spotting on the back and tail, and by the dark, solid black gums of the lower jaw. Parr have 6 to 12 parr marks, each equal to or wider than the spaces between them and most centered on the lateral line. The adipose fin of parr is pigmented on the upper edge, but clear at its base. The dorsal fin occasionally has one or more spots on it but the other fins are clear.

2.1.3 Life History/Habitat Requirements

Chinook salmon is the most important commercial species of anadromous fish in California. Chinook salmon have evolved a broad array of life history patterns that allow them to take advantage of diverse riverine conditions throughout the year. Four principal life history variants are recognized and are named for the timing of their upstream migration: fall-run, late fall-run, winter-run, and spring-run. The Sacramento River supports all four runs of Chinook salmon. The larger tributaries to the Sacramento River (American, Yuba, and Feather rivers) and rivers in the San Joaquin Basin also provide habitat for one or more of these runs.

Winter-run Chinook salmon are unique because they spawn during summer months when air temperatures usually approach their yearly maximum. As a result, winter-run Chinook salmon require stream reaches with cold water sources that will protect embryos and juveniles from the warm ambient conditions in summer.

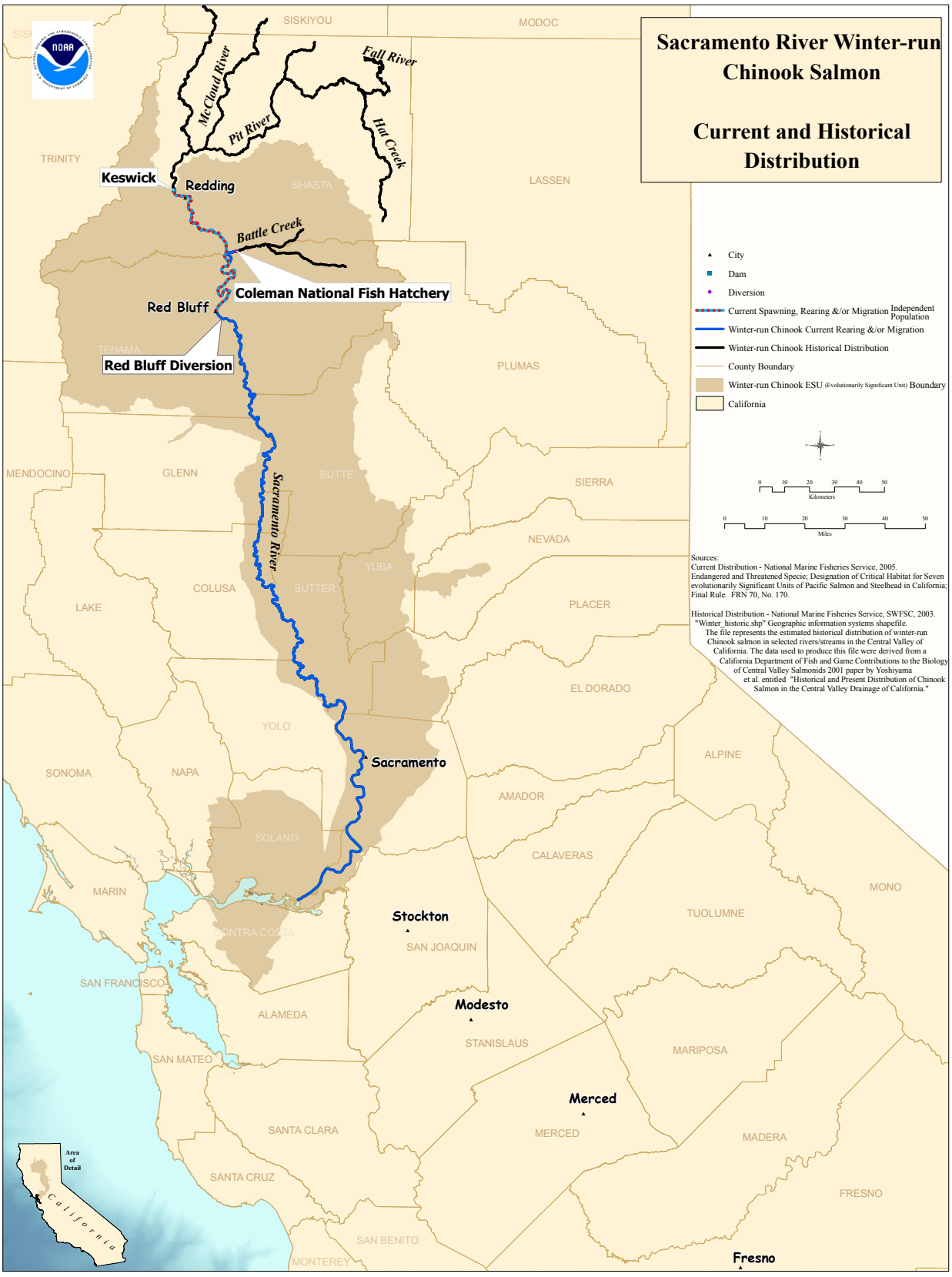


Figure 2-1. Current and Historical Sacramento River Winter-run Chinook Salmon Distribution.

Table 2-1 depicts the temporal occurrence of winter-run Chinook salmon life stages in the Sacramento River. Adult winter-run Chinook salmon immigration and holding (upstream spawning migration) through the Delta and into the lower Sacramento River occurs from December through July, with a peak during the period extending from January through April (USFWS 1995). Winter-run Chinook salmon are sexually immature when upstream migration begins, and they must hold for several months in suitable habitat prior to spawning. Winter-run Chinook salmon primarily spawn in the mainstem Sacramento River between Keswick Dam (River Mile [RM] 302) and the Red Bluff Diversion Dam (RBDD) (RM 243). Spawning occurs between late-April and mid-August, with a peak in June and July as reported by CDFW annual escapement surveys (2000-2006). Winter-run Chinook salmon embryo incubation in the Sacramento River can extend into October (Vogel and Marine 1991).

Winter-run Chinook salmon fry rearing in the upper Sacramento River exhibit peak abundance during September, with fry and juvenile emigration past RBDD primarily occurring from July through November (Poytress and Carillo 2010, 2011, 2012). Emigration of winter-run Chinook salmon juveniles past Knights Landing, located approximately 155.5 river miles downstream of the RBDD, reportedly occurs between November and March, peaking in December, with some emigration continuing through May in some years (Snider and Titus 2000a; Snider and Titus 2000c).

A description of freshwater habitat requirements for winter-run Chinook salmon is presented in the following sections. Habitat requirements are organized by life stage.

Adult Immigration and Holding

Suitable water temperatures for adult winter-run Chinook salmon migrating upstream to spawning grounds range from 57°F to 67°F (NMFS 1997). However, winter-run Chinook salmon are immature when upstream migration begins, and need to hold in suitable habitat for several months prior to spawning. The maximum suitable water temperature reported for holding is 59°F to 60°F (NMFS 1997). Because water temperatures in the lower Sacramento River below the RBDD generally begin exceeding 60 degrees Fahrenheit (°F) in April, it is likely that little, if any, suitable holding habitat exists in the lower Sacramento River. It most likely is only used by adults as a migration corridor. Following installation of the water temperature control device on Shasta Dam in 1997, it is possible that some deep water pool habitat may exist for a short distance downstream of the RBDD with suitable cold water temperatures for adult holding.

Adult Chinook salmon reportedly require water deeper than 0.8 feet and water velocities less than 8 feet per second (ft/sec) for successful upstream migration (Thompson 1972). Adult Chinook salmon are less capable of negotiating fish ladders, culverts, and waterfalls during upstream migration than steelhead, due in part to slower swimming speeds and inferior jumping ability (Bell 1986; Reiser *et al.* 2006).

Chinook salmon generally hold in pools with deep, cool, well-oxygenated water. Holding pools for adult Chinook salmon have reportedly been characterized as having moderate water velocities ranging from 0.5 to 1.3 ft/sec (DWR 2000).

Table 2-1. The Temporal Occurrence of Adult and Juvenile Sacramento River Winter-run Chinook Salmon in the Sacramento River

Winter run relative abundance	High				Medium				Low			
a) Adult freshwater												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento River basin[a,b]												
Sacramento River spawning[c]												
b) Juvenile migration												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento River@ Red Bluff[d]												
Sacramento River @ Knights Landing[e]												
Sacramento trawl @ Sherwood Harbor[f]												
Midwater trawl @Chipps Island[g]												

Sources: [a] (Yoshiyama *et al.* 1998); (Moyle 2002); [b](Myers *et al.* 1998) ; [c] (Williams 2006) ; [d] (Martin *et al.* 2001); [e] Knights Landing Rotary Screw Trap Data, CDFW (1999-2011)); [f,g] Delta Juvenile Fish Monitoring Program(DJFMP), USFWS (1995-2012)

Spawning

Spawning occurs from mid-April to mid-August, peaking in June and July, in the Sacramento River reach between Keswick Dam and RBDD (Vogel and Marine 1991; CDFW Annual escapement survey reports, 2000-2006). Chinook salmon spawn in clean, loose gravel, in swift, relatively shallow riffles, or along the margins of deeper river reaches where suitable water temperatures, depths, and velocities favor redd construction and oxygenation of incubating eggs. Winter-run Chinook salmon were adapted for spawning and rearing in the clear, spring-fed rivers of the upper Sacramento River Basin, where summer water temperatures were typically 50°F to 59°F. Water temperature conditions were created by glacial and snowmelt water percolating through porous volcanic formations that surround Mt. Shasta and Lassen Peak, which cover much of northeastern California. Chinook salmon require clean loose gravel from 0.75 to 4.0 inches in diameter for successful spawning (NMFS 1997). The construction of dams in the upper Sacramento River has eliminated the major source of suitable gravel recruitment to reaches of the river below Keswick Dam. Gravel sources from the banks of the river and floodplain have also been substantially reduced by levee and bank protection measures. Levee and bank protection measures restrict the meandering of the river, which would normally release gravel into the river through natural erosion and deposition processes. Moyle (2002) reported that water velocity preferences (i.e., suitability greater than 0.5) for Chinook salmon spawning range from 0.98 ft/sec to 2.6 ft/sec (0.3 to 0.8 meters per second (m/sec)) at a depth of a few

centimeters (cm) to several meters (m), whereas USFWS (2003) reported that winter-run Chinook salmon prefer water velocities range from 1.54 ft/sec to 4.10 ft/sec (0.47 to 1.25 meters per second) at a depth of 1.4 to 10.1 feet (0.4 to 3.1 m).

Today, Shasta Dam denies access to historical winter-run Chinook salmon spawning habitats and they persist mainly because water released from Shasta Reservoir during the summer has been, for the most part, sufficiently cold. Spawning habitat for Sacramento River winter-run Chinook salmon is restricted to the Sacramento River primarily between RBDD and Keswick Dam.

Embryo Incubation

In the Sacramento River, winter-run Chinook salmon spawning occurs from late April through mid-August. Because the embryo incubation life stage begins with fertilized egg deposition and ends with fry emergence from the gravel, embryo incubation occurs from late April through mid-October. Fry emergence occurs from mid-June through mid-October (NMFS 1997). Within the appropriate water temperature range, eggs normally hatch in 40 to 60 days. Newly hatched fish (alevins) normally remain in the gravel for an additional four to six weeks until the yolk sac has been absorbed (NMFS 1997).

Physical habitat requirements for embryo incubation are the same as the requirements discussed above for spawning. However, it is also important that flow regimes remain relatively constant or at least not decrease significantly during the embryo incubation life stage.

Juvenile Rearing and Outmigration

Upon emergence from the gravel, fry swim or are displaced downstream (Healey 1991). Fry seek streamside habitats containing beneficial aspects such as riparian vegetation and associated substrates that provide aquatic and terrestrial invertebrates for food, predator avoidance cover, and slower water velocities for resting (NMFS 1996a). These shallow water habitats have been described as more productive juvenile salmon rearing habitat than the deeper main river channels. Higher juvenile salmon growth rates, partially due to greater prey consumption rates, as well as favorable environmental temperatures have been associated with shallow water habitats (Sommer *et al.* 2001b). Similar to adult salmon upstream movement, juvenile salmon downstream movement is primarily crepuscular. Once downstream movement has commenced, salmon fry continue this movement until reaching the estuary or they might reside in the stream for a time period that varies from weeks to a year (Healey 1991). Juvenile Chinook salmon migration rates vary considerably, presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson *et al.* (1981) found Chinook salmon fry traveled as fast as 30 kilometers (km) per day in the Sacramento River. Sommer *et al.* (2001b) found travel rates ranging from approximately 0.8 km (0.5 miles) per day, up to more than 9.7 km (6 miles) per day in the Yolo Bypass.

As juvenile Chinook salmon grow they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento by the USFWS (USFWS 1997) exhibited larger juvenile captures in the main channel and smaller-sized fry along the margins. Where the river channel is greater than nine to ten feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1979). Streamflow and/or turbidity increases in the

upper Sacramento River basin are thought to stimulate emigration (Poytress 2007).

Emigration of juvenile Sacramento River winter-run Chinook salmon past RBDD may begin after almost one year in the river. They begin to move down river as early as mid-July, typically peaking numbers in September, and can continue through March in dry years (NMFS 1997; Vogel and Marine 1991). From 1995 to 1999, all Sacramento River winter-run Chinook salmon outmigrating as fry passed RBDD by October, and all outmigrating pre-smolts and smolts passed RBDD by March (Martin *et al.* 2001).

As Chinook salmon begin the smoltification stage, they are found rearing further downstream where ambient salinity reaches 1.5 to 2.5 parts per thousand (Healey 1979). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and vegetated zones (Healey 1979). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson *et al.* 1981; MacFarlane and Norton 2002; Sommer *et al.* 2001a).

Juvenile Chinook salmon movements within the estuarine habitat are dictated by the interaction between tidally-driven salt water intrusions through the San Francisco Bay and fresh water outflow from the Sacramento and San Joaquin rivers. Juvenile Chinook salmon follow rising tides into shallow water habitats from the deeper main channels and return to the main channels when the tides recede (Healey 1991). Kjelson *et al.* (1981) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper three meters of the water column. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay, and grew little in length or weight until they reached the Gulf of the Farallon Islands (MacFarlane and Norton 2002).

Juvenile Sacramento River winter-run Chinook salmon occur in the Delta primarily from November through early May, using size-at-date criteria from trawl data in the Sacramento River at West Sacramento (RM 57) (USFWS 2001). The timing of migration varies somewhat due to changes in river flows, dam operations, and water year type. Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length (FL) of approximately 118 millimeters (mm) and are from five to 10 months of age. Emigration to the ocean begins as early as November and continues through May (Fisher 1994; Myers *et al.* 1998). The importance of the Delta in the life history of Sacramento River winter-run Chinook salmon is not well understood.

Central Valley Chinook salmon begin their ocean life in the Gulf of the Farallones, then they distribute north and south along the continental shelf primarily between Point Conception and Point Arena, although some winter-run Chinook salmon migrate up and beyond Washington State. Upon reaching the ocean, juvenile Chinook salmon feed voraciously on larval and juvenile fishes, plankton, and terrestrial insects (Healey 1991; MacFarlane and Norton 2002). Chinook salmon grow rapidly in the ocean environment, with growth rates dependent on water temperatures and food availability (Healey 1991).

2.1.4 Abundance Trends and Distribution

One of the main threats to the Sacramento River winter-run Chinook salmon ESU is that it consists of only one population. Furthermore the one population is small (Good *et al.* 2005). The population declined from an escapement of near 100,000 in the late 1960s to fewer than 200 in the early 1990s (Good *et al.* 2005). More recent population estimates of 8,218 (2004), 15,730 (2005), and 17,153 (2006) show a three-year average of 13,700 returning winter-run Chinook salmon (CDFW Website 2007). However, the run size decreased to 2,542 in 2007 and 2,850 in 2008. **Figure 2-2** depicts the estimated run sizes of Sacramento River winter-run Chinook salmon from 1967 through 2012.

The LSNFH winter-run Chinook salmon conservation program on the upper Sacramento River is one of the most important reasons that Sacramento River winter-run Chinook salmon still persist. The LSNFH has been producing and releasing winter-run Chinook salmon since 1998. This conservation program has apparently resulted in a net increase in the numbers of returning adult winter-run Chinook salmon, although hatchery fish make up a significant portion of the population (Brown and Nichols 2003). Since 2003, LSNFH winter-run program has exceeded best management practices for conservation and recovery of natural salmonid populations.

Table 2-2 shows the annual number of winter-run Chinook salmon released from the facility from 1998 through 2012. The fish are marked with coded wire tags (CWT), adipose fin clipped and released as smolts each winter in late January or early February. The table also provides information based on data acquired during mark-recapture studies on the amount of time required by the smolts to migrate through the Delta.

Winter-run Chinook salmon originally spawned in the upper Sacramento River system (Little Sacramento, Pit, McCloud and Fall rivers) and in Battle Creek (Yoshiyama *et al.* 1996). There is no evidence that the winter-run existed in any of the other drainages prior to watershed development (Yoshiyama *et al.* 1996). The unique life history timing pattern of winter-run Chinook salmon, requiring cold summer flows, argues against this run occurring in drainages other than the upper Sacramento system and Battle Creek. Watershed development has eliminated all historical spawning habitats above Keswick Dam (approximately 200 river miles) and approximately 47 of the 53 miles of potential habitat in Battle Creek (Yoshiyama *et al.* 1996). Figure 2-1 depicts the current and historical distribution of Sacramento River winter-run Chinook salmon.

Currently, winter-run Chinook salmon spawning habitat is likely limited to the reach of the Sacramento River extending from Keswick Dam downstream to the RBDD. Prior to construction of Shasta and Keswick dams, the mainstem Sacramento River primarily functioned as a rearing and migration corridor because warm water temperatures likely precluded spawning. Winter-run Chinook salmon still have access to Battle Creek throughout the duration of their migration period by either passing through the Coleman National Fish Hatchery (CNFH) (December through February) or by ascending the fish ladder located at the CNFH weir (March through July).

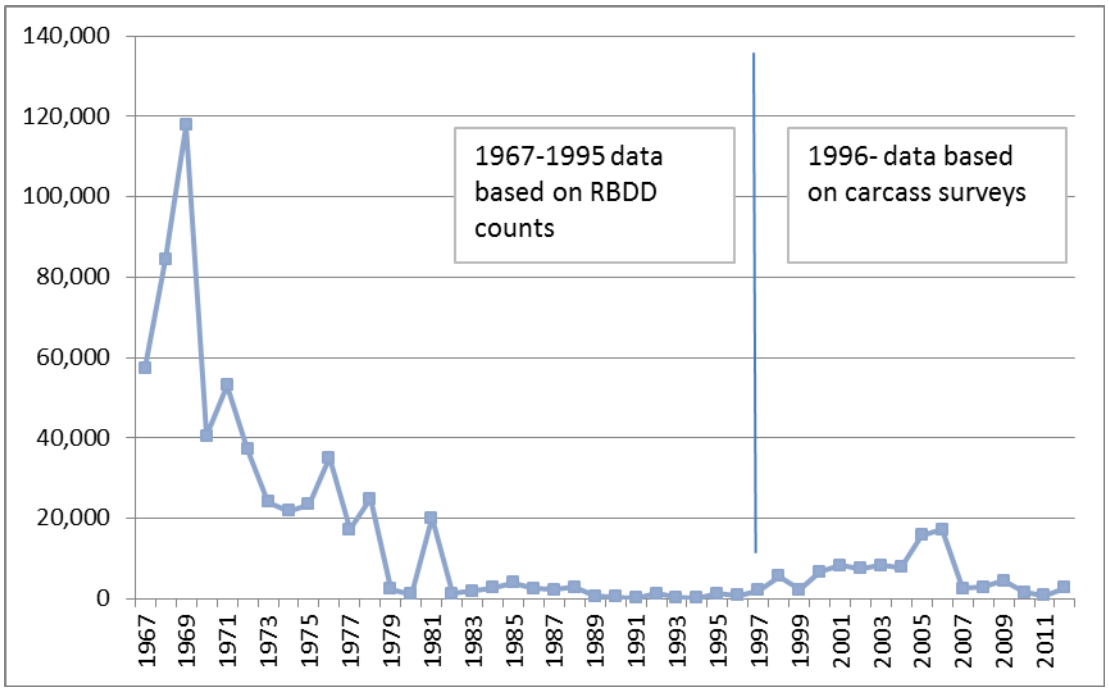


Figure 2-2. Estimated Sacramento River Winter-run Chinook Salmon Run Size (1967 – 2012).
Source: **http://www.fws.gov/stockton/afrp/**

Table 2-2. Winter-run Chinook Salmon Juvenile Releases from LSNFH (Broodyears 1998-2012) and Date of Initial Recapture at Chipps Island.

Brood Year	Upper Sacramento River Release Date	Number of Pre-Smolts Released[1]	Initial Date[2] of Recapture at Chipps Island
1998	1/28/1999	153,908	3/15/1999
1999	1/27/2000	30,840	3/18/2000
2000	2/01/2001	166,206	3/09/2001
2001	1/30/2002	252,684	3/20/2002
2002	1/30/2003	233,613	2/14/2003
2003	2/05/2004	218,617	2/20/2004
2004	2/03/2005	168,261	2/22/2005
2005	2/02/2006	173,344	2/17/2006
2006	2/08/2007	196,288	2/17/2007
2007	1/31/2008	71,883	3/12/2008
2008	1/29/2009	146,211	2/20/2009
2009	2/10-11/2010	198,582	2/26/2010
2010	2/3/2011	123,859	3/21/2011
2011	2/9/2012	194,264	3/23/2012
2012	2/7/2013	181,857	
Source: ([1]USFWS Red Bluff; [2] Redler 2013)			

Winter-run Chinook salmon are believed to have historically occurred in Battle Creek as one of four independent Central Valley populations (Lindley *et al.* 2004). Hydroelectric facilities and operations likely caused the extirpation of winter-run Chinook salmon from the Battle Creek watershed in the early 1900s (Reynolds *et al.* 1993). Watershed restoration actions associated with the Battle Creek Salmon and Steelhead Restoration Project are expected to restore conditions that will allow for successful reintroduction of winter-run Chinook salmon to Battle Creek.

The USFWS initiated the winter-run Chinook salmon propagation program at the CNFH in 1989. Although the winter-run Chinook salmon propagation program was located on Battle Creek, the program had the goal of supplementing natural spawning in the mainstem of the upper Sacramento River. To encourage adults to return to the Sacramento River rather than the location of the hatchery on Battle Creek, hatchery-produced juvenile winter-run Chinook salmon were released into the mainstem Sacramento River at the pre-smolt life stage. Unfortunately, this strategy was not successful at achieving a successful imprint to the upper Sacramento River and adults instead returned to the location of the hatchery on Battle Creek. To improve imprinting to the upper Sacramento River, the winter-run Chinook salmon propagation program was moved in 1997 to a new facility, the LSNFH, located immediately downstream of Shasta Dam. Within a few years of relocating the winter-run Chinook salmon propagation program, returns of adult winter-run Chinook salmon to Battle Creek declined to zero. During recent years, a few winter-run Chinook salmon adults have been observed in Battle Creek; these fish are likely strays from the mainstem Sacramento River.

A winter-run Chinook salmon migration to the Calaveras River may have occurred between 1972 and 1984, but this population appears to have been extirpated by drought conditions, which were exacerbated by irrigation diversions (NMFS 1997; NMFS 1999; NMFS 2003). This Calaveras River population is also thought to have been late fall-run or fall-run Chinook salmon that were mistakenly identified as winter-run Chinook salmon (Yoshiyama *et al.* 2000). Winter-run Chinook salmon did not historically occur in the Calaveras River because the natural river conditions were not suitable to support the species life history requirements (e.g., cold water during the spring and summer for holding, spawning, and embryo incubation).

The Sacramento River winter-run Chinook salmon population is dependent upon the provision of suitably cool water temperatures during the spawning, embryo incubation, and juvenile rearing period. Water temperatures in the upper Sacramento River are the result of interaction among: (1) ambient air temperature; (2) volume of water; (3) water temperature at release from Shasta and Trinity dams; (4) total reservoir storage; (5) location of reservoir thermocline; (6) ratio of Spring Creek Power Plant release to Shasta Dam release; (7) operation of Temperature Control Device (TCD) on Shasta Dam; and (8) tributary inflows (NMFS 1997). Water temperature varies with location and distance downstream of Keswick Dam, and depends upon the annual hydrologic conditions and annual operation of the Shasta-Trinity Division of the CVP (NMFS 1997). In general, water released from Keswick Dam warms as it moves downstream during the summer and early fall months at a critical time for the successful development and survival of juvenile winter-run Chinook salmon (NMFS 1997).

2.1.5 Critical Habitat

Critical habitat for listed salmonids is comprised of physical and biological features essential to the conservation of the species including: space for the individual and population growth and for normal behavior; cover; sites for breeding, reproduction and rearing of offspring; and habitats protected from disturbance or are representative of the historical geographical and ecological distribution of the species. Physical and biological features that are essential for the conservation of winter-run Chinook salmon, based on the best available information, include (1) access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River; (2) the availability of clean gravel for spawning substrate; (3) adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles; (4) water temperatures between 42.5 and 57.5 °F (5.8 and 14.1 degrees Celsius (°C)) for successful spawning, egg incubation, and fry development; (5) habitat and adequate prey free of contaminants; (6) riparian habitat that provides for successful juvenile development and survival; and (7) access of juveniles downstream from the spawning grounds to San Francisco Bay and the Pacific Ocean (58 FR 33212, 33216-17; June 16, 1993).

On August 14, 1992, NMFS published a proposed critical habitat designation for winter-run Chinook salmon (57 FR 36626). The habitat proposed for designation included: (1) the Sacramento River from Keswick Dam, Shasta County (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta; (2) all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; (3) all waters of San Pablo Bay westward of the Carquinez Bridge; and (4) all waters of San Francisco Bay to the Golden Gate Bridge (NMFS 1997).

On June 16, 1993, NMFS issued the final rule designating critical habitat for winter-run Chinook salmon (58 FR 33212). The habitat identified in the final designation is identical to that in the proposed ruling except that critical habitat in San Francisco Bay is limited to those waters north of the San Francisco-Oakland Bay Bridge. **Figure 2-3** depicts the designated critical habitat and distribution for Sacramento River winter-run Chinook salmon.

2.1.6 Reasons for Listing

Section 4 of the ESA requires the Secretary of the Interior or Commerce, depending upon the species involved, to determine if any species is an endangered or threatened species for any of the following factors: (1) present or threatened destruction, modification or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. Each of these factors with respect to winter-run Chinook salmon are discussed in detail in past status reviews (52 FR 6041, February 27, 1987; Good *et al.* 2005; NMFS 2011) and are summarized below.

The Present or Threatened Destruction, Modification, or Curtailment of Winter-run Chinook Salmon's Habitat or Range.

Habitat Loss and Degradation

Key reasons why winter-run Chinook salmon were listed under the ESA in 1989 include blockage of historical habitat by Shasta and Keswick dams, warm water releases from

Shasta Dam, juvenile and adult passage constraints at RBDD and Anderson-Cottonwood Irrigation District's (ACID) diversion dam, water exports in the southern Delta, loss of rearing habitat, heavy metal contamination from Iron Mountain Mine, and entrainment in a large number of unscreened or poorly screened water diversions (NMFS 1997). Since winter-run Chinook salmon were listed, the passage problems at RBDD and ACID's dam have been addressed and contamination from Iron Mountain Mine has been contained. Additionally, water temperature management has improved since the time when the ESU was listed, although warm water temperatures in the Sacramento River downstream of Keswick Dam remain a concern, particularly in drier years.

A Single Population

The range of winter-run Chinook salmon has been greatly reduced by Keswick and Shasta dams on the Sacramento River and by hydroelectric development on Battle Creek. Currently, winter-run Chinook salmon spawning is limited to the mainstem Sacramento River downstream of Shasta and Keswick dams where the naturally-spawning population is artificially maintained by cool water releases from the dams. Within the Sacramento River, the spatial distribution of spawners is largely governed by water year type and the ability of the CVP to manage water temperatures.

The fact that this ESU is comprised of a single population with very limited spawning and rearing habitat increases its risk of extinction due to local catastrophe or poor environmental conditions. There are no other natural populations in the ESU to buffer it from natural fluctuations. A single catastrophe with effects persisting for four or more years could result in extinction of the Sacramento River winter-run Chinook salmon ESU (Lindley *et al.* 2007). Such potential catastrophes include volcanic eruption of Lassen Peak, prolonged drought which depletes the cold water pool in Shasta Reservoir or some related failure to manage cold water storage, a spill of toxic materials with effects that persist for four years, or a disease outbreak.

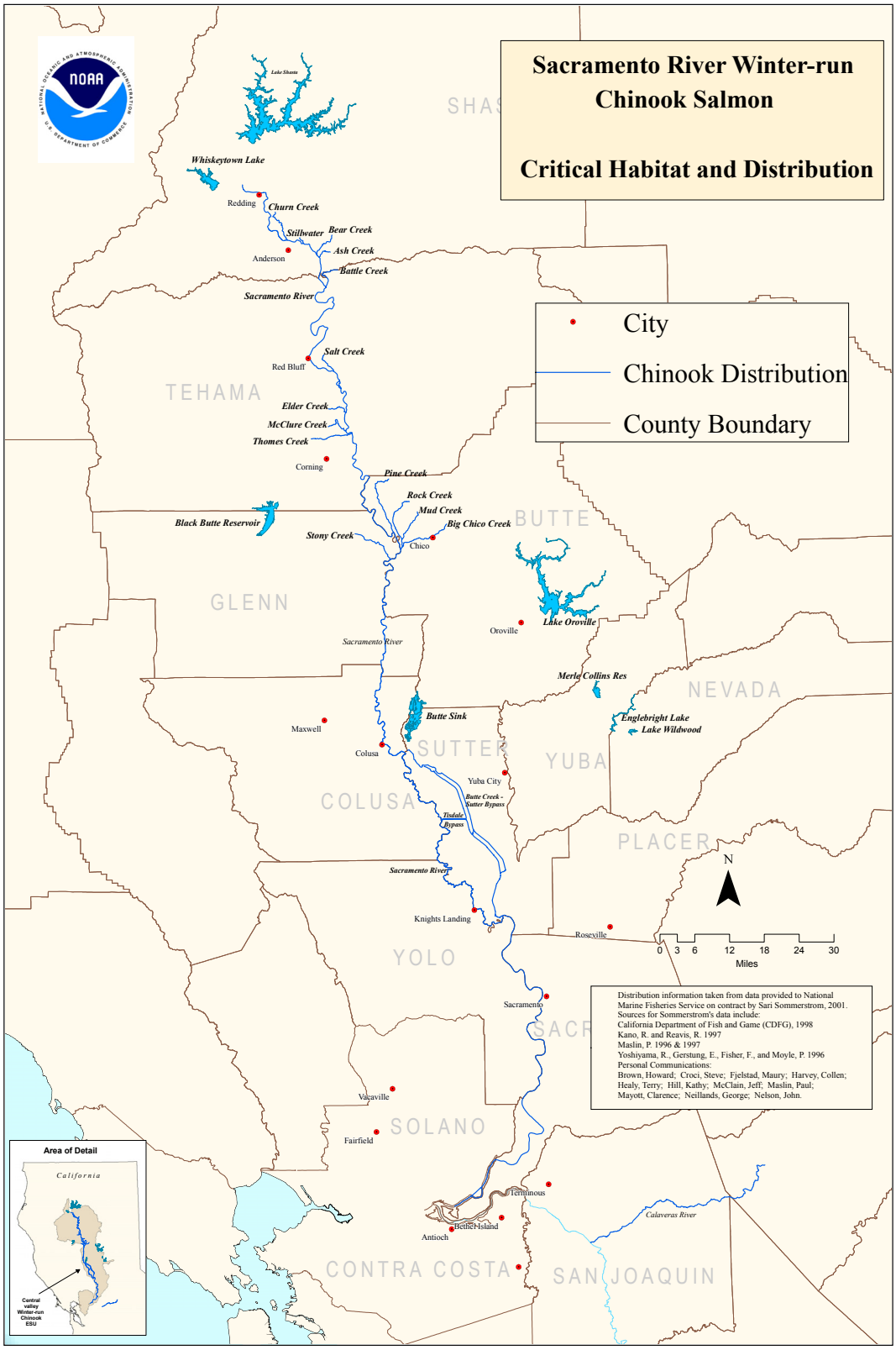


Figure 2-3. Sacramento River Winter-run Chinook Salmon Designated Critical Habitat and Distribution

After two years of drought, Shasta Reservoir storage would be insufficient to provide cold water throughout the winter-run Chinook salmon spawning and embryo incubation season, resulting in partial or complete year-class failure. A severe drought lasting more than 3 years would likely result in the extinction of winter-run Chinook salmon. The probability of extended droughts is increasing as the effects of climate change continue (see Chapter 6).

An ESU that is represented by a single population is less able to withstand environmental variation than an ESU with multiple populations because of reduced life history and genetic diversity. The genetic integrity of winter-run Chinook salmon has been compromised due to having passed through several "bottlenecks" in the 20th century. Construction of Shasta Dam merged at least three independent winter-run Chinook populations into a single population, representing a substantial loss of genetic diversity, life history variability, and local adaptation. Episodes of critically low abundance, particularly in the early 1990s, for the single remaining population imposed ''bottlenecks'' that further reduced genetic diversity (Good *et al.* 2005).

Small Population Size

Chief among the threats facing winter-run Chinook salmon is small population size—escapement fell below 200 fish in the 1990s. In 1989, the CDFW estimated that the winter-run Chinook salmon size was only 547 fish. This unexpectedly small return represented nearly a 75 percent decline from the consistent, but low, run size of 2,000 to 3,000 fish that had occurred since 1982. The run size estimate made by the CDFW for 1991 was 191 fish. Population size declined from highs of near 100,000 fish in the late 1960s, indicating a sustained period of poor survival (Good *et al.* 2005).

Overutilization of Winter-Run Chinook Salmon for Commercial, Recreational, Scientific, or Educational Purposes

Commercial and Recreational Fisheries

When the winter-run Chinook salmon ESU was being evaluated by NMFS for listing under the ESA in the late 1980s, overutilization was not considered to be an important factor in the species decline. A winter-run Chinook salmon status review published in 1987 stated: "NMFS believes that any stock (even marginally healthy one) should be able to maintain stable population levels at the moderate harvest levels to which winter-run chinook are subjected and that harvests have not been instrumental in the decline of winter-run chinook in the Sacramento River" (52 FR 6041, 6045; February 27, 1987). Two years later when the emergency rule to list winter-run Chinook salmon was published, overutilization was still considered unimportant; the primary reasons for the species decline were identified as the construction and operation of RBDD and other human activities that had degraded spawning and rearing habitat in the Sacramento River (54 FR 32085; August 4, 1989).

In the years following the ESA listing of winter-run Chinook salmon, more information on the impacts of the ocean fisheries on the ESU became available, and it was recognized that the fisheries may play a greater role in the viability of the ESU than previously thought. In 1996 and 1997 NMFS issued a biological opinion and amendment which considered the effects of ocean salmon fisheries on winter Chinook salmon. Those documents determined that the ocean fisheries jeopardize

winter-run Chinook salmon and, as part of the reasonable and prudent alternative, fishery restrictions were adopted to protect the ESU.

There have been five biological opinions issued for the ocean salmon fishery's effects on winter-run (1991, 1996/1997, 2002, 2004, and 2010). Similar to the 1996/1997 biological opinion, the 2010 biological opinion determined that the fisheries jeopardized the species. To avoid jeopardy, the action agency (NMFS Sustainable Fisheries Division) continues to implement the reasonable and prudent alternative, which: (1) specifies that the previous consultation standards for winter-run Chinook salmon regarding minimum size limits and seasonal windows south of Point Arena for both the commercial and recreational fisheries will continue to remain in effect at all times regardless of abundance estimates or impact rate limit; and (2) establishes an abundance-based management framework where, during periods of relatively low abundance, the fisheries are restricted in order to lower the impact rate on winter-run Chinook salmon.

Based on data from 1968-73 and 1975, Hallock and Fisher (1985) reported that the freshwater sport fishery harvested an average of 8.5 percent of the in-river run. Freshwater harvest of winter-run Chinook salmon was largely eliminated in 2002 when the opening of the Sacramento River recreational fishing season was adjusted so that the fishery would have only limited overlap with the adult immigration and spawning life stages.

Disease or Predation

Disease

Disease was not an important factor in the listing of winter-run Chinook salmon (52 FR 6041, 6045; February 27, 1987) and the impact of disease has probably been negligible since then. There is no evidence that winter-run Chinook salmon experience unusual levels of disease. Winter-run Chinook salmon juveniles from LSNFH have been notably healthy and free of disease problems. There have been no outbreaks of Infectious Hematopoietic Necrosis Virus or Bacterial Kidney Disease at LSNFH (USFWS 2011).

Predation

Predation is an ongoing threat to this ESU, especially in the lower Sacramento River and Delta where there are high densities of non-native (i.e., striped bass, smallmouth bass, and largemouth bass) and native species (e.g., pikeminnow) that prey on outmigrating juvenile salmon. The presence of man-made structures in the freshwater habitat likely contributes to increased predation levels. Since the 1970s, RBDD has been an area of high salmon predation, primarily by pikeminnow (Vogel 2011). Numerous corrective measures at RBDD have been taken over the last few decades to reduce predation. Since 2012, the dam is no longer operated with the gates in. This operational change should greatly reduce predation on juvenile salmon at RBDD.

Degraded conditions in the lower Sacramento River and Delta are a significant source of mortality for Chinook salmon (Cummins *et al.* 2009; Vogel 2011). Predation is hypothesized to be an important source of this mortality (Cummins *et al.* 2009; Vogel 2011; Moyle 2002). Moyle (2002) states, "*What we do not know is whether these species [native species], now mostly depleted, can recover their populations in the presence of a large population of striped bass…A large population of striped bass, for example, could devastate a small population of salmon*." Consistent with Moyle (2002), a predation model developed by Lindley and Mohr (2003)

found that a large striped bass population may impede winter-run Chinook salmon recovery.

The Inadequacy of Existing Regulatory Mechanisms

Laws relevant to the protection and restoration of winter-run Chinook salmon are the ESA, the Magnuson-Stevens Fishery Conservation and Management Act, the CVPIA, the Federal Power Act, the Fish and Wildlife Coordination Act, the Clean Water Act, the National Environmental Policy Act, and numerous State laws administered by CDFW, DWR, or the SWRCB. These laws and associated regulations generally provide adequate mechanisms for recovering winter-run Chinook salmon (52 FR 6041, 6046; February 27, 1987); however some of the goals of these existing mechanisms have not yet been achieved.

Other Natural or Manmade Factors Affecting the Continued Existence of Winter-Run Chinook Salmon

Hatchery Production

Although the LSNFH winter-run Chinook salmon program is one of the most important reasons that the species still persists, the use of a hatchery program to supplement the population raises concerns about the genetic integrity and fitness of the population. There is a strong perception that hatchery fish may negatively affect the genetic constitution of wild fish (Allendorf *et al.* 1997; Hindar *et al.* 1991; Waples 1991). One of the main factors contributing to this perception is the observation of a reduction in wild fish populations following the initiation of a hatchery release program (Hilborn 1992; Washington and Koziol 1993). An explanation offered for this observation is that hatchery fish are adapted to the hatchery environment; therefore, natural spawning with wild fish reduces the fitness of the natural population (Taylor 1991). Researchers from the University of California at Davis have documented that hatchery Chinook salmon were more vulnerable to predation by Sacramento pikeminnow as they pass RBDD than were wild Chinook salmon (Lufkin 1996). To minimize hatchery effects in the population, LSNFH preferentially collects wild winter-run Chinook salmon adults for the program. A maximum of 15 percent of the estimated winter-run Chinook salmon run, but no more than 120 natural-origin winter-run Chinook salmon per broodyear may be collected for broodstock use. If necessary, up to 10 percent (a maximum of 12 fish) of the LSNFH broodstock may be composed of hatchery adult returns. To ensure that hatchery production does not overwhelm the recovering population, annual hatchery releases are kept within the 200,000 to 250,000 range and the effects of the program are well-monitored.

The rising proportion of hatchery fish among returning adults threatens to shift the population from a low to moderate risk of extinction. Lindley *et al.* (2007) recommend that in order to maintain a low risk of genetic introgression with hatchery fish, no more than five percent of the naturally-spawning population should be composed of hatchery fish. Since 2001, hatchery origin winter-run Chinook salmon have made up more than five percent of the run, and in 2005 the contribution of hatchery fish exceeded 18 percent (Lindley *et al.* 2007). Potential consequences to wild fish stocks from hatchery production include hybridization and genetic introgression, competition, predation, and increasing fishing pressure (Waples 1991).

Because LSNFH is a conservation hatchery using best management practices, a more appropriate tool to determine associated genetic risk may be the Proportionate Natural Influence (PNI). PNI is an index of gene flow rates between hatchery and natural populations that can be calculated by using the following formula:

PNI Approx = pNOB/(pNOB+pHOS)

Where pNOB is defined as the Proportion of Natural Origin Brood Stock, and pHOS as the Proportion of Hatchery Origin In-River Spawners.

The Hatchery Scientific Review Group (HSRG), an independent scientific review panel for the Pacific Northwest Hatchery Reform Project, developed guidelines as minimal requirements for minimizing genetic risks of hatchery programs to naturally spawning populations. One of those guidelines is that PNI must exceed 0.5 in order for the natural environment to have a greater influence than the hatchery environment on the genetic constitution of a naturally-spawning population. A second guideline is that PNI should be greater than 0.67 for natural populations considered essential for the recovery or viability of an ESU/DPS.

The average PNI for LSNFH winter-run Chinook salmon from 2003 through 2012 is 0.89 (Null 2013); a level which satisfies the HSRG guidelines for minimizing the genetic effects of hatchery programs on natural populations.

In summary, LSNFH is one of the most important reasons that Sacramento River winter-run Chinook salmon still persist and the hatchery is considered beneficial to the ESU over the short term. However, if the continued existence of the ESU depends on LSNFH, it by any reasonable definition cannot be characterized as having a low risk of extinction, and therefore the ESU should not be delisted on that basis. If the status of the ESU improves such that it has a high likelihood of persistence without LSNFH, then the LSNFH winter-run Chinook program should be phased out and eventually terminated. To obtain long-term sustainability, ESUs need to have some low-risk populations with essentially no hatchery influence in the long run; they could have additional populations with some small hatchery influence, but there needs to be a core of populations that are not dependent on hatchery production.

2.1.7. Threats Assessment

A detailed threats assessment was conducted for the Sacramento River winter-run Chinook salmon ESU (Appendix B). The threats/stressors affecting each winter-run Chinook salmon life stage are described in that appendix. A stressor matrix[3], in the form of a single Microsoft Excel worksheet, was developed to structure the winter-run Chinook salmon population, life stage, and stressor information into hierarchically-related tiers so that stressors to the ESU could be prioritized. The individual tiers within the matrix, from highest to lowest, are: (1) population; (2) life stage; (3) primary stressor category; and (4) specific stressor. These individual tiers were related hierarchically so that each variable within a tier had several associated variables at the next lower tier, except at the lowest (i.e., fourth) tier.

[3] For winter-run Chinook salmon, a single stressor matrix was developed corresponding to the mainstem upper Sacramento River population, whereas for spring-run Chinook salmon and steelhead, multiple individual stressor matrices were developed corresponding to each of the extant populations for these species.

The general steps required to develop and utilize the winter-run Chinook salmon stressor matrix are described as follows:

- Each life stage within the population was weighted so that all life stage weights in the population summed to one
- Each primary stressor category within a life stage was weighted so that all primary stressor category weights in a life stage summed to one
- Each specific stressor within a primary stressor category was weighted so that all specific stressor weights in a primary stressor category summed to one
- A composite weight for each specific stressor was obtained by multiplying the product of the population weight, the life stage weight, the primary stressor weight, and the specific stressor weight by 100
- A normalized weight for each specific stressor was obtained by multiplying the composite weight by the number of specific stressors within a particular primary stressor group
- The stressor matrix was sorted by the normalized weight of the specific stressors in descending order

Specific information explaining the individual steps taken to generate this prioritized list are provided in Appendix B.

The completed stressor matrix sorted by normalized weight is a prioritized list of the life stage-specific stressors affecting the ESU. Each life stage of winter-run Chinook salmon is affected by stressors of "Very High" importance. These stressors include:

- The barriers of Keswick and Shasta dams, which block access to historic staging and spawning habitat
- Flow fluctuations, water pollution, water temperature impacts in the upper Sacramento River during embryo incubation
- Loss of juvenile rearing habitat in the form of lost natural river morphology and function, and lost riparian habitat and instream cover
- Predation during juvenile rearing and outmigration
- Ocean harvest
- Entrainment of juveniles at the C.W. Jones and Harvey O. Banks pumping plants

The complete prioritized list of life stage-specific stressors to the Sacramento River winter-run Chinook salmon ESU is presented in Appendix B.

2.1.8 Conservation Measures

Artificial Propagation

Captive broodstock and conservation hatchery programs were established for the Sacramento River winter-run Chinook salmon ESU in the early 1990s. The captive broodstock program was originally located at the Bodega Marine Laboratory and the hatchery program was initially established at the CNFH and then later re-located to the LSNFH. These programs were established to augment the

naturally spawning population in the Sacramento River as well as to provide a captive broodstock in case the natural population was unexpectedly decimated. The programs were successful in helping to stop winter-run Chinook salmon from going extinct. The captive broodstock program was discontinued in January 2005 and the final captive broodstock fish were utilized for a research study in 2006. The LSNFH winter-run Chinook salmon hatchery program continues to supplement the natural population while minimizing genetic risks.

LSNFH is expected to play a continuing role as a conservation hatchery for the protection and enhancement of the existing winter-run Chinook salmon population below Keswick and Shasta dams, and potentially will play a role in re-establishing winter-run salmon to habitats upstream of Shasta Dam and to Battle Creek.

Endangered Species Act

Actions taken by Reclamation and DWR to ensure that their operations of the CVP and SWP comply with Section 7 of the ESA likely contributed to habitat improvements benefiting the Sacramento River winter-run Chinook salmon ESU. Implementation of the reasonable and prudent alternative in biological opinions for the CVP and SWP has improved fish habitat and passage conditions in the Sacramento River and the Delta through maintenance of minimum water flows during fall and winter months, establishment of temperature criteria to support spawning and rearing upstream of RBDD (coupled with water releases from Shasta Dam), operation of the RBDD gates for improved adult and juvenile fish passage, and constraints on Delta water exports to reduce impacts on juvenile outmigrants.

Ecosystem Restoration Program

Two large, ongoing comprehensive conservation programs in the Central Valley provide a wide range of ecosystem and species-specific protective efforts potentially benefiting Chinook salmon – the State's ERP (formerly the CALFED Bay/Delta Program) and the CVPIA. CALFED was a cooperative effort of more than 20 State and Federal agencies working with local communities to improve water quality and reliability for California's water supplies, and has made efforts to restore the Bay/Delta. The ERP has funded projects involving habitat restoration, floodplain restoration and protection, instream and riparian habitat restoration and protection, fish screening and passage, research on non-native species and contaminants, research and monitoring of fishery resources, and watershed stewardship and outreach. A full description of ERP projects and achievements is available at http://www.dfg.ca.gov/ERP/. A few ERP accomplishments that improved salmon and steelhead habitat include:

- restoration and protection of 8,000 acres of wetlands in San Pablo Bay and Suisun Marsh;
- protection of more than 11,000 acres and 18 river miles for riparian and shaded-riverine-aquatic habitat;
- restoration of more than 3,900 acres and 59 miles of riparian and riverine aquatic habitat; and
- installation or improvement of 70 fish screens (11 that draw >250 cfs).

Overall, the ERP has been a beneficial program for winter-run Chinook salmon. Continued implementation of stage two of ERP, which runs through the year 2030, will be needed to advance winter-run Chinook salmon recovery.

CALFED also established the Environmental Water Account (EWA) to protect migratory fish from entrainment and to increase water supply reliability for the SWP and CVP. A review of the success of EWA revealed that the benefit to salmon is unclear (White and Brandes 2004).

Central Valley Project Improvement Act

The CVPIA balances the priorities of fish and wildlife protection, restoration, and mitigation with irrigation, domestic water use, fish and wildlife enhancement, and power augmentation. The CVPIA was enacted in 1992 with a mandated goal of doubling the natural production of anadromous fish, including winter-run Chinook salmon. Reclamation and USFWS have conducted studies and implemented hundreds of actions, including modifications of CVP operations, management and acquisition of water for fish and wildlife needs, flow management for fish migration and passage, increased water flows, replenishment of spawning gravels, restoration of riparian habitats, and screening of water diversions. Individual actions implemented under the CVPIA that have improved conditions for winter-run Chinook salmon include:

- Installing and operating the Shasta Temperature Control Device;
- Improved and continued efforts for passage at RBDD;
- Completion of state-of-the-art screen and passage improvements at the diversions for the Glen-Colusa Irrigation District and Anderson-Cottonwood Irrigation District; and
- Screening most of the larger diversions in the system (Cummins *et al.* 2009).

An independent review of the CVPIA Fisheries Program identified several successes of the program, but ultimately concluded that, "*After 16 years of implementation the CVPIA anadromous fish program is not close to its stated doubling goal, nor has it solved the problems that led to the listing of several species of salmon and steelhead under the ESA* (Cummins *et al*. 2009)."

Fisheries Management Measures

Seasonal time/area restrictions and minimum size limits for the sport and commercial ocean salmon fisheries are in place for the protection of winter-run Chinook salmon. Additionally, there is a regulatory management framework to further reduce ocean fishery impacts when the status of winter-run is declining or unfavorable (NMFS 2012a). The State has established specific in-river fishing regulations and no-retention prohibitions designed to protect winter-run Chinook salmon during their freshwater life stages.

2.2 Spring-run Chinook Salmon

2.2.1 ESA Listing Status

Central Valley spring-run Chinook salmon (*O. tshawytscha*), currently listed as threatened, were proposed as endangered by NMFS on March 9, 1998 (63 FR 11482). NMFS (1998) concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction because native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin, which represented a large portion of the historic range and abundance of the ESU as a whole. Moreover, the only streams considered to have wild spring-run Chinook salmon at that time were Mill and Deer creeks, and Butte Creek (tributaries to the Sacramento River). These populations were considered relatively small with sharply declining trends.

Hence, demographic and genetic risks due to small population sizes were considered to be high. NMFS (NMFS 1998) also determined that habitat problems were the most important source of ongoing risk to this ESU.

On September 16, 1999, NMFS listed the Central Valley ESU of spring-run Chinook salmon as a "threatened" species (64 FR 50394). Although in the original Chinook salmon status review and proposed listing it was concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction (Myers *et al.* 1998), in the status review update, the Biological Review Team (BRT) majority shifted to the view that this ESU was not in danger of extinction, but was likely to become endangered in the foreseeable future. A major reason for this shift was data indicating that a large run of spring-run Chinook salmon on Butte Creek in 1998 was naturally produced, rather than strays from the Feather River Fish Hatchery (FRFH).

NMFS determined that the Central Valley spring-run Chinook salmon ESU is likely to become endangered in the foreseeable future throughout all or a significant portion of their range after reviewing the best available information, including public and peer review comments, biological data on the species' status, and an assessment of protective efforts (64 FR 50394). On March 11, 2002, pursuant to a January 9, 2002 rule issued by NMFS under Section 4(d) of the ESA (16 USC § 1533(d)), the take restrictions that apply statutorily to endangered species began to apply with specific limitations to the Central Valley ESU of spring-run Chinook salmon (67 FR 1116). On June 14, 2004, following a five-year species status review, NMFS proposed that the Central Valley spring-run Chinook salmon remain a threatened species based on the BRT strong majority opinion that the Central Valley spring-run Chinook ESU is ''likely to become endangered within the foreseeable future'' (69 FR 33102). The BRT based its conclusions on the greatly reduced distribution of the Central Valley spring-run Chinook ESU and hatchery influences on natural populations. In addition, the BRT noted moderately high risk for the abundance, spatial structure, and diversity Viable Salmonid Population (VSP) criteria, and a lower risk for the productivity criterion reflecting positive trends. On June 28, 2005, NMFS reaffirmed the threatened status of the Central Valley spring-run Chinook salmon ESU (70 FR 37160). **Figure 2-4** depicts the Central Valley spring-run Chinook salmon ESU.

2.2.2 Species Description and Taxonomy

The Chinook salmon, also largely referred to as king salmon in California, are the largest of the Pacific salmon. The following physical description of the species is provided by Moyle (2002). Spawning adults are olive to dark maroon in color, without conspicuous streaking or blotches on the sides. Spawning males are darker than females, and have a hooked jaw and slightly humped back. There are numerous small black spots in both sexes on the back, dorsal fins, and both lobes of the tail. They can be distinguished from other spawning salmon by the color pattern, particularly the spotting on the back and tail, and by the dark, solid black gums of the lower jaw. Parr have 6 to 12 parr marks, each equal to or wider than the spaces between them and most centered on the lateral line. The adipose fin of parr is pigmented on the upper edge, but clear at its base. The dorsal fin occasionally has one or more spots on it but the other fins are clear.

2.2.3 Life History/Habitat Requirements

The habitat requirements for spring-run Chinook salmon are the same as those described above for winter-run Chinook salmon. The primary differences in the habitat requirements between the two runs are the duration and the time of year that the different life stages of the species utilize the habitat.

Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFW 1998), and enter the Sacramento River between March and September, primarily in May and June (Moyle 2002; Yoshiyama *et al.* 1998). Spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning (Moyle 2002). While maturing, adults hold in deep pools with cold water. Spawning normally occurs between mid-August and early October, peaking in September (Moyle 2002).

The length of time required for embryo incubation and emergence from the gravel is dependent on water temperature. For maximum embryo survival, water temperatures reportedly must be between 41°F and 55.4°F and oxygen saturation levels must be close to maximum (Moyle 2002).

Under those conditions, embryos hatch in 40 to 60 days and remain in the gravel as alevins (the life stage between hatching and egg sack absorption) for another 4 to 6 weeks before emerging as fry (Moyle 2002).

Spring-run fry emerge from the gravel from November to March (Moyle 2002). Juveniles may reside in freshwater for 12 to 16 months, but some migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching (CALFED 2000b). The average size of fry migrants (approximately 40 mm between December and April in Mill, Butte, and Deer creeks) reflects a prolonged emergence of fry from the gravel (Lindley *et al.* 2004). By contrast, studies in Butte Creek (Ward *et al.* 2003) found the majority of spring-run migrants to be fry moving downstream primarily during December, January, and February, and that these movements appeared to be influenced by flow. Small numbers of spring-run juveniles remained in Butte Creek to rear and migrate as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill and Deer creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley *et al.* 2004). By contrast, data collected on the Feather River suggests that the bulk of juvenile emigration occurs during November and December (DWR and Reclamation 1999; Painter *et al.* 1977). Seesholtz *et al.* (2003) speculate that because juvenile rearing habitat in the Low Flow Channel of the Feather River is limited, juveniles may be forced to emigrate from the area early due to competition for resources. **Table 2-3** depicts the temporal occurrence of spring-run life stages in the Sacramento River.

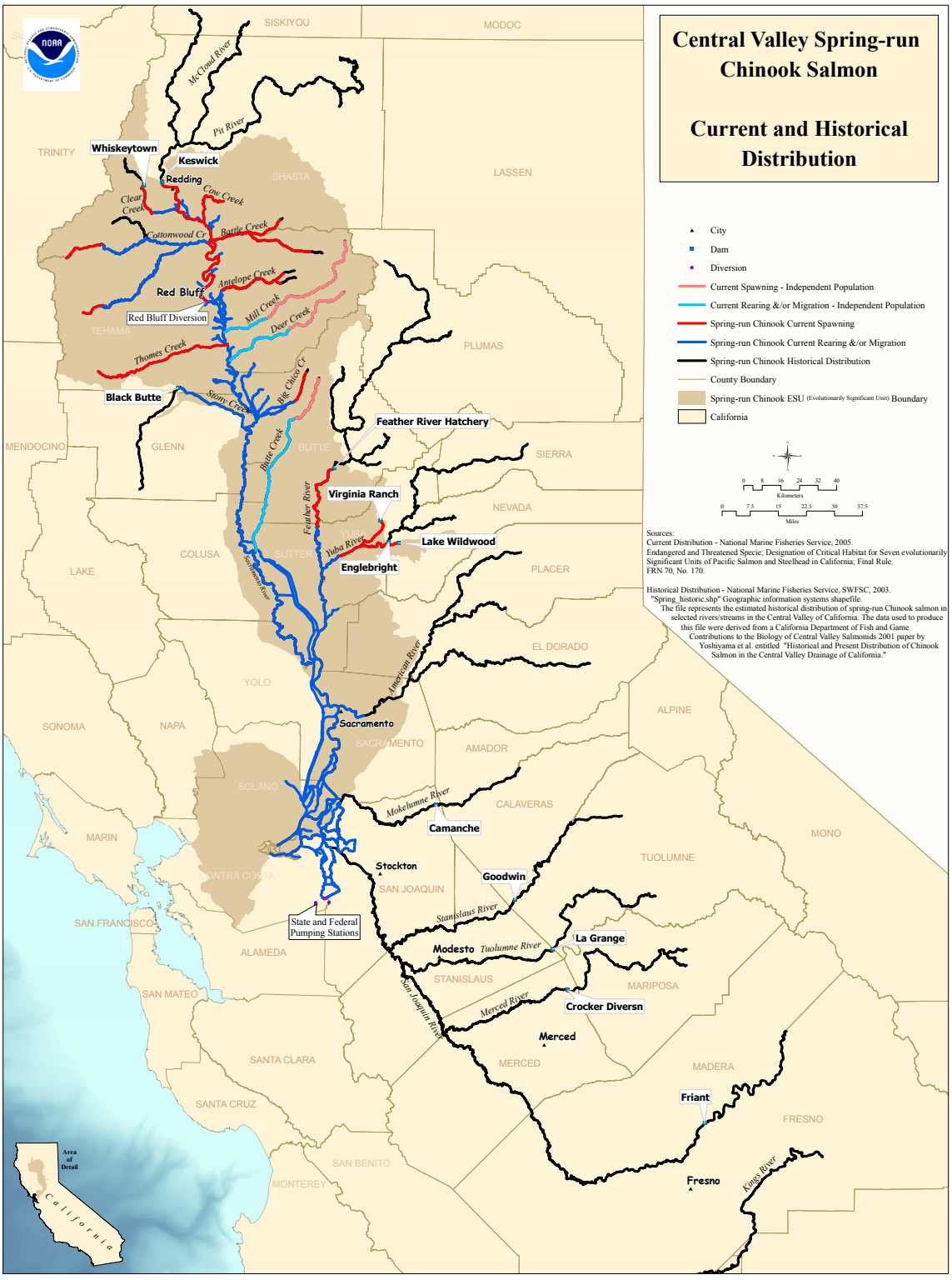


Figure 2-4. Central Valley Spring-run Chinook Salmon ESU, and Current and Historical Distribution.

2.2.4 Abundance Trends and Distribution

Historically, spring-run Chinook salmon occurred in the headwaters of all major river systems in the Central Valley where natural barriers to migration were absent.

The Central Valley as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFW 1998). More than 500,000 Central Valley spring-run Chinook salmon were caught in the Sacramento-San Joaquin commercial fishery in 1883 (Yoshiyama *et al.* 1998).

Although spring-run Chinook salmon were probably the most abundant salmonid in the Central Valley under historic conditions, large dams eliminated access to almost all historical habitat and the spring-run has suffered the most severe declines of any of the four Chinook salmon runs in the Sacramento River Basin (Fisher 1994).

Beginning in the 1880s, harvest, water development, construction of dams that prevented access to headwater areas and habitat degradation significantly reduced the number and range of spring-run Chinook salmon.

Before construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River (Fry 1961). The San Joaquin populations essentially were extirpated by the 1940s, with only small remnants of the run persisting through the 1950s in the Merced River (Yoshiyama *et al.* 1998). From 1970 through 2012, Central Valley spring-run Chinook salmon run size estimates have fluctuated from highs near 30,000 to lows near 3,000 (**Figure 2-5**).

The only known streams that currently support self-sustaining populations of non-hybridized spring-run Chinook salmon in the Central Valley are Mill, Deer and Butte creeks (CDFW 1998). Each of these populations is small and isolated. **Figure 2-6** depicts the annual run size estimates for these populations. These populations are genetically distinct from other populations classified as spring-run in the Central Valley (e.g., Feather River) (DWR 2004a). Banks *et al.* (2000) suggest the spring-run phenotype in the Central Valley is shown by two genetically distinct subpopulations, 1) Butte Creek, and 2) Deer and Mill creeks. Although the spring-run Chinook salmon in Deer and Mill creeks represent a single genetically distinct subpopulation, they are considered in this Recovery Plan as two separate populations because Deer and Mill creeks provide two discrete spawning areas with independent population dynamics Lindley *et al.* (2004).

The FRFH was constructed in the mid-1960s by DWR to mitigate for the loss of Chinook salmon and steelhead spawning habitat by construction of Oroville Dam. The FRFH was opened in 1967 (DWR 2002) and is operated by CDFW. The FRFH is the only hatchery in the Central Valley producing spring-run Chinook salmon. The current production target for spring-run Chinook salmon at the FRFH is two million smolts.

Prior to 2004, FRFH hatchery staff differentiated spring-run from fall-run by opening the ladder to the hatchery on September 1. Those fish ascending the ladder from September 1 through September 15 were assumed to be spring-run Chinook salmon while those ascending the ladder after September 15 were assumed to be fall-run (Kastner 2003). This practice led to considerable hybridization between spring- and fall-run Chinook salmon (DWR 2004a). Since 2007, the fish ladder remains open for 9.5 months of the year (September 15

through June 30) and those fish ascending the ladder are marked with an external tag and returned to the river. This practice allows FRFH staff to identify those previously marked fish as phenotypic spring-run when they re-enter the ladder in September reducing the potential for hybridization between the spring and fall runs (DWR 2004a).

The FRFH also releases a significant portion of its spring-run production into San Pablo Bay (1,000,000 juvenile smolts). This practice increases the chances that these fish will stray into other Central Valley streams when they return as adults to spawn. This straying has the potential for genetic hybridization to occur between FRFH spring-run with local spring-run and fall-run populations, increasing the risk of genetic introgression and subsequent homogeneity among Central Valley Chinook salmon runs. In addition, this straying has the potential to transfer genetic material from hatchery fish to wild naturally-spawning fish and is generally viewed as an adverse hatchery impact. Of particular concern would be the straying of hatchery fish into Deer, Mill, or Butte creeks, affecting the genetic integrity of the only significantly distinct spring-run Chinook salmon in the Central Valley (DWR 2004a). **Figure 2-7** shows the total Central Valley spring-run Chinook salmon spawning run size estimates broken down by constituent component for the years 1970 through 2008. The figure indicates that since about 1982, the proportion of the spring-run in the Central Valley comprised of FRFH fish has substantially increased. The current and historical distribution of Central Valley spring-run Chinook salmon was presented in **Figure 2-4**.

Table 2-3. Temporal Occurrence of Adult and Juvenile Sacramento River Spring-run Chinook Salmon in the Sacramento River

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Sacramento River Basin[1,2]												
Sacramento River[3]												
Mill Creek[4]												
Deer Creek[4]												
Butte Creek[4]												
Juvenile												
Sacramento River Tributaries[5]												
Upper Butte Creek[6]												
Mill, Deer, Butte Creeks[4]												
Sacramento River at RBDD[3]												
Sacramento River at KL[7]												
Chipps Island (Trawl)[8*]												

Sources: [1]Yoshiyama et al. 1998; [2]Moyle 2002; [3]Myers et al. 1998; [4]Lindley et al. 2006a; [5]CDFW 1998; [6]McReynolds et al. 2005; Ward et al. 2002, 2003; [7]Snider and Titus 2000, [8]USFWS 2001

Relative Abundance: = High = Medium = Low

* Note: By the time yearly spring-run Chinook salmon reach Chipps Island they cannot be distinguished from fall-run yearlings.

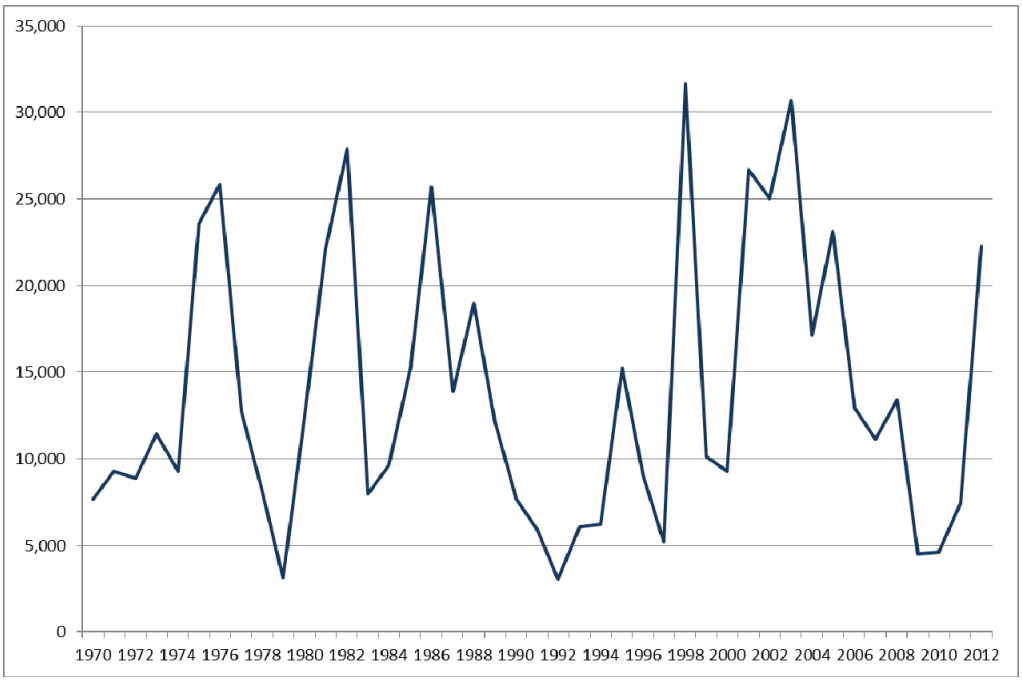


Figure 2-5. Central Valley Spring-run Chinook Salmon Run Size Estimates (1970–2012).

Source: (CDFW GRANDTAB http://www.fws.gov/stockton/*)*

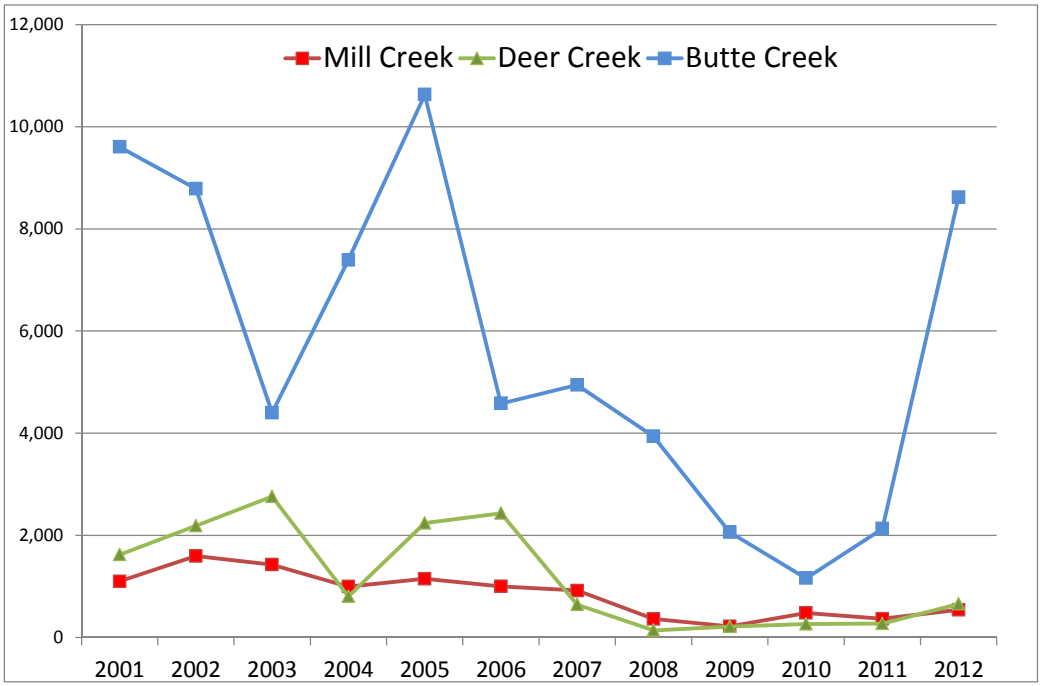


Figure 2-6. Mill, Deer, and Butte Creek Spawning Run Size Estimates for Central Valley Spring-run Chinook Salmon (2001–2012). All estimates were obtained by snorkel surveys. Source: (CDFW GRANDTAB and Annual Reports)

RECIRC2590.

2.2.5 Critical Habitat

When designating critical habitat, NMFS focuses on "Primary Constituent Elements" (PCEs), which are the principal biological or physical constituent elements within the defined area that are essential to the conservation of the listed species (50 CFR 424.12(b)). PCEs considered essential for the conservation of the Central Valley spring-run Chinook salmon ESU are those sites and habitat components that support one or more life stages(50 CFR 226.211(c)), including:

- Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.
- Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
- Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.
- Estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

NMFS proposed[4] critical habitat for Central Valley spring-run Chinook salmon on December 10, 2004 (69 FR 71880), and published a final rule designating critical habitat for this species on September 2, 2005 (70 FR 52488). **Figure 2-8** depicts the designated critical habitat and distribution for Central Valley spring-run Chinook salmon.

[4] NMFS proposed critical habitat for Central Valley spring-run Chinook salmon on February 5, 1999 (63 FR 11482) in compliance with Section 4(a)(3)(A) of the ESA, which requires that, to the maximum extent prudent and determinable, NMFS designates critical habitat concurrently with a determination that a species is endangered or threatened (NMFS 1999). On February 16, 2000 (65 FR 7764), NMFS published a final rule designating critical habitat for Central Valley spring-run Chinook salmon. Critical habitat was designated to include all river reaches accessible to listed Chinook salmon in the Sacramento River and its tributaries in California. Also included were river reaches and estuarine areas of the Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait, all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge.

In response to litigation brought by the National Association of Homebuilders (NAHB) (NAHB v. Evans, 2002 WL 1205743 No. 00–CV–2799 (D.D.C.)), NMFS sought judicial approval of a consent decree withdrawing critical habitat designations for 19 Pacific salmon and *O. mykiss* ESUs. The District Court in Washington DC approved the consent decree and vacated the critical habitat designations by Court order on April 30, 2002 (NAHB v. Evans, 2002 WL 1205743 (D.D.C. 2002)).

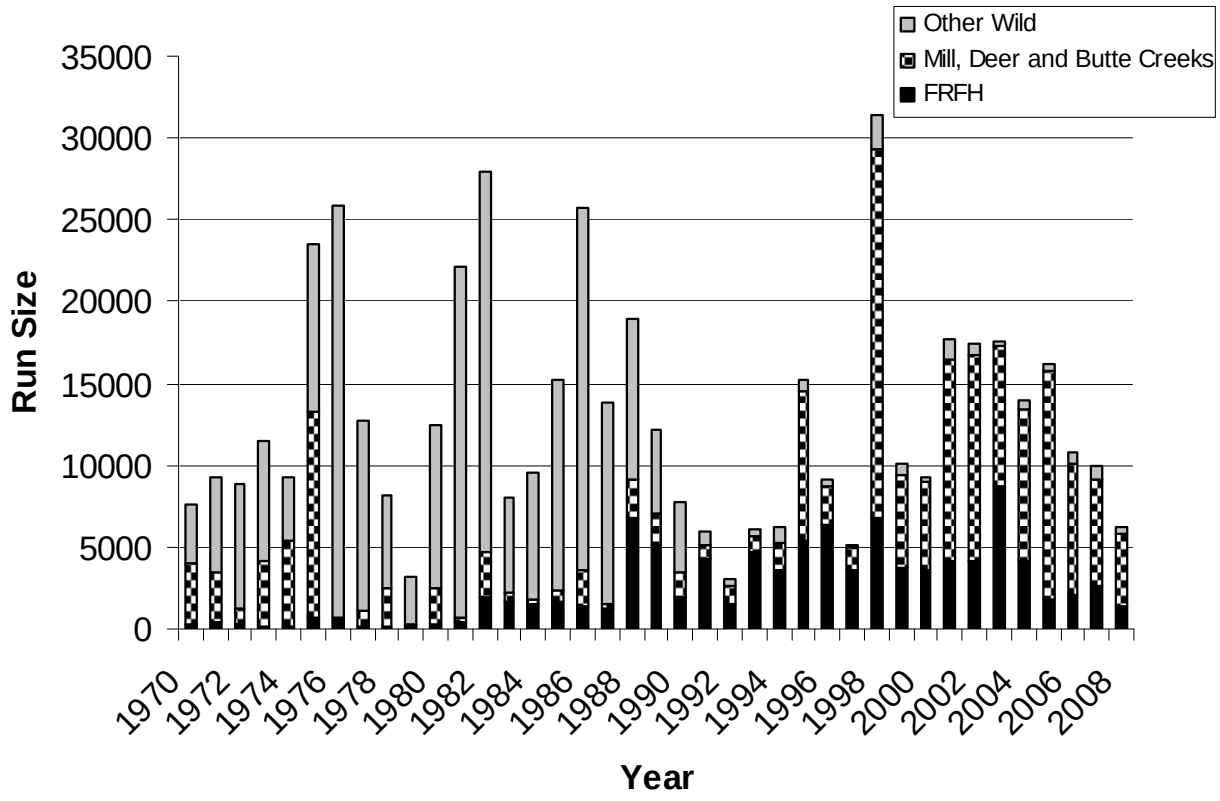


Figure 2-7. Central Valley Spring-run Chinook Salmon Spawning Run Size Composition (1970–2008)

Source: (CDFW GRANDTAB 2009)

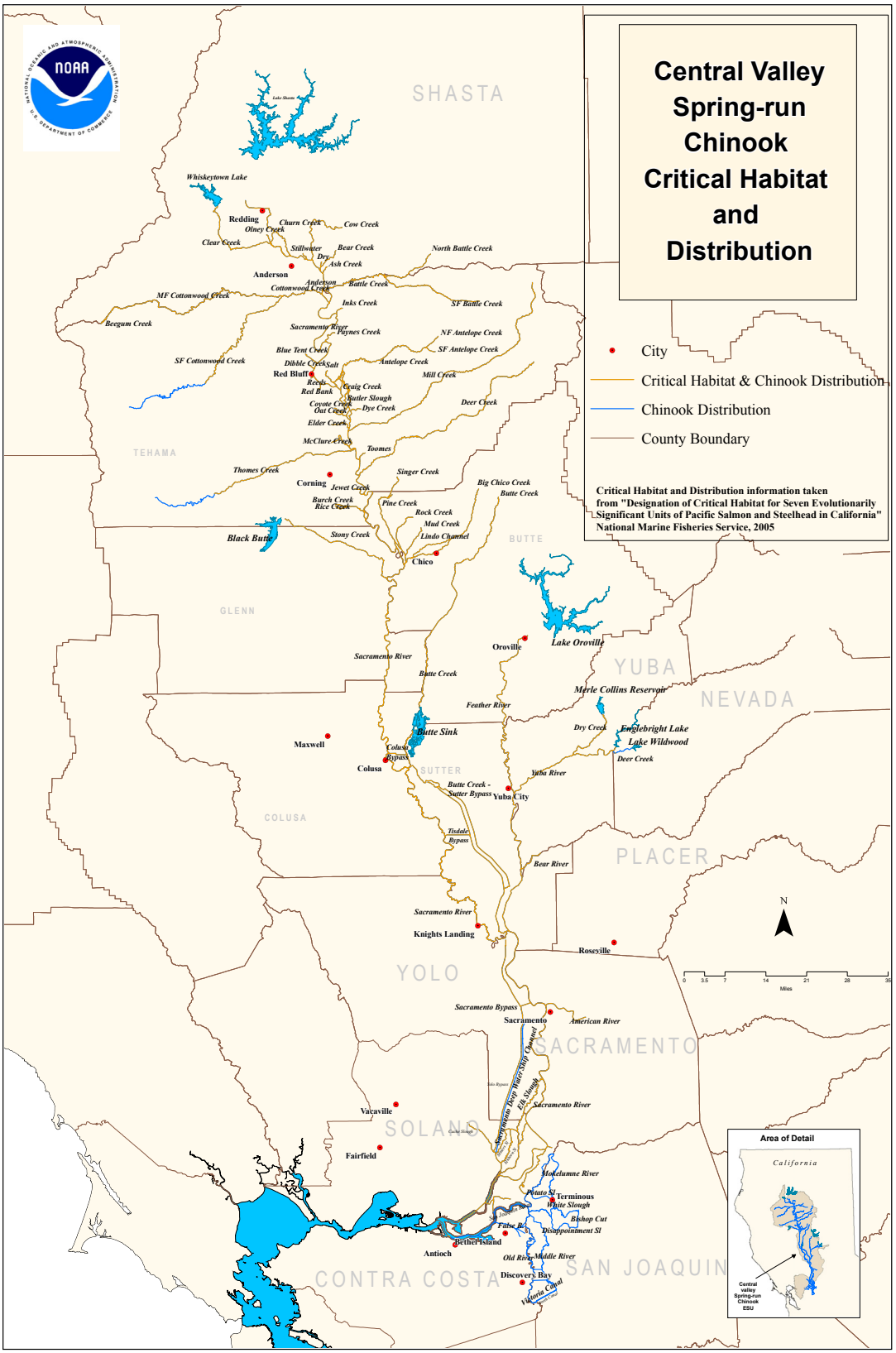


Figure 2-8. Central Valley Spring-run Chinook Salmon Designated Critical Habitat and Distribution

2.2.6 Reasons for Listing

The Central Valley spring-run Chinook salmon ESU is currently faced with three primary threats: (1) loss of most historic spawning habitat; (2) degradation of the remaining habitat; and (3) genetic introgression with the FRFH spring-run Chinook salmon strays. Spring-run Chinook salmon require cool freshwater in summer, most of which is upstream of impassable dams. The ESU is currently limited to independent populations in Mill, Deer, and Butte creeks, persistent and presumably dependent populations in the Feather and Yuba rivers and in Big Chico, Antelope, and Battle creeks, and a few ephemeral or dependent populations in the Northwestern California region (e.g., Beegum, Clear, and Thomes creeks). This ESU continues to be threatened by habitat loss, degradation and modification, small hydropower dams and water diversions that reduce or eliminate instream flows during migration, unscreened or inadequately screened water diversions, excessively high water temperatures, and predation by non-native species.

The potential effects of climate change are likely to adversely affect spring-run Chinook salmon and their recovery. These effects are more thoroughly discussed in Chapter 6.

Listing Factors for Spring-run Chinook Salmon

Section 4 of the ESA requires the Secretary of the Interior or Commerce, depending upon the species involved, to determine if any species is an endangered or threatened species for any of the following listing factors: (1) present or threatened destruction, modification or curtailment of its habitat or range; (2) overutilization for commercial, recreational. scientific or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. Each of these listing factors with respect to spring-run Chinook salmon are summarized below.

The Present or Threatened Destruction, Modification, or Curtailment of Spring-run Chinook Salmon's Habitat or Range.

Habitat Loss

Loss of historic spawning habitat was a major reason for listing spring-run Chinook salmon under the ESA and it remains an important threat, as most of that habitat continues to be blocked by the direct or indirect effects of dams. Perhaps 15 of the 19 historical populations of Central Valley spring-run Chinook salmon are extinct, with their entire historical spawning habitats behind various impassable dams (Lindley *et al*. 2007). The construction of dams in the Central Valley has eliminated virtually all historic spawning habitat of spring-run Chinook salmon in the basin. Native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin, which represents a large portion of the historic range and abundance of the ESU.

Like most spring-run Chinook salmon, Central Valley spring-run Chinook salmon require cool freshwater while they mature over the summer. In the Central Valley, summer water temperatures are reportedly suitable for Chinook salmon only above 150 to 500-m elevations, and most of that high elevation habitat is now upstream of impassable dams (NMFS 2005). Current spawning is restricted to the mainstem and a few river tributaries in the Sacramento River

(NMFS 1998). Naturally-spawning populations of Central Valley spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and Yuba River (CDFW 1998).

The construction of Shasta and Keswick dams on the Sacramento River and Oroville Dam on the Feather River and subsequent blocking of upstream migration has eliminated the spatial separation between spawning fall-run and spring-run Chinook salmon. Reportedly, spring-run Chinook salmon migrated to the upper Feather River and its tributaries from mid-March through the end of July (CDFW 1998). Fall-run Chinook salmon reportedly migrated later and spawned in lower reaches of the Feather River than spring-run Chinook salmon (Yoshiyama *et al.* 2001). The same pattern likely also existed on the Sacramento River. Restricted access to historic spawning grounds currently causes spring-run Chinook salmon to spawn in the same lowland reaches that fall-run Chinook salmon use as spawning habitat. The overlap in spawning site locations, combined with an overlap in spawning timing (Moyle 2002) with temporally adjacent runs, is responsible for interbreeding between spring-run and fall-run Chinook salmon in the lower Feather River (Hedgecock *et al.* 2001) and in the Sacramento River below Keswick Dam.

In the upper Sacramento River, lower Feather River, and lower Yuba River, spring-run Chinook salmon spawning may occur a few weeks earlier than fall-run spawning, but currently there is no clear distinction between the two because of the disruption of spatial segregation by Shasta and Keswick dams on the Sacramento River, Oroville Dam on the Feather River, and Englebright Dam on the Yuba River. Thus, spring-run and fall-run Chinook salmon spawning overlap temporally and spatially. This presents difficulties from a management perspective in determining the proportional contribution of total spawning escapement by the spring- and fall-runs. Because of unnaturally high densities of spawning, particularly in the in the Low Flow Channel of the Feather River, spawning habitat is likely a limiting factor. Intuitively, it could be inferred that the slightly earlier spawning Chinook salmon displaying spring-run behavior would have better access to the limited spawning habitat, although early spawning likely leads to a higher rate of redd superimposition. Redd superimposition occurs when spawning Chinook salmon dig redds on top of existing redds dug by other Chinook salmon. The rate of superimposition is a function of spawning densities and typically occurs in systems where spawning habitat is limited (Fukushima *et al.* 1998). Redd superimposition may disproportionately affect early spawners and, therefore, potentially affect Chinook salmon exhibiting spring-run life history characteristics.

Habitat Degradation

Another major reason why spring-run Chinook salmon are in need of ESA protection is because the remaining spawning and rearing habitat for this species is severely degraded (63 FR 11482, March 9, 1998; Myers *et al*. 1998; Good *et al*. 2005; NMFS 2011b). Threats to spring-run Chinook salmon habitat include, but are not limited to: (1) operation of antiquated fish screens, fish ladders, and diversion dams on streams throughout the Sacramento River Basin including on Deer, Mill, Butte, and Antelope creeks; (2) levee construction and

maintenance projects that have greatly simplified riverine habitat and have disconnected rivers from the floodplain; and (3) water delivery and hydroelectric operation on the main-stem Sacramento River (Central Valley Project), and the Feather River (State Water Project).

General degradation of rearing and migrating habitat includes elevated water temperatures, agricultural and municipal diversions and returns, restricted and regulated flows, entrainment of migrating fish into unscreened or poorly screened diversions, predation by nonnative species, and the poor quality and quantity of remaining habitat (NMFS 1998). Hydropower dams and water diversions in some years have greatly reduced or eliminated in-stream flows during spring-run migration periods (NMFS 1998b).

Overutilization of Spring-run Chinook Salmon for Commercial, Recreational, Scientific, or Educational Purposes

Overutilization of spring-run Chinook salmon for commercial, recreational, scientific, or educational purposes was not identified as an important risk to spring-run Chinook salmon when the species was listed in 1999 (63 FR 11482; March 9, 1998). The spring-run Chinook salmon status review that informed the 1999 listing determination stated that, "*Harvest rates* [of spring-run Chinook salmon] *appear to be moderate*. (Myers *et al*. 1998)." No spring-run Chinook salmon ocean harvest rate data were available to support that statement. Some limited information obtained since spring-run Chinook salmon were listed suggests that harvest in the ocean fisheries may be more of a risk to the species than originally thought. An analysis done by Grover *et al*. (2004) indicated that Butte Creek spring-run Chinook salmon are vulnerable to the commercial and recreational ocean salmon fisheries with an estimated 36 percent of brood year 1998 and 42 percent of brood year 1999 harvested in the ocean, respectively. Those harvest rates are about twice that of winter-run Chinook salmon (NMFS 2010c). Grover *et al*. (2004) cautioned the interpretation of their own results because of the low number of coded wire tag recoveries and the analysis covered just two cohorts. Further analysis of spring-run Chinook salmon harvest rates is needed to better understand the ocean fisheries' impacts on this ESU.

Disease or Predation

Disease

Disease was not an important factor in the listing of spring-run Chinook salmon (63 FR 11482, March 9, 1998; Myers *et al*. 1998). There is no evidence that spring-run Chinook salmon have experienced unusual levels of disease in the wild. There have been numerous outbreaks of infectious hematopoietic necrosis virus (IHNV) in Chinook salmon at CNFH and the FRFH. Although the virus had been detected in stream salmonids, there have been no reported epizootics of IHNV in Central Valley stream populations (i.e., the virus was detected but the fish themselves were asymptomatic of the disease) (DWR 2009). It appears that IHNV is not readily transmitted from hatchery fish to salmon and other fish in streams, estuary or the ocean (DWR 2009).

Predation

Predation was not identified as an important factor in the listing of spring-run Chinook salmon (63 FR 11482, March 9, 1998; Myers *et al*. 1998), but more recently it has gained attention as a potentially significant source of mortality (Moyle 2002; Vogel

2011). See section 2.1.6 above for information on predators of juvenile Chinook salmon in the Central Valley and their potential impact.

The Inadequacy of Existing Regulatory Mechanisms

Laws relevant to the protection and restoration of spring-run Chinook salmon are the ESA, the Magnuson-Stevens Fishery Conservation and Management Act, the CVPIA, the Federal Power Act, the Fish and Wildlife Coordination Act, the Clean Water Act, the National Environmental Policy Act, and numerous State laws administered by CDFW, DWR, or the SWRCB. These laws and associated regulations provide adequate mechanisms for recovering spring-run Chinook salmon; however some of the goals of these existing mechanisms have not yet been achieved. The effectiveness of applying the regulatory mechanisms is to some extent controlled by societal values. The people of California will need to place a higher value on improving natural ecosystems in order for existing regulatory mechanisms to be most effective at recovering anadromous salmonids in the Central Valley.

Other Natural or Manmade Factors Affecting the Continued Existence of Spring-run Chinook Salmon

Reduced Genetic Integrity

Threats to the genetic integrity of spring-run Chinook salmon was identified as a serious concern to the species when it was listed in 1999 (63 FR 11482, March 9, 1998; Myers *et al*. 1998). Three main factors compromised the genetic integrity of spring-run Chinook salmon: (1) the lack of reproductive isolation following dam construction throughout the Central Valley resulting in introgression with fall-run Chinook salmon in the wild; (2) within basin and inter-basin mixing between spring- and fall- broodstock for artificial propagation, resulting in introgression in hatcheries; and (3) releasing hatchery-produced juvenile Chinook salmon in the San Francisco estuary, which contributes to the straying of returning adults throughout the Central Valley.

In the 1940s, trapping of adult Chinook salmon that originated from areas above Keswick and Shasta dams may have resulted in stock mixing, and further mixing with fall-run Chinook salmon apparently occurred with fish transferred to the CNFH. Deer Creek, one of the locations generally believed most likely to retain essentially native spring-run Chinook salmon, was a target of adult outplants from the 1940s trapping operation, but the success of those transplants is uncertain (Myers *et al*. 1998).

Much of the Central Valley Chinook salmon production is of hatchery origin, and over the years hatchery fish have interbred with wild populations of both fall-run and spring-run Chinook salmon. This problem has been exacerbated by the continued practice of trucking juvenile Chinook salmon to the Delta for release, contributing to the straying of returning adults throughout the Central Valley.

The FRFH spring-run Chinook salmon program releases half its production near the hatchery and the other half is released far downstream of the hatchery (CDFW 2001a). Given the large number of juveniles released off station, the potential contribution of straying adults to rivers throughout the Central Valley is considerable (Myers *et al*. 1998). Cramer (1996) reported that up to 20 percent of the Feather River spring-run Chinook salmon are recovered in the

American River sport fishery. From 2004 through 2010 on the Yuba River, hatchery origin Chinook salmon accounted for an average of 21.4% of the total annual run of spring-run Chinook salmon passing upstream of Daguerre Point Dam (USACE 2012). Analysis of coded wire tags suggests that most of those hatchery fish originated from the FRFH (USACE 2012).

Catastrophic Environmental Disturbance

Although not identified as a reason for listing spring-run Chinook salmon under the ESA, the potential for a catastrophic environmental disturbance has more recently been recognized as a key threat to the species. Lindley *et al.* (2007) report that the current distribution of viable populations makes the Central Valley spring-run Chinook salmon ESU vulnerable to catastrophic disturbance. All three extant independent populations are in basins whose headwaters lie within the debris and pyroclastic flow radii of Lassen Peak, an active volcano that USGS views as highly dangerous. Additionally, a fire with a maximum diameter of 30 km, big enough to burn the headwaters of Mill, Deer, and Butte creeks simultaneously, has roughly a 10 percent chance of occurring somewhere in the Central Valley each year. Impacts on salmon and their habitat from fires include potential death during a fire that goes through a drainage, reduced water quality from fire suppression activities and associated chemicals, increased water temperatures from lost canopy, increased sedimentation, and reduced habitat complexity and large woody debris. A catastrophic environmental disturbance affecting Mill, Deer, and Butte creeks would greatly reduce the abundance and distribution of the spring-run Chinook salmon ESU.

2.2.7 Threats Assessment

A detailed threats assessment was conducted for the Central Valley spring-run Chinook salmon ESU, and followed the same general procedure previously described for winter-run Chinook salmon. The threats/stressors affecting each spring-run Chinook salmon diversity group and population are described in Appendix B.

The completed stressor matrix sorted by normalized weight is a prioritized list of the life stage-specific stressors affecting the ESU. For spring-run Chinook salmon, threats were prioritized within each diversity group, as well as within each population. Specific information explaining the individual steps taken to generate these prioritized lists are provided in Appendix B.

Some major stressors to the entire Central Valley spring-run Chinook salmon ESU include passage impediments/barriers, ocean harvest, warm water temperatures for holding and rearing, limited quantity and quality of rearing habitat, predation, and entrainment. The complete prioritized list of life stage-specific stressors to this ESU is presented in Appendix B.

Some of the most important specific stressors to each diversity groups within the ESU are described below.

Northern Sierra Nevada Diversity Group

- Agricultural diversions, diversion dams, and/or weirs on Deer, Mill, Antelope, and Butte creeks impeding or blocking access to upstream spawning habitat;
- Warm water temperatures in Antelope, Butte, and Big Chico creeks during the adult immigration

and holding life stage, especially in dry or extreme years;

- Englebright Dam blocking access to habitat historically used by Yuba River spring-run Chinook salmon;
- Oroville Dam blocking access to habitat historically used by Feather River spring-run Chinook salmon;
- Entrainment in Antelope Creek resulting from terminal diversions and loss of channel connectivity;
- Loss of rearing habitat in the lower and middle sections of the Sacramento River and in the Delta;
- Ocean harvest on all populations; and
- Predation on juveniles from all populations rearing and migrating through the Sacramento River and Delta.

Basalt and Porous Lava Diversity Group

- Keswick and Shasta dams blocking access to habitat historically used by spring-run Chinook salmon in the upper Sacramento River watershed;
- Passage impediments and flow fluctuations resulting from hydropower operations on the North and South Forks of Battle Creek;
- Loss of rearing habitat in the Sacramento River and Delta;
- Ocean harvest on all populations; and
- Predation on juveniles from all populations rearing and migrating through the Sacramento River and Delta.

Northwestern California Diversity Group

- Warm water temperatures in all three watersheds during the adult immigration and holding life stage;
- Limited spawning habitat availability in all three watersheds;
- Loss of rearing habitat in the lower and middle sections of the Sacramento River and in the Delta;
- Whiskeytown Dam blocking access to habitat potentially historically used by Clear Creek spring-run Chinook salmon;
- Ocean harvest on all populations; and
- Predation on juveniles from all populations rearing and migrating through the Sacramento River and Delta.

2.2.8 Conservation Measures

ERP and CVPIA actions in the Sacramento River tributaries have focused on riparian and shaded riverine aquatic habitat restoration, improved access to available upstream habitat, improved instream flows, and reduced loss of juveniles at diversions, particularly for spring-run Chinook salmon and steelhead. For a description of ERP, CVPIA and other actions, refer to the previous discussion of Conservation Measures for winter-run Chinook salmon.

The Delta Pumping Plant Fish Protection Agreement (Delta Agreement) signed in 1986 was intended to mitigate for SWP and

pumping plant impacts. From 1986 through 2007, approximately $60 million from the Delta Agreement has been spent on over 40 fish mitigation projects. These funds resulted in the screening of water diversions, enhanced law enforcement efforts to reduce illegal fish harvest, installation of seasonal barriers to guide fish away from undesirable spawning habitat or migration corridors, salmon habitat restoration, and removal of four dams to improve fish passage on Butte Creek for Chinook and steelhead. Approximately one-third of the approved funding for salmon projects specifically targeted spring-run Chinook salmon and steelhead in the upper Sacramento River tributaries. Projects implemented under the agreement that have most directly benefited spring-run Chinook salmon include water exchange projects to improve passage flows on Mill and Deer creeks, and fish screens and fish ladder improvements on Butte Creek.

Harvest protective measures benefiting spring-run Chinook salmon include seasonal constraints on sport and commercial fisheries south of Point Arena. In addition, the State has listed spring-run Chinook under the CESA, and has thus established specific in-river fishing regulations and no-retention prohibitions designed to protect this ESU (e.g., fishing method restrictions, gear restrictions, bait limitations, seasonal closures, and zero bag limits), in tributaries such as Deer, Big Chico, Mill, and Butte creeks.

2.3 Steelhead

2.3.1 ESA Listing Status

NMFS proposed to list Central Valley steelhead (anadromous *O. mykiss*), which is currently listed as threatened, as endangered on August 9, 1996 (61 FR 41541). NMFS concluded that the California Central Valley steelhead ESU was in danger of extinction because of habitat degradation and destruction, blockage of freshwater habitats, water allocation problems, the pervasive opportunity for genetic introgression resulting from widespread production of hatchery steelhead and the potential ecological interaction between introduced stocks and native stocks. Moreover, NMFS proposed to list steelhead as endangered because steelhead had been extirpated from most of their historical range.

On March 19, 1998, NMFS listed the Central Valley steelhead as a threatened species (63 FR 13347). NMFS concluded that the risks to Central Valley steelhead had diminished since the completion of the 1996 status review based on a review of existing and recently implemented State conservation efforts and Federal management programs (e.g., CVPIA AFRP, CALFED) that address key factors for the decline of this species. In addition, NMFS noted that additional actions benefiting Central Valley steelhead included efforts to enhance fisheries monitoring and conservation actions to address artificial propagation.

On September 8, 2000, pursuant to a July 10, 2000, rule issued by NMFS under Section 4(d) of the ESA (16 USC § 1533(d)), the take restrictions that apply statutorily to endangered species began to apply with specific limitations to Central Valley steelhead (65 FR 42422). On January 5, 2006, NMFS reaffirmed the threatened status of the Central Valley steelhead and applied the DPS policy to the species because the resident and anadromous life forms of steelhead remain "markedly separated" as a consequence of physical, ecological and behavioral factors, and may therefore warrant delineation as a

separate DPS (71 FR 834). NMFS (1998) based its conclusion on conservation and protective efforts that, "*mitigate the immediacy of extinction risk facing the Central Valley steelhead DPS*." **Figure 2-9** depicts the California Central Valley steelhead DPS.

2.3.2 Species Description and Taxonomy

Steelhead and rainbow trout are the same species. In general, steelhead refers to the anadromous form of the species. Normally, adult steelhead reach a larger size than resident rainbow trout. Sacramento River Basin steelhead immigrants range in size from 12 to 18 inches (30.5 to 45.7 cm) FL for adults returning after 1 year in the ocean, to 18 to 23 inches (45.7 to 58.4 cm) FL for adults returning after 2 years in the ocean (S.P. Cramer & Associates 1995).

Steelhead can be identified by the numerous black spots on the caudal fin, adipose fin, dorsal fin and back (Moyle 2002). When in freshwater, steelhead often display the pinkish to red lateral band and cheeks typical of resident rainbow trout. The back is normally an iridescent blue to brown, the sides and belly are silver, white or yellowish (Moyle 2002). The resident forms are usually darker than the sea-run. Juvenile coloration is similar to adults except that juveniles often have 8 to 13 widely spaced parr marks centered on the lateral line, 5 to 10 dark marks on the back between the head and dorsal fin, white to orange tips on the dorsal and anal fins, and few, if any, dark spots on the tail (Moyle 2002).

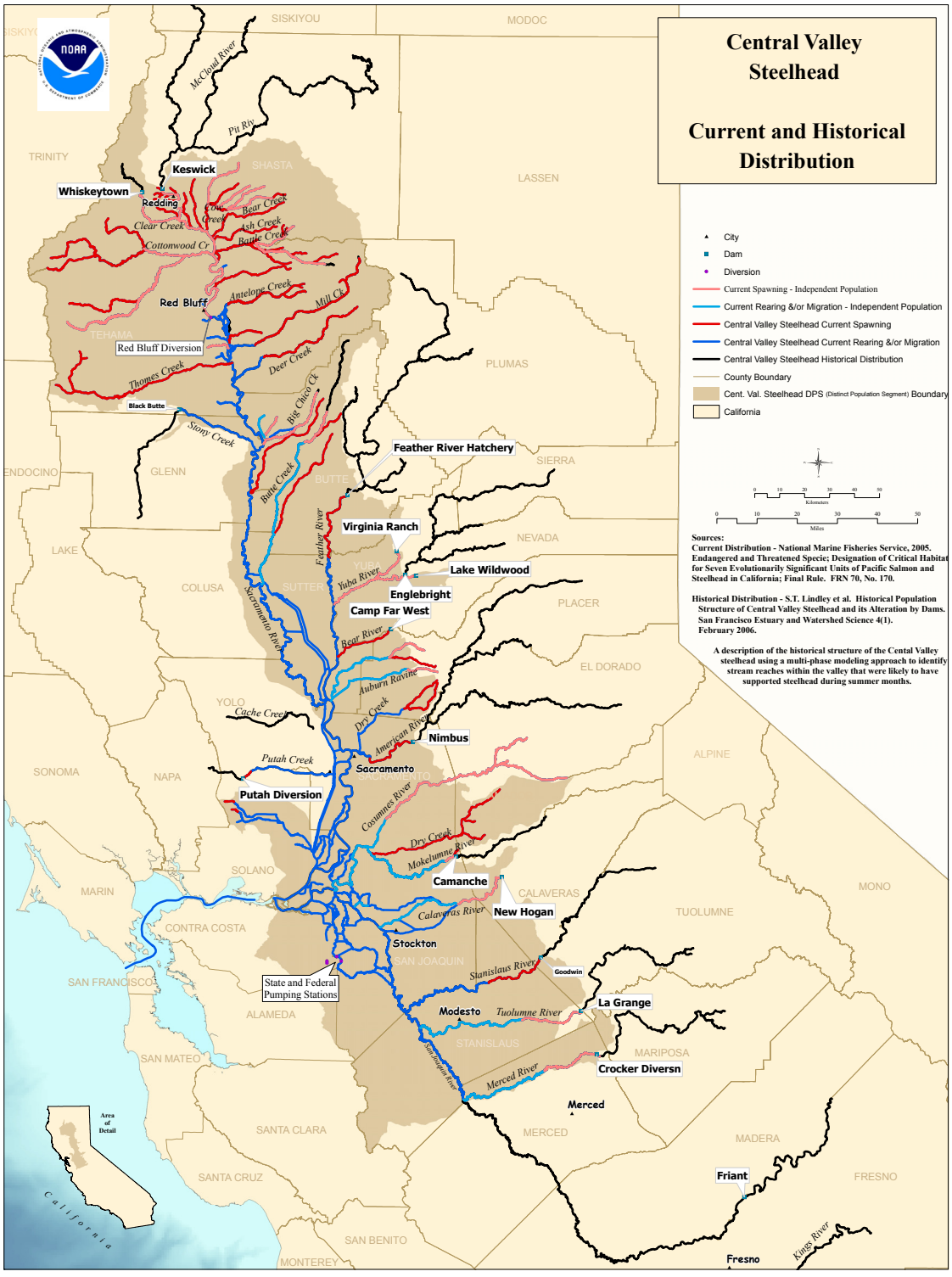


Figure 2-9. California Central Valley Steelhead Distinct Population Segment, and Current and Historical Distribution. See Lindley *et al.* 2006 (Table 1) in Appendix C for a list of the 81 historic independent steelhead populations in the Central Valley**.** Note: this figure does not include populations in the Suisun Bay Tributaries diversity group, the Central Western diversity group, or populations in the southern Sierra Nevada diversity group that are south of the upper San Joaquin River.

2.3.3 Life History/Habitat Requirements

Life History

Oncorhynchus mykiss may exhibit anadromy or freshwater residency. Resident forms are usually referred to as rainbow trout, while anadromous life forms are termed ‘‘steelhead.’’ Zimmerman *et al.* (2008) demonstrated that resident rainbow trout can produce anadromous smolts and anadromous steelhead can produce resident rainbow trout in the Central Valley. That study indicated that the proportion of resident rainbow trout to anadromous steelhead in the Central Valley is largely in favor of the resident form with 740 of 964 *O. mykiss* examined being the progeny of resident rainbow trout (Zimmerman *et al.* 2008).

Steelhead typically migrate to marine waters after spending two years in fresh water. They reside in marine waters for typically two or three years prior to returning to their natal stream to spawn as four- or five-year-olds. Unlike Pacific salmon, steelhead are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying, and most that do so are females (Moyle 2002).

Currently, Central Valley steelhead are considered “ocean-maturing” (also known as winter) steelhead, although summer steelhead may have been present prior to construction of large dams (Moyle 2002). Ocean maturing steelhead enter fresh water with well-developed gonads and spawn shortly after river entry. Central Valley steelhead enter fresh water from August through April. They hold until flows are high enough in tributaries to enter for spawning (Moyle 2002). Steelhead adults typically spawn from December through April, with peaks from January through March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock *et al.* 1961; McEwan 2001). Depending on water temperature, steelhead eggs may incubate in redds for over one month before hatching as alevins. Following yolk sac absorption, alevins emerge from the gravel as young juveniles or fry and begin actively feeding (Moyle 2002).

In the Sacramento River, juvenile steelhead generally migrate to the ocean in spring and early summer at 1 to 3 years of age and 10 to 25 cm FL, with peak migration through the Delta in March and April (Reynolds *et al.* 1993). Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River Basin migrate downstream during most months of the year, but the peak emigration period occurred in the spring, with a much smaller peak in the fall.

Table 2-4 depicts the temporal occurrence of steelhead life stages in the Sacramento River. Steelhead may remain in the ocean from one to four years, growing rapidly as they feed in the highly productive currents along the continental shelf (Barnhart 1986). Oceanic and climate conditions such as sea surface temperatures, air temperatures, strength of upwelling, El Niño events, salinity, ocean currents, wind speed, and primary and secondary productivity affect all facets of the physical, biological and chemical processes in the marine environment. Some of the conditions associated with El Niño events include warmer water temperatures, weak upwelling, low primary productivity (which leads to decreased zooplankton biomass), decreased southward transport of subarctic water, and increased sea levels (Pearcy 1997). For juvenile steelhead, warmer water and weakened upwellings are possibly the

most important of the ocean conditions associated with El Niño. Because of the weakened upwelling during an El Niño year, juvenile California steelhead would need to migrate more actively offshore through possibly stressful warm waters with numerous inshore predators.

Strong upwelling is probably beneficial because of the greater transport of smolts offshore, beyond major concentrations of inshore predators (Pearcy 1997).

Habitat Requirements

A description of freshwater habitat requirements for steelhead is presented in the following sections. Habitat requirements are organized by the species life stage.

Adult Immigration and Holding

Adult steelhead immigration into Central Valley streams typically begins in August and continues into March (McEwan 2001; NMFS 2004). Steelhead immigration generally peaks during January and February (Moyle 2002). Optimal immigration and holding temperatures have been reported to range from 46°F to 52°F (CDFW 1991b).

Central Valley steelhead are known to use the Sacramento River as a migration corridor to spawning areas in upstream tributaries. Historically, steelhead likely did not utilize the mainstem Sacramento River downstream from the Shasta Dam site except as a migration corridor to and from headwater streams. Likewise, the Feather River below the current site of Oroville Dam was likely used only as a migration corridor to upstream reaches.

Adult Spawning

Central Valley steelhead spawn downstream of dams on every major tributary within the Sacramento and San Joaquin River systems. The female steelhead selects a site with good intergravel flow, digs a redd with her tail, usually in the coarse gravel of the tail of a pool or in a riffle, and deposits eggs while an attendant male fertilizes them. Water velocities over redds are typically 20 to 155 cm/sec, and depths are 10 to 150 cm (Moyle 2002). The preferred water temperature range for steelhead spawning is reported to be 30°F to 52°F (CDFW 2000).

Embryo Incubation

Following deposition of fertilized eggs in the redd, they are covered with loose gravel. Central Valley steelhead eggs can reportedly survive at water temperature ranges of 35.6°F to 59°F (Myrick and Cech 2001). However, steelhead eggs reportedly have the highest survival rates at water temperature ranges of 44.6°F to 50.0°F (Myrick and Cech 2001). The eggs hatch in three to four weeks at 50°F to 59°F, and fry emerge from the gravel four to six weeks later (Shapovalov and Taft 1954).

Juvenile Rearing and Outmigration

Regardless of life history strategy, for the first year or two of life rainbow trout and steelhead are found in cool, clear, fast-flowing permanent streams and rivers where riffles predominate over pools, there is ample cover from riparian vegetation or undercut banks, and invertebrate life is diverse and abundant (Moyle 2002). The smallest fish are most often found in riffles, intermediate size fish in runs, and larger fish in pools. Steelhead can be found where daytime water temperatures range from nearly 32°F to 81°F in the summer, although mortality may result at extremely low (i.e.,

<39°F) or extremely high (i.e., > ~73°F) water temperatures if the fish have not been gradually acclimated (Moyle 2002). Juvenile steelhead in northern California rivers reportedly exhibited increased physiological stress, increased agonistic activity, and a decrease in forage activity after ambient stream temperatures exceeded 71.6°F (Nielsen *et al*. 1994).

When water temperatures become stressful in streams, juvenile steelhead are faced with the increased energetic costs of living at high water temperatures. Hence, juvenile steelhead will move into fast flowing riffles to feed because of the increased abundance of food, even though there are costs associated with maintaining position in fast water. At higher water temperatures, steelhead are more vulnerable to stress which can be fatal (Moyle 2002). Predators also have a strong effect on microhabitats selected by steelhead. Small steelhead select places to live based largely on proximity to cover in order to hide from predators.

Optimal water temperatures for growth of steelhead have been reported to be 59°F to 64.4°F (Moyle 2002). Many factors affect choice of water temperatures by steelhead, including the availability of food. As steelhead grow, they establish individual feeding territories. Some juvenile steelhead utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the ocean.

2.3.4 Abundance Trends and Distribution

Prior to dam construction, water development and watershed perturbations, Central Valley steelhead were distributed throughout the Sacramento and San Joaquin rivers (Busby *et al.* 1996; NMFS 1996b, McEwan 2001). Steelhead were found from the upper Sacramento and Pit rivers (now inaccessible due to Shasta and Keswick dams) south to the Kings and possibly the Kern River systems, and in both east- and west-side Sacramento River tributaries (Yoshiyama *et al.* 1996). Lindley *et al.* (Lindley *et al.* 2006) estimated that historically there were at least 81 independent Central Valley steelhead populations distributed primarily throughout the eastern tributaries of the Sacramento and San Joaquin rivers (**see Appendix C**). Presently, impassable dams block access to 80 percent of historically available habitat, and block access to all historical spawning habitat for about 38 percent of historical populations (Lindley *et al.* 2006).

The current and historical distribution of Central Valley steelhead was presented in **Figure 2-9**. Existing wild steelhead populations in the Sacramento River basin occur in the upper Sacramento River and its tributaries, including Cottonwood, Antelope, Deer, and Mill creeks and the Yuba River. Other Sacramento River basin populations may exist in Big Chico and Butte creeks, and a few wild steelhead are produced in the American and Feather rivers (McEwan 2001). Snorkel surveys conducted from 1999 to 2008 indicate that steelhead are present in Clear Creek (Giovannetti and Brown 2009; Good *et al.* 2005). Monitoring data from 2005 to 2009 shows that steelhead are also present in Battle Creek (Newton and Stafford 2011).

A hatchery supported population of steelhead also occurs in the Mokelumne River, which flows directly into the Delta in between where the Sacramento and San Joaquin rivers enter the Delta.

Central Valley steelhead were thought to be extirpated from the San Joaquin River system, until recent monitoring detected small populations of *O.mykiss* in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). It is uncertain whether the *O.mykiss* in those rivers are predominantly resident or anadromous *O.mykiss*; presumably, both the anadromous and resident life history form of *O.mykiss* are present. On the Stanislaus River, small numbers of steelhead smolts have been captured in rotary screw traps at Caswell State Park and Oakdale each year since 1995 (S.P. Cramer and Associates Inc. 2000, 2001). Steelhead also currently occur in the Stanislaus, Calaveras, Merced, and Tuolumne rivers.

It is possible that naturally-spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced Rivers during fall-run Chinook salmon monitoring activities, indicating that *O.mykiss* are widespread, throughout accessible streams and rivers in the Central Valley (Good *et al.* 2005).

Table 2-4. The Temporal Occurrence of Adult and Juvenile Steelhead in the Sacramento River

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Sacramento River[1,3]												
Sacramento River at Red Bluff[2,3]												
Mill, Deer Creeks[4]												
Sacramento River at Fremont Weir[6]												
Sacramento River at Fremont Weir[6]												
San Joaquin River[7]												
Juvenile												
Sacramento River[1,2]												
Sacramento River at Knights Landing[2,8]												
Sacramento River at KL[9]												
Chipps Island (Wild)[10]												
Mossdale[8]												
Woodbridge Dam[11]												
Stanislaus River at Caswell[12]												
Sacramento River at Hood[13]												

Sources: [1]Hallock et al. 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFW 1995; [5](Hallock et al. 1957); [6]Bailey 1954; [7]CDFW Steelhead Report Card Data; [8]CDFW unpublished data; [9]Snider and Titus 2000; [10]Nobriga and Cadrett 2003; [11]Jones & Stokes Associates, Inc., 2002; [12]S.P. Cramer and Associates, Inc. 2000 and 2001; [13]Schaffter 1980

Relative Abundance:	= High	= Medium	= Low

Note: NMFS recognizes that CDFW Steelhead Report Card Data provides a small sample size and involves some known sampling bias, but these data represent the best information available for the temporal distribution of adult steelhead in the San Joaquin River.

Historic Central Valley steelhead run sizes are difficult to estimate because of the lack of data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 (CDFW 1996). Over the last 30 years the steelhead populations in the upper Sacramento River have declined substantially. In 1996, NMFS estimated the Central Valley total run size based on dam counts, hatchery returns, and past spawning surveys was probably fewer than 10,000 fish. Both natural and hatchery runs have declined since the 1960s. Counts at RBDD averaged 1,400 fish from 1991 to 1993, compared to counts in excess of 10,000 fish in the late 1960. Because of adverse impacts on winter-run Chinook salmon, the operation of RBDD was changed so that the dam gates were raised earlier in the season, and this eliminated the ability to generate steelhead run-size estimates (McEwan 2001).

American River redd surveys and associated monitoring from 2002 through 2007 indicate that only a few hundred steelhead spawn in the river and the majority of those spawners originated from Nimbus Hatchery (Hannon and Deason 2008).

In analyzing flow-habitat relationships for anadromous salmonids in the upper Sacramento River upstream of the Battle Creek confluence and downstream of Keswick Dam, USFWS (2003) reported that it was not possible to differentiate between steelhead and resident rainbow trout. Specific information regarding steelhead spawning within the mainstem Sacramento River is limited due to lack of monitoring (NMFS 2004). Currently, the number of steelhead spawning in the Sacramento River is unknown because redds cannot be distinguished from a large resident rainbow trout population that has developed as a result of managing the upper Sacramento River for coldwater species.

2.3.5 Critical Habitat

When designating critical habitat, NMFS focuses on "Primary Constituent Elements" (PCEs), which are the principal biological or physical constituent elements within the defined area that are essential to the conservation of the listed species (50 CFR 424.12(b)). PCEs considered essential for the conservation of the California Central Valley steelhead DPS are those sites and habitat components that support one or more life stages (50 CFR 226.211(c)), including:

- Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.
- Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
- Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.
- Estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between

fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

NMFS proposed[5] critical habitat for Central Valley steelhead on December 10, 2004 (69 FR 71880) and published a final rule designating critical habitat for this species on September 2, 2005 (70 FR 52488). **Figure 2-10** depicts the designated critical habitat and distribution for Central Valley steelhead.

2.3.6 Reasons for Listing

Section 4 of the ESA requires the Secretary of the Interior or Commerce, depending upon the species involved, to determine if any species is an endangered or threatened species for any of the following listing factors: (1) present or threatened destruction, modification or curtailment of its habitat or range; (2) overutilization for commercial, recreational. scientific or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. Each of these listing factors with respect to Central Valley steelhead are summarized below.

The Present or Threatened Destruction, Modification, or Curtailment of Central Valley Steelhead's Habitat or Range.

The widespread degradation, destruction, and blockage of freshwater habitats within the Central Valley, and the continuing impacts to habitat resulting from water management were identified as key reasons why Central Valley steelhead were listed under the ESA (61 FR 41541, August 9, 1996; 63 FR 13347, March 19, 1998). These reasons are briefly discussed below under two categories – (1) habitat loss, and (2) habitat degradation.

Habitat Loss

About 80% of habitat identified by the TRT that was historically available to anadromous *O. mykiss* is now behind impassable dams, and 38% of the populations identified by the TRT have lost all of their habitat (Lindley *et al.* 2006). Anadromous *O. mykiss* populations may have been extirpated from their entire historical range in the San Joaquin Valley and most of the larger basins of the Sacramento River. The roughly 52% of watersheds with at least half of their historical area below impassable dams are all small, low elevation systems (Lindley *et al*. 2006).

[5] NMFS proposed critical habitat for Central Valley steelhead on February 5, 1999 (64 FR 5740) in compliance with Section 4(a)(3)(A) of the ESA, which requires that, to the maximum extent prudent and determinable, NMFS designates critical habitat concurrently with a determination that a species is endangered or threatened (NMFS 1999). On February 16, 2000 (65 FR 7764), NMFS published a final rule designating critical habitat for Central Valley steelhead. Critical habitat was designated to include all river reaches accessible to listed steelhead in the Sacramento and San Joaquin rivers and their tributaries in California. Also included were river reaches and estuarine areas of the Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait, all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge.

In response to litigation brought by the National Association of Homebuilders (NAHB) (NAHB v. Evans, 2002 WL 1205743 No. 00–CV–2799 (D.D.C.)), NMFS sought judicial approval of a consent decree withdrawing critical habitat designations for 19 Pacific salmon and *O. mykiss* ESUs. The District Court in Washington DC approved the consent decree and vacated the critical habitat designations by Court order on April 30, 2002 (NAHB v. Evans, 2002 WL 1205743 (D.D.C. 2002)).

Habitat Degradation

The habitat in the Central Valley that remains accessible to anadromous *O. mykiss* has been drastically altered and degraded. Reynolds *et al.* (1993) reported that declines in Central Valley steelhead stocks are *"due mostly to water development, inadequate instream flows, rapid flow fluctuations, high summer water temperatures in streams immediately below reservoirs, diversion dams which block access, and entrainment of juveniles into unscreened or poorly screened diversions."* Other problems related to land use practices (agriculture and forestry) and urbanization also have certainly contributed to the decline of Central Valley steelhead (McEwan 2001).

Overutilization of Steelhead for Commercial, Recreational, Scientific, or Educational Purposes

The overutilization of Central Valley steelhead was not identified as an important reason for the species' listing (61 FR 41541; 63 FR 13347).

Commercial or Recreational Fishery Impacts on Central Valley Steelhead

Because there is no commercial fishery for Central Valley steelhead and the recreational fishery is regulated to protect wild steelhead, there is some reason to think that fishing impacts would not be a significant problem for this species. However, because the sizes of Central Valley steelhead populations are largely unknown, it is difficult to make conclusions about the impact of the recreational fishery (Good *et al*. 2005).

Scientific or Educational Utilization of Central Valley Steelhead

NMFS issues permits under the ESA for scientific research that stipulate specific conditions to minimize take of steelhead. These permitted studies provide information about steelhead in the Central Valley that is useful for management and conservation of the DPS and are not considered a factor for the decline of this species (NMFS 2011c).

Disease or Predation

Disease

Infectious disease is one of many factors which can influence adult and juvenile steelhead survival. Steelhead are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environments. Specific diseases such as bacterial kidney disease (BKD), ceratomyxosis, columnaris, Furunculosis, infectious hematopoietic necrosis (IHNV), redmouth and black spot disease, Erythrocytic Inclusion Body Syndrome (EIBS), and whirling disease among others are present and are known to affect steelhead and salmon (NMFS 1996).

Although disease was recognized as a potential factor in the decline of west coast steelhead (NMFS 1996), it was not specifically identified as an important reason why Central Valley steelhead were listed under the ESA (61 FR 41541; 63 FR 13347).

The Inadequacy of Existing Regulatory Mechanisms

The inadequacy of existing regulatory mechanisms was not identified as a key factor in the listing of Central Valley steelhead. Although there is a lengthy discussion of this listing factor in the Final Rule listing Central Valley steelhead as threatened, most of the discussion applies to other steelhead ESUs, which were also considered for listing at that time (63 FR 13347).

Other Natural or Manmade Factors Affecting the Continued Existence of Central Valley Steelhead

Hatchery Management/Reduced Genetic Integrity

Along with habitat loss and habitat degradation, hatchery management was identified as a key factor in the listing of Central Valley steelhead (61 FR 41541; 63 FR 13347). Over the past several decades, the genetic integrity of Central Valley steelhead has been diminished by increases in the proportion of hatchery fish relative to naturally produced fish, the use of out-of-basin stocks for hatchery production, and straying of hatchery produced fish (CDFW and NMFS 2001; California Hatchery Scientific Review Group 2012). Four hatcheries in the Central Valley produce steelhead, and each hatchery has specific production targets, as identified in Table 2-5. Currently there is still great concern about the ecological and genetic impacts of steelhead hatchery management in the Central Valley (California Hatchery Scientific Review Group 2012). These concerns continue to be related to the proportion of hatchery fish relative to naturally produced fish, the predominance of Eel River steelhead genetics in the Nimbus Hatchery steelhead program, and straying of hatchery produced steelhead.

Potential adverse effects to wild steelhead populations associated with hatchery production are similar to those described above for winter-run Chinook salmon. Research has indicated that approximately 63 to 92 percent of steelhead smolt production is of hatchery origin (NMFS 2003). Overall, hatchery-origin fish appear to comprise the majority of the DPS (Lindley *et al*. 2007)

Habitat fragmentation and population declines resulting in small, isolated populations also pose genetic risk from inbreeding, loss of rare alleles, and genetic drift.

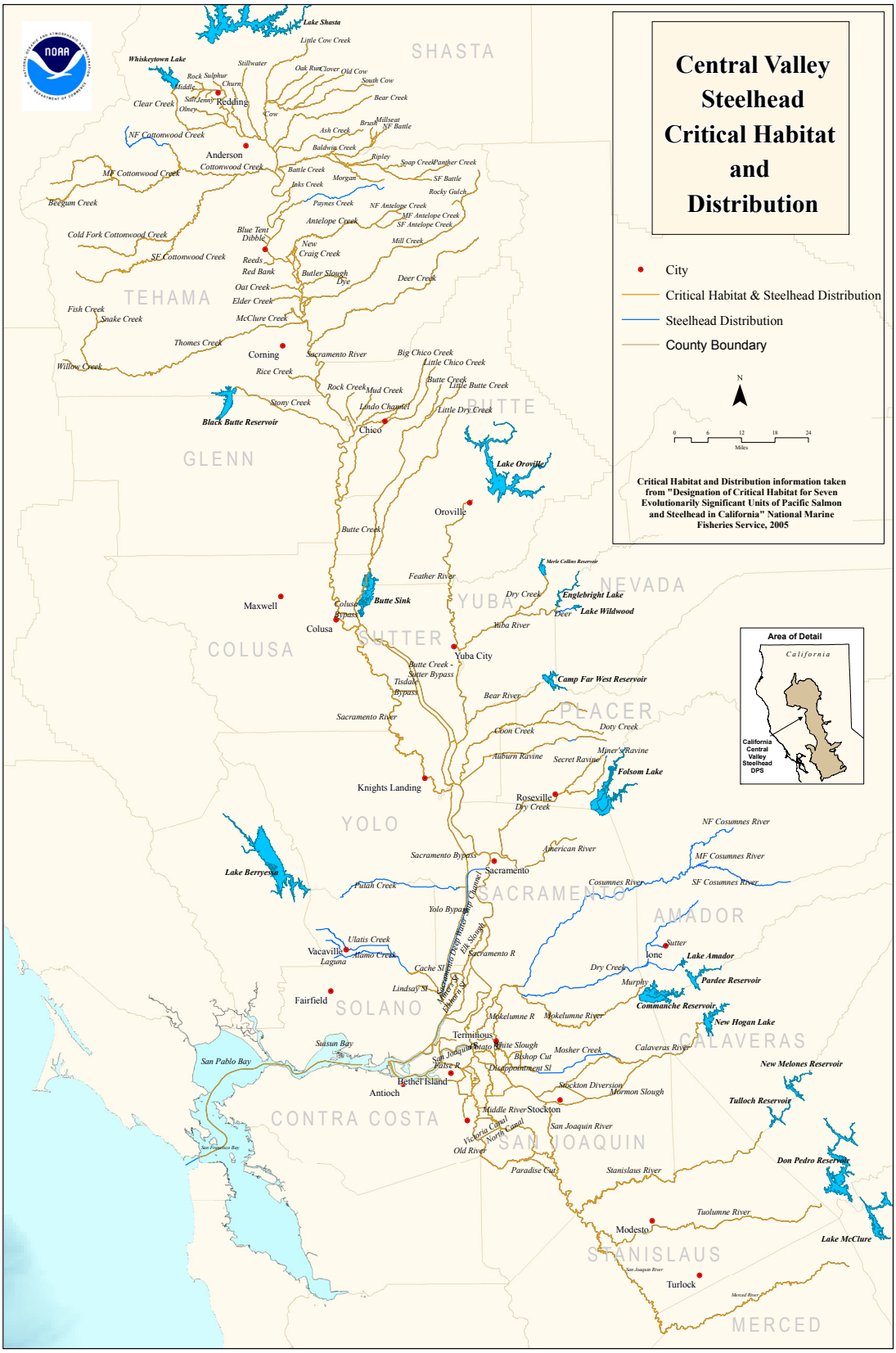


Figure 2-10. Central Valley Steelhead Designated Critical Habitat and Distribution

Table 2-5. Annual Steelhead Production Targets for Central Valley Hatcheries

Hatchery	Production Target
Coleman National Fish Hatchery	600,000
Feather River Fish Hatchery	500,000
Nimbus Hatchery	430,000
Mokelumne Fish Hatchery	100,000

There is still significant local genetic structure to Central Valley steelhead populations. Hatchery effects appear to be localized – for example, Feather River and the FRFH steelhead are closely related, as are American River and Nimbus Hatchery fish (DWR 2002). The Coleman National Fish Hatchery steelhead program was derived from the endemic stock of steelhead in the upper Sacramento River. Early-returning (October – December) steelhead in Battle Creek are similar genetically to the Coleman NFH adults and late-returning (March –May) natural-origin steelhead in Battle Creek are similar genetically to mainstem Sacramento River steelhead (Capton *et al*. 2004).

In general, although genetic structure was found, all naturally-spawned *O. mykiss* populations within the Central Valley basin were closely related, regardless of whether they were sampled above or below a known barrier to anadromy. This is due to some combination of pre-impoundment historic shared ancestry, downstream migration and, possibly, limited, anthropogenic upstream migration. However, lower genetic diversity in above-barrier populations indicates a lack of substantial genetic input upstream and highlights lower effective population sizes for above-barrier populations. Above-barrier populations clustered with one another and below-barrier populations are most closely related to populations in far northern California, specifically the genetic groups that include the Eel and Klamath rivers. Since Eel River origin broodstock were used for many years at Nimbus Hatchery on the American River, it is likely that Eel River genes persist there and have also spread to other basins by migration, and that this is responsible for the clustering of the below-barrier populations with northern California ones. This suggests that the below-barrier populations in this region appear to have been widely introgressed with hatchery fish from out of basin broodstock sources. The consistent clustering of the above-barrier populations with one another, and their position in the California-wide trees, indicate that they are likely to most accurately represent the ancestral population genetic structure of steelhead in the Central Valley (Garza and Pearse 2008).

A significant transfer of genetic material has occurred among hatcheries within the Central Valley, as well as some transfer from systems outside the Central Valley. For example, an Eel River strain of steelhead was used as the founding broodstock for the Nimbus Hatchery (DWR 2002). Additionally, eyed eggs from the Nimbus Hatchery were transferred to the FRFH several times in the late 1960s and early 1970s (DWR 2002). There have also been transfers of steelhead from the FRFH to the Mokelumne Hatchery. In the late 1970s, a strain of steelhead was brought in from Washington State for the FRFH (DWR 2002).

Environmental Variability

Variability in natural environmental conditions has both masked and exacerbated the problems associated with degraded and altered riverine and estuarine habitats. Floods and persistent drought conditions have periodically reduced steelhead spawning, rearing, and migration habitats.

El Nino events and periods of poor ocean conditions can threaten the survival of steelhead populations already reduced to low abundance levels due to the loss and degradation of freshwater and estuarine habitats. Alternatively, periods of favorable ocean conditions can offset the poor condition of inland habitats and result in increased population abundance and productivity by increasing the size and correlated fecundity of returning adults (NMFS 1996).

2.3.7 Threats Assessment

A detailed threats assessment was conducted for the California Central Valley steelhead DPS, and followed the same general procedure previously described for winter-run Chinook salmon. The threats/stressors affecting each steelhead diversity group and population are described by life stage in Appendix B.

Some major stressors to the entire California Central Valley steelhead DPS include passage impediments and barriers, warm water temperatures for rearing, hatchery effects, limited quantity and quality of rearing habitat, predation, and entrainment. The complete prioritized list of life stage-specific stressors to the DPS is presented in Appendix B.

Many of the most important stressors specific to the steelhead diversity groups correspond to the diversity group-specific stressors described for the Central Valley spring-run Chinook salmon ESU in section 2.2.7. The only diversity group (i.e., area) unique to the California Central Valley steelhead DPS, relative to the diversity groups in the Central Valley spring-run Chinook salmon ESU is the southern Sierra Nevada diversity group. Some of the most important stressors to steelhead in the southern Sierra Nevada diversity group include:

- Friant Dam blocking access to habitat historically used by San Joaquin River steelhead;
- Passage impediments on Calaveras River including Bellota Weir and flash board dams;
- Limited habitat availability in each watershed and in the mainstem San Joaquin River for spawning and juvenile rearing;
- La Grange and Don Pedro dams blocking access to habitat historically used by Tuolumne River steelhead;
- Goodwin and New Melones dams blocking access to habitat historically used by Stanislaus River steelhead;
- McSwain and Crocker Huffman dams blocking access to habitat historically used by Merced River steelhead;
- Camanche and Pardee dams blocking access to habitat historically used by Mokelumne River steelhead;
- Entrainment at the Jones and Banks Pumping Plants and associated losses from predation; and
- Inadequate summer flow on the Tuolumne River.

2.3.8 Conservation Measures

Conservation measures that have been taken to improve habitat for steelhead include, activities under the Clear Creek Restoration Program, the Battle Creek Salmon and Steelhead Restoration Project, several actions taken by the AFRP and the ERP, the Lower Yuba River Habitat Restoration Project, and actions under the San Joaquin River

Restoration Program. Specific information on how each of these programs and projects has benefited steelhead is described in the 5-year status review published in 2011 (NMFS 2011c).

Other ongoing measures to protect steelhead in the State of California include 100 percent adipose fin-clipping of all hatchery steelhead, although they are not coded-wire tagged and, therefore, determination of hatchery of origin, as well as straying rates, remain problematic for stock identification.

The State also works closely with NMFS to review and improve inland fishing regulations. As a result, zero bag limits for unmarked steelhead, gear restrictions, closures, and size limits designed to protect smolts are additional inland harvest measures that protect Central Valley steelhead.

While some conservation measures have been successful in improving habitat conditions for Central Valley steelhead, access to historic habitat remains blocked in many cases and fundamental problems still remain with the quality of the species' remaining habitat (see Lindley *et al*. 2009 and Cummins *et al*. 2008) and it continues to be highly degraded. The loss of historical habitat and the degradation of remaining habitat both continue to be major threats to this DPS.

3.0 Recovery Strategy

"The wide-ranging migration patterns and unique life histories of anadromous salmonids take them across ecosystem and management boundaries in an increasingly fragmented world, which creates the need for analyses and strategies at similarly large scales."

- Good *et al.* 2007. Recovery Planning for Endangered Species Act-listed Pacific Salmon: Using Science to Inform Goals and Strategies

3.1 INTRODUCTION

A broad strategic framework is necessary to serve as a strategic planning guide to integrate the actions contributing to the overarching goal of recovery of the two Chinook salmon ESUs and the steelhead DPS, which contain a mixture of hatchery and wild fish, and resident and anadromous fish. To address the complexity associated with the multi-faceted considerations for recovery efforts within the Central Valley Domain, San Francisco Estuary, and Pacific Ocean, this recovery strategy: explains the connection between the biological needs and situational background of the ESUs/DPS and the recovery program; and, presents the most effective means to achieve the individual recovery criteria and objectives, and, in turn, the delisting of the ESUs/DPS.

This chapter describes where we want to get to in terms of the number and spatial distribution of viable and dependent populations. Eliminating differences between the current viability and the desired viability is at the core of the recovery strategy. Having a strong rationale for, and understanding of, what a recovered Central Valley ESU/DPS will look like is critical to developing an effective strategy.

To convey this rationale and understanding, the chapter first describes the key facts and assumptions upon which the recovery plan is based. These facts and assumptions cover salmonid conservation principles, recovery implementation principles, and specific watershed classifications for recovery. Next, the primary objectives of the recovery plan are described. Lastly, adaptive management and monitoring are discussed because both will play a critical role in recovering the Chinook salmon ESUs and steelhead DPS.

3.2 FACTS AND ASSUMPTIONS

3.2.1 Salmonid Conservation Principles

Recovery of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead across such vast and altered ecosystems as the Central Valley, the San Francisco Estuary, and the Pacific Ocean, will require a broadly focused, science-based strategy. The scientific rationale for the strategy in this plan focuses on two key salmonid conservation principles. The first is that functioning, diverse, and interconnected habitats are necessary for a species to be viable.

That is, we cannot achieve salmon and steelhead recovery without providing sufficient habitat. Anadromous salmonids persisted in the Central Valley for thousands of years because the available habitat capacity and diversity allowed species to withstand and adapt to environmental changes including catastrophes such as prolonged droughts, large wildfires, and volcanic eruptions. The second salmonid conservation principle guiding the recovery strategy is that a species' viability is determined by its spatial structure, diversity, productivity, and abundance (McElhany *et al*. 2000). Life history diversity, genetic diversity, and metapopulation organization are ways that salmonids adapt to their complex and connected habitats. These factors are the basis of salmonid productivity and contribute to the ability of salmonids to cope with environmental variation that is typical of freshwater and marine environments.

Habitat Capacity and Diversity

A purpose of the ESA is to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, so that these species no longer require the protections of the ESA (i.e., can be delisted).

The availability and quality of habitat is fundamental to species viability; viable ESUs/DPSs and populations require a network of complex and interconnected habitats that are created, altered, and maintained by natural physical processes in freshwater, the estuary, and the ocean. Restoration of Central Valley anadromous salmonids must address the entire natural and cultural ecosystem, which encompasses the continuum of freshwater, estuarine, and ocean habitats where salmonid fishes complete their life histories. This consideration includes human developments, as well as natural habitats.

These diverse and high-quality habitats, which have been extensively degraded by human activities, are crucial for salmonid spawning, rearing, migration, maintenance of food webs, and predator avoidance. Ocean conditions, which are variable, are important in determining the overall patterns of productivity of salmon populations.

Unfortunately, habitat for Central Valley salmonids has been extensively altered. Dams have disconnected fish from their historic habitats and altered flow regimes downstream by storing winter and spring runoff and releasing higher–than-historic flows during summer for agricultural and municipal uses. More than 1,600 miles of levee construction in the Central Valley have constricted river channels, disconnected floodplains from active river channels, reduced riparian habitat, and reduced natural channel function, particularly in the Delta and the lower reaches of the Sacramento and San Joaquin Rivers. Thousands of water diversions within the Central Valley reduce instream flows, and the state and federal pumping facilities in the south Delta reverse natural river flows, disrupt natural tidal patterns, and alter the migration patterns and survival of salmonid individuals and populations.

Habitat conservation and enhancement efforts should focus on the sites and areas identified in NMFS's critical habitat designations for each of the three species. Additionally, consideration should be given to the PCEs and other relevant habitat conditions as summarized below.

Freshwater Spawning Sites

- have good water quality and quantity
- have substrate for spawning, incubation, and larval development

Freshwater Rearing Sites

- have good water quality and quantity and floodplain connectivity to maintain habitat conditions
- have forage for juvenile development
- have natural cover to provide refuge (such as submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large rocks or boulders, side channels, undercut banks, etc.)

Freshwater Migration Corridors

- are unobstructed
- have good water quality and quantity
- have natural cover to provide refuge to support juvenile and adult mobility and survival
- afford safe passage conditions for migrations

Estuarine Areas

- are unobstructed
- have good water quality and quantity, with salinity conditions to support juvenile and adult physiological transitions between freshwater and saltwater
- have natural cover to provide refuge to support migrations among systems
- have forage for juvenile and adult migrating fish
- are free from overabundance of non-native predators

Nearshore Marine Areas[6]

- are unobstructed
- have good water quality and quantity conditions
- have forage to support growth and maturation of fish
- have natural cover to provide refuge

Offshore Marine Areas[6]

- have good water quality conditions
- have prey to support growth and maturation

Population Viability

Recovery planning seeks to ensure the viability of protected species. In the short term, viability of populations (and ESU/DPS) depends on the demographic properties of the population or ESU/DPS, such as population size, growth rate, the variation in growth rate, and carrying capacity (Tuljapurkar and Orzack 1980), all of which depend largely on the quality and quantity of habitat. In the longer term, genetic diversity, and the diversity of habitats that support genetic diversity, become increasingly important (McElhany

[6] For winter-run Chinook salmon marine areas are not explicitly included as physical biological features in the final rule designating critical habitat for that ESU (58 FR 33212; June 16, 1993); however, marine areas are important as the species spends the majority of its life cycle in the ocean. The preamble to the final rule designating critical habitat for CV spring-run Chinook salmon and CV steelhead discussed marine areas as primary constituent elements for the ESUs addressed in the final rule (70 FR 52488, 52521; September 2, 2005); however, the final rule did not include marine areas as primary constituent elements for CV spring-run Chinook salmon and CV steelhead (50 CFR 226.211(c); 70 FR 52488, 52537, September 2, 2005), and there are no marine areas designated as critical habitat for these species..

et al. 2000; Kendall and Fox 2002; Williams and Reeves 2003).

NMFS has developed guidelines to apply the four Viability of Salmon Population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Application of the guidelines determines whether or not a population is viable (McElhany *et al.* 2000). The four parameters and their associated attributes are presented in **Figure 3-1.** The rationale applies these factors to define viable populations.

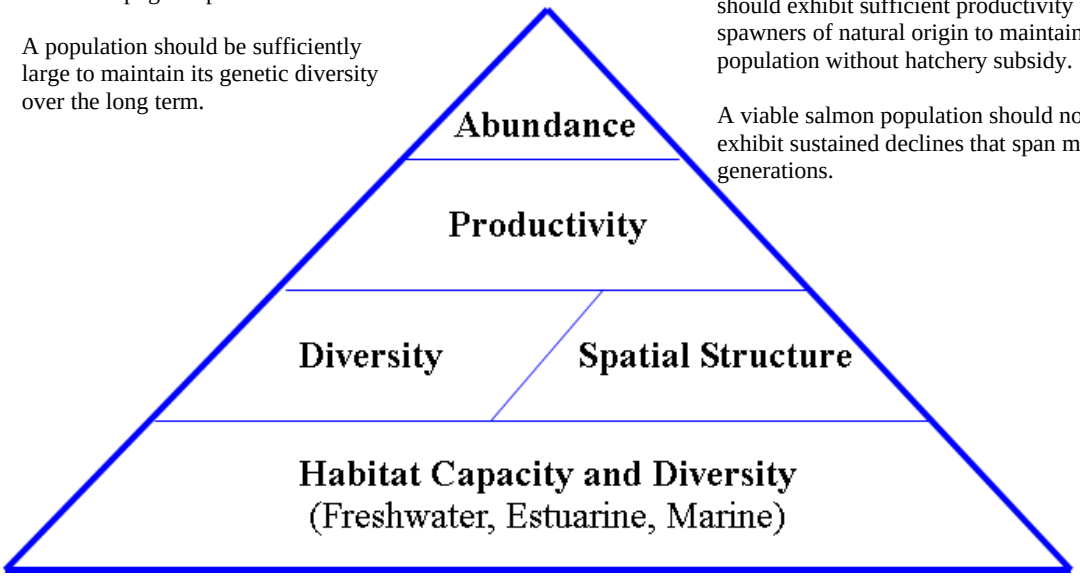
As presented in Good *et al.* (2005), criteria for VSP are based on population characteristics that reasonably predict extinction risk and reflect processes important to populations. Abundance is critical, because small populations are generally at greater risk of extinction than large populations. Stage-specific or lifetime productivity (i.e., population growth rate) provides information on important demographic processes. Abundance and productivity data are used to assess the status of populations of threatened and endangered ESUs (Good *et al.* 2005). Genotypic and phenotypic diversity are important in that they allow species to use a wide array of environments, respond to short-term changes in the environment, and survive long-term environmental change. Spatial structure reflects how abundance is distributed among available or potentially available habitats.

ABUNDANCE
A population should be large enough to have a high probability of surviving environmental variation of the patterns and magnitudes observed in the past and expected in the future.
A population should have sufficient abundance for compensatory processes to provide resilience to environmental and anthropogenic perturbation.

A population should be sufficiently large to maintain its genetic diversity over the long term.

PRODUCTIVITY (POPULATION GROWTH RATE)
Natural productivity should be sufficient to reproduce the population at a level of abundance that is viable.
Productivity should be sufficient throughout freshwater, estuarine, and nearshore life stages to maintain viable abundance levels, even during poor ocean conditions.
A viable salmon population that includes naturally spawning hatchery-origin fish should exhibit sufficient productivity from spawners of natural origin to maintain the population without hatchery subsidy.

A viable salmon population should not exhibit sustained declines that span multiple generations.



DIVERSITY

Human-caused factors such as habitat changes, harvest pressures, artificial propagation, and exotic species introduction should not substantially alter variation in traits such as run timing, age structure, size, fecundity (birth rate), morphology, behavior, and genetic characteristics.
The rate of gene flow among populations should not be altered by human caused factors.

Natural processes that cause ecological variation should be maintained.

SPATIAL STRUCTURE

Habitat patches should not be destroyed faster than they are naturally created.
Human activities should not increase or decrease natural rates of straying among salmon sub-populations.
Habitat patches should be close enough to allow the appropriate exchange of spawners and the expansion of population into underused patches.

Some habitat patches may operate as highly productive sources for population production and should be maintained.

Due to the time lag between the appearance of empty habitat and its colonization by fish, some habitat patches should be maintained that appear to be suitable, or marginally suitable, even if they currently contain no fish.

Figure 3-1. Viable salmonid population (VSP) parameters and their attributes. The quality and diversity of habitat (habitat capacity and diversity) available to the species in each of its three main habitat types (freshwater, estuarine and marine environments) are critical factors to VSP.

ESU Viability

Good *et al.* (2007) reported that viability of Pacific salmon ESUs depends on the status and distribution of populations within the entire ESU. In general, the ESU is more likely to be viable if it contains multiple populations (metapopulations), some of which meet viability criteria. Viability of the ESU is also more likely if: (1) populations are geographically widespread but some are close enough together to facilitate connectivity; (2) populations do not all share common catastrophic risks; and (3) populations display diverse life-histories and phenotypes (McElhany *et al.* 2000).

Considerations regarding ESU viability are discussed in ISAB (2005), and are generally adopted herein for application to the two Chinook salmon ESUs and the steelhead DPS in the Central Valley Domain. To be viable, an ESU needs more than simple persistence over time; it needs to be in an ecologically and evolutionarily functional state. Evaluation of ESU viability depends not only on the numbers of component populations and the abundance and productivity of those individual populations, but also on the integration of population dynamics within the ecosystem as a whole. For an ESU to fulfill the entire complement of ecological and evolutionary interactions and functions (ISAB 2005), it needs to contain viable populations inhabiting a variety of different habitats, interconnected as a metapopulation.

A viable ESU consists of a group of populations existing as a metapopulation that is self-sustaining for the foreseeable future. Populations within a viable ESU need to exhibit the abundance, productivity, diversity, and spatial distribution of natural spawners, sufficient to accomplish the following: avoid the loss of genetic and/or life history diversity during short-term reductions in abundance that are expected parts of environmental cycles; fulfill key ecological functions that are attributable to the species, such as nutrient cycling and food web roles; and provide for long-term evolutionary adaptability to changing environmental conditions.

This Recovery Plan endeavors to avoid loss of currently small, peripheral, or in any way seemingly less-valuable populations. The importance of these populations is not well understood, but it is likely they contribute significantly to ESU and DPS scale viability by providing increased life history diversity. They also are likely to buffer against local catastrophic occurrences.

In addition to the considerations presented by ISAB (2005), the Central Valley TRT addressed ESU viability for the Central Valley Domain, using two other approaches. The goal of these two approaches is to distribute risk and maximize future potential for adaptation.

In the first approach, the Central Valley TRT assessed ESU viability by examining the number and distribution of viable populations across the landscape, and their proximity to sources of catastrophic disturbance. Risk-spreading examines how viable populations are distributed among geographically-defined regions within an ESU. For example, the Puget Sound, Willamette/Lower Columbia and Interior Columbia TRTs have used the idea of dividing ESUs into subunits (Myers *et al.* 2003; Ruckelshaus *et al.* 2002; Interior Columbia Basin Technical Recovery Team 2003), and of requiring population presence and redundancy in the subunits (The Central Valley TRT referred to this approach as the "representation and redundancy" rule). ESU

subunits are intended to capture geographically important components of habitat, life history, or genetic diversity that contribute to the viability of salmonid ESUs (Hilborn *et al.* 2003; Bottom *et al.* 2005).

In practice, this approach holds that if extinction risks are not strongly correlated, two populations, each with low risk of extinction, would be extremely unlikely to go extinct simultaneously (McElhany *et al.* 2003). Should a catastrophic event cause one of the populations to go extinct, the other(s) could serve as a source of colonists to re-establish the extirpated population.

In the second approach, the TRT attempted to account explicitly for the spatial structure of the ESU and the spatial structure of various catastrophic risks, including volcanoes, wildfires, and droughts. The product of this approach is a set of diversity groups. A diversity group is a geographically-distinct portion of the ESU/DPS which is ecologically or otherwise identifiable and which is essential to the recovery of the entire listed entity (e.g., to conserve genetic robustness, demographic robustness, and important life history stages).

To meet the objective of representation and redundancy, diversity groups need to contain multiple populations to survive in a dynamic ecosystem subject to unpredictable stochastic events, such as pyroclastic events or wild fires.

As discussed in Lindley *et al.* (2004), the Central Valley Basin is characterized by a wide range of climatological, hydrological, and geological conditions. The Central Valley TRT used the Jepson floristic ecoregions defined by Hickman (1993) as a starting point for salmon ecoregions, but modified them to account for geologic characteristics that produce spring-dominated base flow. Such conditions strongly influence salmonid habitat, but not upland plants. The resulting ecoregions for salmon and steelhead consider geology and are referred to herein as "Diversity Groups".

Delineation of Recovery Units

The four diversity groups listed below serve as recovery units, in that each one that was historically occupied by a species is essential for the recovery of that species. The diversity group structure is presented in **Figure 3-2** for the Chinook salmon ESUs and in **Figure 3-3** for the steelhead DPS in the Central Valley Domain.

The Central Valley Domain Diversity Groups are:

- The **basalt and porous lava diversity group** composed of the upper Sacramento River (including watersheds upstream of Shasta Dam), Cow Creek and Battle Creek watersheds

- The **northwestern California diversity group** composed of streams that enter the mainstem Sacramento River from the northwest, such as Clear Creek

- The **northern Sierra Nevada diversity group** composed of streams tributary to the Sacramento River from the east, from Antelope Creek to the Mokelumne River, and

- The **southern Sierra Nevada diversity group** composed of streams tributary to the San Joaquin River from the east.

The diversity groups reflect the historic distribution of each species. As a result, the number (and geographic range) of diversity groups differs by species. For winter-run Chinook salmon, all populations required for

recovery are located in a single diversity group. This is the northernmost area called the "basalt and porous lava" diversity group. This recovery unit includes the streams that historically supported winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. All of these streams receive large inflows of cold water from springs throughout the summer, upon which winter-run Chinook salmon depend. This region includes part of the upper Sacramento drainage (currently blocked by Shasta Dam), part of the Modoc Plateau region, and extends south to the Battle Creek watershed.

Three additional recovery units have been identified for spring-run Chinook salmon and steelhead. Though the southern part of the Cascades region (i.e., the drainages of Mill, Deer and Butte creeks) also contain some geology that results in spring-fed baseflows, these streams are included in the northern Sierra Nevada diversity group. The Sierra Nevada watersheds are divided into northern and southern diversity groups (split at the Mokelumne River watershed). This division reflects the greater importance of snowmelt runoff in the southern Sierra, and also places tributaries to the Sacramento and San Joaquin rivers in different diversity groups. The fourth diversity group includes tributaries that drain the watersheds on the west side of the northern Sacramento watershed and extends from Shasta Dam in the north to Willow Creek and Black Butte Reservoir in the south.

Lindley *et al.* (2006) report that historically steelhead populations were located in tributaries to Suisun Bay and to the San Joaquin River from the west (i.e., Central Western California diversity group). Recovery of Central Valley steelhead can be achieved without the presence of populations in either the Suisun Bay or Central Western California diversity groups. This conclusion is based on the fact that the four Chinook salmon diversity groups, which did not include the Suisun Bay or Central Western California regions, supported abundant and diverse Chinook salmon populations for thousands of years. As such, the extent and diversity of habitats historically available in those four diversity groups would likely also support a viable steelhead DPS, if the quantity and quality of habitat currently available in those regions was sufficiently increased. Additionally, based on the quantity and quality of available steelhead habitat, the Central Western California diversity group, which drains the relatively low elevation watersheds along the west side of the San Joaquin River, likely contributed little to the abundance of Central Valley steelhead. The Sacramento River basin was the source of most steelhead production (Lindley *et al.* 2006).

Because recovery can be reached without them, the Suisun area and the Central Western California diversity groups are not considered to be steelhead recovery units in this plan.

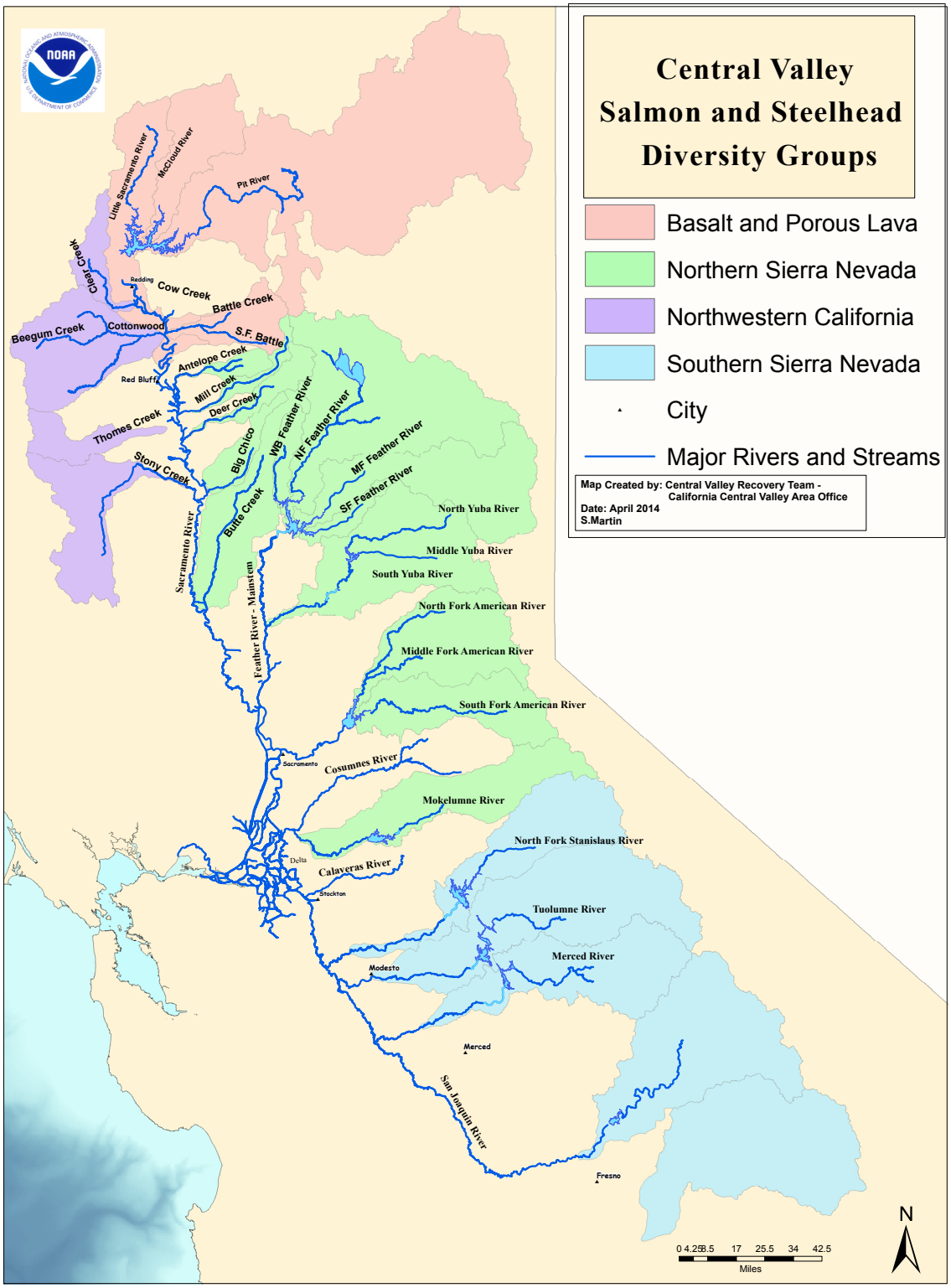


Figure 3-2. Diversity Groups for the Sacramento River Winter-run Chinook salmon and Central Valley Spring-run Chinook salmon ESUs in the Central Valley Domain. The Sacramento River Winter-run Chinook Salmon ESU Historically Occurred in the Basalt and Porous Lava Diversity Group, while Spring-run Chinook Salmon Occurred in all of the Diversity Groups Shown.



Figure 3-3. Diversity Groups for the California Central Valley Steelhead DPS in the Central Valley Domain.

3.2.2. Recovery Implementation Principles

The Strategy is based on five foundational implementation principles. The principles take into account the magnitude of the actions required by the strategy and the significant investment of resources required. Success is dependent on actions throughout the range of the species, in freshwater, estuarine, and ocean habitats and will require public understanding and support. Key elements in sustaining public support are investing in the most cost-effective practices, and continually assessing and reporting recovery plan progress and effectiveness. The five principles are described briefly below.

System wide Approach

Because the listed species are wide-ranging, and depend on headwater, riverine, estuarine, and ocean habitats, recovery implementation should address this entire set of ecosystems.

Cost Effectiveness

To focus investments on those actions with the highest likelihood of success, implementation of the strategy should give priority to measures with a proven record of success within the ESUs and DPS, or in ecologically comparable environments. Prior to initiating actions, similar actions previously implemented in the ESUs or DPS should be reviewed for lessons learned. It will also be beneficial to review the success of actions undertaken in other locations.

Self-Sustaining Improvements

Due to the uncertainty of future budgets, priority will be given to measures that, once implemented, are self-sustaining. In cases in which necessary actions will need maintenance (e.g., reintroductions into habitat upstream of impassible dams), priority will be given to options that need the least intervention in the long term.

Stakeholder Cooperation and Public Support

Partnerships and collaboration between all stakeholders and regulatory agencies are necessary to accelerate actions, increase available resources, reduce duplication of effort, encourage innovative solutions, improve communication, and increase public involvement and support through shared authority and ownership of habitat restoration (USFWS 2001). The Department of the Interior AFRP and the ERP contain processes for building partnerships to pursue restoration actions. The AFRP and the ERP continue to build partnerships and provide funds to local agencies and watershed groups, as well as other Federal and State agencies, in order to implement specific restoration actions throughout the Central Valley Domain. NMFS is engaged in both of these efforts, as well as with local agency and stakeholder efforts.

NMFS recognizes the high cost, broad geographic scope, and the economic, social, and cultural implications of necessary actions. NMFS therefore encourages local agencies and stakeholder groups to share or lead implementation of recovery and habitat restoration actions within the Central Valley Domain, and views such involvement as essential to success of the Recovery Plan.

In addition to participation by local, state and other Federal agencies, public support is necessary for the acceptance and successful implementation of the Recovery Plan for the Central Valley Domain. As stated by USFWS (2001), public sentiment is an indicator of perceived economic and social effects of restoration actions, and public support for an action will facilitate implementation and attract partners for future actions. NMFS will continue to coordinate with public stakeholders to assist in identifying, planning, and implementing recovery actions.

Adaptive Management and Monitoring

The plan will incorporate adaptive management into all components and actions. The reduced distribution and abundance of the listed species necessitates immediate action, but some key data gaps exist. Incorporating effective monitoring into plan actions will assist in addressing data needs and in modifying recovery actions where necessary. Effective monitoring, evaluation, and reporting will also provide for accountability.

Recovery Plan implementation includes an adaptive management and monitoring component to increase the effectiveness of, and to address the scientific uncertainty associated with specific restoration actions. The adaptive management component allows NMFS, as well as local water agencies and irrigation districts, municipal and county governmental agencies, watershed groups, and state and other Federal agencies, to learn from past experiences and to alter actions based on their measured effectiveness. There will be a thorough review of the effectiveness of the recovery actions implemented, as reflected by population and habitat condition responses, at the 5-year status reviews of the Chinook salmon ESUs and the steelhead DPS.

Within the framework of the Recovery Plan, NMFS has the flexibility to work with partners. This includes support in developing and implementing recovery actions that address specific problems as they arise or intensify. As additional information becomes available regarding threats abatement, the links between threats and population responses, and the viability of Chinook salmon and steelhead in the Central Valley Domain, specific measures as well as the plan itself will be modified. The adaptive management and monitoring component provides a framework to obtain the appropriate types and amounts of data to evaluate the effectiveness of recovery actions and the progress toward recovery. Therefore, the adaptive management and monitoring program needs to address system-wide, watershed, population, and action-specific scales. The program is outlined in greater detail in at the end of this chapter in section 3.4.

3.2.3 Watershed Classifications (Core 1, 2, or 3)

A key element of this recovery strategy is focus of actions on watersheds that can support viable populations and contribute to meeting Diversity Group requirements for distribution and redundancy. To assess their potential to contribute to species recovery, watersheds in the four Diversity Groups that supported historic populations of any of the three listed species have been placed into three categories, based on their potential to support populations with low risk of extinction. The three categories are Core 1, Core 2, and Core 3. Watersheds that supported the three species, historic and current distribution, and watershed classifications are presented in Tables 3-1, 3-2 and 3-3.

Core 1 watersheds possess the known ability or potential to support a viable population. For a population to be considered viable, it must meet the criteria for low extinction risk for Central Valley salmonids (Lindley *et al.* 2007). The criteria include population size, population decline, catastrophic decline and hatchery influence (see Table 4-1). Only a few of the Core 1 populations meet the long-term objective of low extinction risk; the remaining Core 1 populations have the potential to do so.

Core 2 populations meet, or have the potential to meet, the biological recovery standard for moderate risk of extinction set out in Table 4-1. These watersheds have lower potential to support viable populations, due to lower abundance, or amount and quality of habitat. These populations provide increased life history diversity to the ESU/DPS and are likely to provide a buffering effect against local catastrophic occurrences that could affect other nearby populations, especially in geographic areas where the number of Core 1 populations is lowest.

Core 3 watersheds have populations that are present on an intermittent basis and require straying from other nearby populations for their existence. These populations likely do not have the potential to meet the abundance criteria for moderate risk of extinction. Core 3 watersheds are important because, like Core 2 watersheds, they support populations that provide increased life history diversity to the ESU/DPS and are likely to buffer against local catastrophic occurrences that could affect other nearby populations. Dispersal connectivity between populations and genetic diversity may be enhanced by working to recover smaller Core 3 populations that serve as stepping stones for dispersal.

Table 3-1. Population presence, risk of extinction and classification of watersheds with historic populations of winter-run Chinook salmon. Currently there is one population in the mainstem Sacramento River downstream of Keswick Dam. "Primary": top priority for reintroduction; "Candidate": possible area for reintroduction; "Non-candidate": reintroduction should not be attempted here. "NA": not applicable.

Diversity Group	River, Creek or sub-reach	Historic Population	Current Population	Population Extinction Risk (from Williams *et al*. 2011)	Classification
Basalt and Porous Lava	Battle Creek	Yes	No	NA	Primary
	Mainstem Sacramento River (below Keswick)	No	Yes	moderate	Core 1
	McCloud River	Yes	No	NA	Primary
	Pit River	Yes	No	NA	Non-Candidate
	Little Sacramento River	Yes	No	NA	Candidate

Table 3-2: Population presence, risk of extinction, and classification of watersheds with historic and current populations of spring-run Chinook salmon. "Primary": top priority for reintroduction; "Candidate": possible area for reintroduction; "Non-candidate": reintroduction should not be attempted here. "NA": not applicable

Diversity Group	River, Creek or Sub-reach	Historic Population	Current Population	Population Extinction Risk (from Williams *et al*. 2011)	Classification
Basalt and Porous Lava	Battle Creek	Yes	Yes	Moderate	Core 1
	Mainstem Sacramento River (blw Keswick)	No	Yes	High	Core 2
	Little Sacramento River	Yes	No	NA	Candidate
	McCloud River	Yes	No	NA	Primary
	Pit River	Yes	No	NA	Non-Candidate
Northwestern California	Stony Creek	Yes	No	NA	Core 3
	Thomes Creek	Yes	Yes	NA	Core 3
	Cottonwood/Beegum	Yes	Yes	High	Core 2
	Clear Creek	Yes	Yes	Moderate	Core 1
Northern Sierra Nevada	Mokelumne (below Comanche)	No	No	NA	Candidate
	Mokelumne (above Pardee)	Yes	No	NA	Candidate
	American River (above Folsom)	Yes	No	NA	Candidate
	American River (below Nimbus)	Yes	No	NA	Non-Candidate
	Feather River (below Oroville)	No	Yes	High	Core 2
	West Branch Feather (above Oroville)	Yes	No	NA	Non-Candidate
	North Fork Feather (above Oroville)	Yes	No	NA	Candidate
	Middle Fork Feather (above Oroville)	Yes	No	NA	Non-Candidate
	South Fork Feather (above Oroville)	Yes	No	NA	Non-Candidate
	Yuba River (below Englebright)	No	Yes	High	Core 2
	North Yuba River (above Englebright)	Yes	No	NA	Primary
	Middle Yuba River (above Englebright)	Yes	No	NA	Primary
	South Yuba River (above Englebright)	Yes	No	NA	Candidate
	Butte Creek	Yes	Yes	Low	Core 1
	Big Chico	Yes	Yes	High	Core 2
	Deer Creek	Yes	Yes	High	Core 1
	Mill Creek	Yes	Yes	High	Core 1
	Antelope Creek	Yes	Yes	High	Core 2
Southern Sierra Nevada	Stanislaus River (below Goodwin)	No	No	NA	Candidate
	Upper Stanislaus River (abv New Melones)	Yes	No	NA	Candidate
	Tuolumne River (below La Grange)	No	No	NA	Candidate
	Upper Tuolumne River (abv La Grange and Don Pedro)	Yes	No	NA	Candidate
	Merced River (below Crocker Huffman)	No	No	NA	Candidate
	Upper Merced River (abv New Exchequer)	Yes	No	NA	Candidate
	San Joaquin River (below Friant)	No	No	NA	Primary
	San Joaquin above Friant	Yes	No	NA	Candidate

Table 3-3. Population presence, risk of extinction, and classification of watersheds with historic and current populations of steelhead. "Primary": top priority for reintroduction; "Candidate": possible area for reintroduction; "Non-candidate": reintroduction should not be attempted here. "NA": not applicable

Diversity Group	River, Creek or Sub-reach	Historic Population	Current Population	Population Extinction Risk (from Williams *et al*. 2011, Lindley *et al*. 2007)	Classification
Basalt and Porous Lava	Battle Creek	Yes	Yes	High	Core 1
	Cow Creek	Yes	Yes	Uncertain	Core 2
	Mainstem Sacramento River (below Keswick)	No	Yes	Uncertain	Core 2
	Little Sacramento River	Yes	No	NA	Candidate
	McCloud River	Yes	No	NA	Primary
	Pit River	Yes	No	NA	Non-Candidate
	Redding Area Tributaries	Yes	Yes	Uncertain	Core 2
Northwestern California	Putah Creek	Yes	Yes	Uncertain	Core 2
	Stony Creek	Yes	Yes	Uncertain	Core 3
	Thomes Creek	Yes	Yes	Uncertain	Core 2
	Cottonwood/Beegum	Yes	Yes	Uncertain	Core 2
	Clear Creek	Yes	Yes	Uncertain	Core 1
Northern Sierra Nevada	Cosumnes River	Yes	Yes	Uncertain	Core 3
	Mokelumne River (below Comanche)	No	Yes	High	Core 2
	Mokelumne River (above Pardee)	Yes	No	NA	Candidate
	American River (below Nimbus)	No	Yes	High	Core 2
	Upper American (above Folsom)	Yes	No	NA	Candidate
	Auburn Ravine	No	Yes	Uncertain	Core 2
	Dry Creek	Yes	Yes	Uncertain	Core 3
	Feather River (below Oroville)	No	Yes	High	Core 2
	West Branch Feather (above Oroville)	Yes	No	NA	Non-Candidate
	North Fork Feather (above Oroville)	Yes	No	NA	Candidate
	Middle Fork Feather (above Oroville)	Yes	No	NA	Non-Candidate
	South Fork Feather (above Oroville)	Yes	No	NA	Non-Candidate
	Bear River	Yes	Yes	Uncertain	Core 3
	Yuba River (below Englebright)	No	Yes	Uncertain	Core 2
	North, Middle, South Yuba Rivers (above Englebright)	Yes	No	NA	Primary
	Butte Creek	Yes	Yes	Uncertain	Core 2
	Big Chico	Yes	Yes	Uncertain	Core 2
	Deer Creek	Yes	Yes	Uncertain	Core 1
	Mill Creek	Yes	Yes	Uncertain	Core 1
	Antelope Creek	Yes	Yes	Uncertain	Core 1
Southern Sierra Nevada	Calaveras River (below New Hogan)	No	Yes	Uncertain	Core 1
	Upper Calaveras River (above New Hogan)	Yes	No	NA	Non-Candidate
	Stanislaus River (below Goodwin)	No	Yes	Uncertain	Core 2
	Upper Stanislaus River (above New Melones)	Yes	No	NA	Candidate
	Tuolumne River (below La Grange)	No	Yes	Uncertain	Core 2
	Upper Tuolumne River (abv La Grange and Don Pedro)	Yes	No	NA	Candidate
	Merced River (below Crocker Huffman)	No	Yes	Uncertain	Core 2
	Upper Merced River (above New Exchequer)	Yes	No	NA	Candidate
	San Joaquin River (below Friant)	No	No	NA	Candidate
	Upper San Joaquin (above Friant)	Yes	No	NA	Non-Candidate

Factoring Climate Change into Watershed Classifications

Areas targeted for emphasis in the strategy were selected based on current population distribution and abundance, existing habitat, and the impacts of existing stressors. Obviously, conditions are not static. The best available projections indicate that the climate is likely to warm considerably in the future. Lindley *et al.* (2007) reported on three greenhouse gas emission scenarios. The scenario with lowest emissions projected a mean summer air temperature increase of at least 2°C (3.6°F) in the geographical area under consideration, the intermediate scenario predicts an increase of around 5°C (9°F), and the highest emissions scenario, which is the least-likely, but still possible, projects an increase of 8°C (14.4°F) by the year 2100. Because spring-run Chinook salmon and steelhead both exhibit juvenile over-summer rearing as part of their life history strategies, long-term climate change considerations are discouraging for both species, unless coldwater refugia at local and larger scales exist or can be provided (see Section 6.6.2).

To generalize, populations in low elevation habitats are more likely to be negatively affected by temperature increases. Vulnerability to adverse climate change effects is assumed to be buffered somewhat in higher elevations (less change in snowmelt and water temperature) and in geology that results in springs and groundwater. Specifically, hydrologic changes are likely to be buffered somewhat in the Basalt and Porous Lava and Southern Sierra Nevada Diversity Groups due to groundwater dominance and elevations high enough to retain snow, respectively. One additional factor is habitat located below reservoirs; the assumption is that releases of cold water could be made in support of listed species, and serve as a buffer.

By screening Core 1 and "primary" watersheds for these characteristics, a very rough assessment of vulnerability of habitats to climate change was done to help identify watershed priorities. Watersheds at the lower elevations, which do not have coldwater springs or other sources of coldwater (e.g., Thomes Creek, Big Chico Creek), were among the lower priority watersheds. By contrast, watersheds where salmon have access to coldwater via high elevation, springs, or releases from storage reservoirs were considered higher priority.

3.3 Primary Objectives of the Recovery Effort

Based on recommendations from the Central Valley TRT, this recovery effort has two primary objectives: (1) secure existing populations by addressing stressors; and (2) reintroduce populations into historically occupied or other suitable areas (Lindley *et al.* 2007). These objectives are considered equal in importance and both should be pursued simultaneously. Each objective is more fully described below.

3.3.1 Secure Existing Populations

All four historic winter-run Chinook salmon populations are extinct, with only one current population that is supplemented with hatchery production. Of the 18 or 19 populations of spring-run Chinook salmon, three remain. One (Butte Creek) has low risk of extinction; the other two (Deer Creek and Mill Creek) are at high risk of extinction. Of perhaps 81 historic steelhead populations, fewer than two dozen remain. These numbers reflect the perilous condition of these species, and underline the importance of the few remaining

populations to the long term recovery of the species. From this current, limited pool must come the individuals and genetic composition to support broader future population distribution. Loss of any of these populations would further jeopardize chances for recovery.

The strategy is consistent with the TRT recommendation that every extant population be viewed as necessary for the recovery of the ESUs and DPS. Wherever possible, the status of extant populations should be improved. Further information on population status and watershed condition can be found in Appendix A- Watershed Profiles.

Protection and enhancement of habitat for existing Core 1 and Core 2 populations are both vitally important. The strategy emphasizes protections and improvements in watersheds that support these populations, as well as actions necessary to eliminate or reduce threats present in the rivers and bay delta that connect them with the ocean.

Actions that protect and improve populations in Core 1 and Core 2 watersheds are the highest priority for investment of limited resources. This does not mean actions should not be taken in watersheds that support Core 3 populations, and, in fact, local groups are encouraged to undertake appropriate actions. It simply means that agencies should not substitute action in Core 3 watersheds for efforts in the Core 1 and Core 2 watersheds.

Address Threats

The primary means of securing existing populations is to reduce or eliminate the threats to the species and their habitats. Therefore, it was necessary to first identify the threats to each of the three species covered in this recovery plan; this was accomplished with the threats assessment described in Appendix B. Next, specific actions that address each prioritized threat must be identified. Those threat abatement actions (i.e., recovery actions), and the steps taken to identify and prioritize them, are described in Chapter 5.

3.3.2 Reintroduce Populations in Historically Occupied or Suitable Habitat

Meeting objectives for redundancy and distribution will require reintroducing some populations to habitats that historically supported the species, but are currently inaccessible because of existing dams (e.g. McCloud River). Also necessary are reintroduction of fish into watersheds that are currently accessible, but not utilized (e.g., winter-run Chinook salmon in Battle Creek).

Efforts to reintroduce fish will be challenging and expensive, and will require tremendous effort. To focus efforts, the strategy sets priorities for redundancy and spatial distribution within the four diversity groups. Priorities, based on existing information for the three listed species, are shown in **Tables 3-4, 3-5, and 3-6**. The highest-priority watersheds (primary watersheds) for re-introduction have been identified based on the current understanding of habitat conditions and the fact that reintroduction planning efforts are already underway in those watersheds. Watersheds with less potential, or where potential has not been assessed are classified as “candidates.”

This classification is based on current information. As the availability of habitat in these areas is further assessed, and measures necessary to facilitate the re-introductions evaluated and compared, priorities may change.

Populations will need to be re-established in some areas now blocked by dams or that have insufficient flows. Assuming that most of these dams will remain in place for the foreseeable future, it will be necessary to

provide fish passage around the dams in both directions. Near-term priority actions will include assessing habitat suitability and passage logistics. In the long-term reintroductions to high elevation habitats will need to be successful in at least a few watersheds, particularly as air temperatures increase and precipitation patterns change (see Chapter 6). Moving forward, information is needed to confirm that conditions are suitable for reintroduction in the priority watersheds, to determine which candidate watersheds have the highest likelihood of successful reintroduction, and to determine what measures are necessary to facilitate reintroductions.

A complete picture of the watershed priorities for each species are displayed in **Figures 3-4, 3-5, and 3-6**. These maps also provide a picture of what the distribution of a recovered ESUs/DPS would look like.

Table 3-4. Priorities for Winter-Run Chinook Salmon by Diversity Group.

Diversity Group	Current Core 1 Population	Diversity Group Objective*	Re-introduction Priorities	Current Core 2 Populations
Basalt and Porous Lava	Sacramento River	3	McCloud River (Primary) Battle Creek (Primary)	None
*number of populations with low risk of extinction				

Table 3-5. Priorities for Spring-Run Chinook Salmon by Diversity Group.

Diversity Group	Current Core 1 Populations	Diversity Group Objective*	Re-introduction Priorities	Current Core 2 Populations
Basalt and Porous Lava	Battle Creek	2	McCloud River (Primary)	Sacramento River (below Keswick)
Northwestern California	Clear Creek	1	None	Cottonwood/Beegum
Northern Sierra Nevada	Mill Creek	4	Yuba River above Englebright (Primary)	Yuba River (below Englebright)
	Deer Creek			Antelope Creek
	Butte Creek			Feather River (below Oroville)
Southern Sierra Nevada	None	2	San Joaquin (below Friant) (Primary) One Candidate Watershed	None Currently Identified
* number of populations with low risk of extinction				

Table 3-6. Priorities for Steelhead by Diversity Group.

Diversity Group	Current Core 1 Populations	Diversity Group Objective	Re-introduction Priorities	Current Core 2 Populations
Basalt and Porous Lava	Battle Creek	2	McCloud River (Primary)	Cow Creek
				Redding Area Tributaries
				Sacramento River (below Keswick)
Northwestern California	Clear Creek	1	None	Thomes Creek
				Putah Creek
				Cottonwood/Beegum
Northern Sierra Nevada	Antelope Creek	4	Yuba River above Englebright (Primary)	Yuba River (below Englebright Dam)
	Deer Creek			Butte Creek
				Feather River (below Oroville Dam)
	Mill Creek			Big Chico Creek
				Auburn Ravine
				American River
Southern Sierra Nevada	Calaveras River	2	One Candidate Watershed	Stanislaus River (below Goodwin)
				Merced River (below Crocker Huffman)
				Tuolumne River (below La Grange)
* number of populations with low risk of extinction				

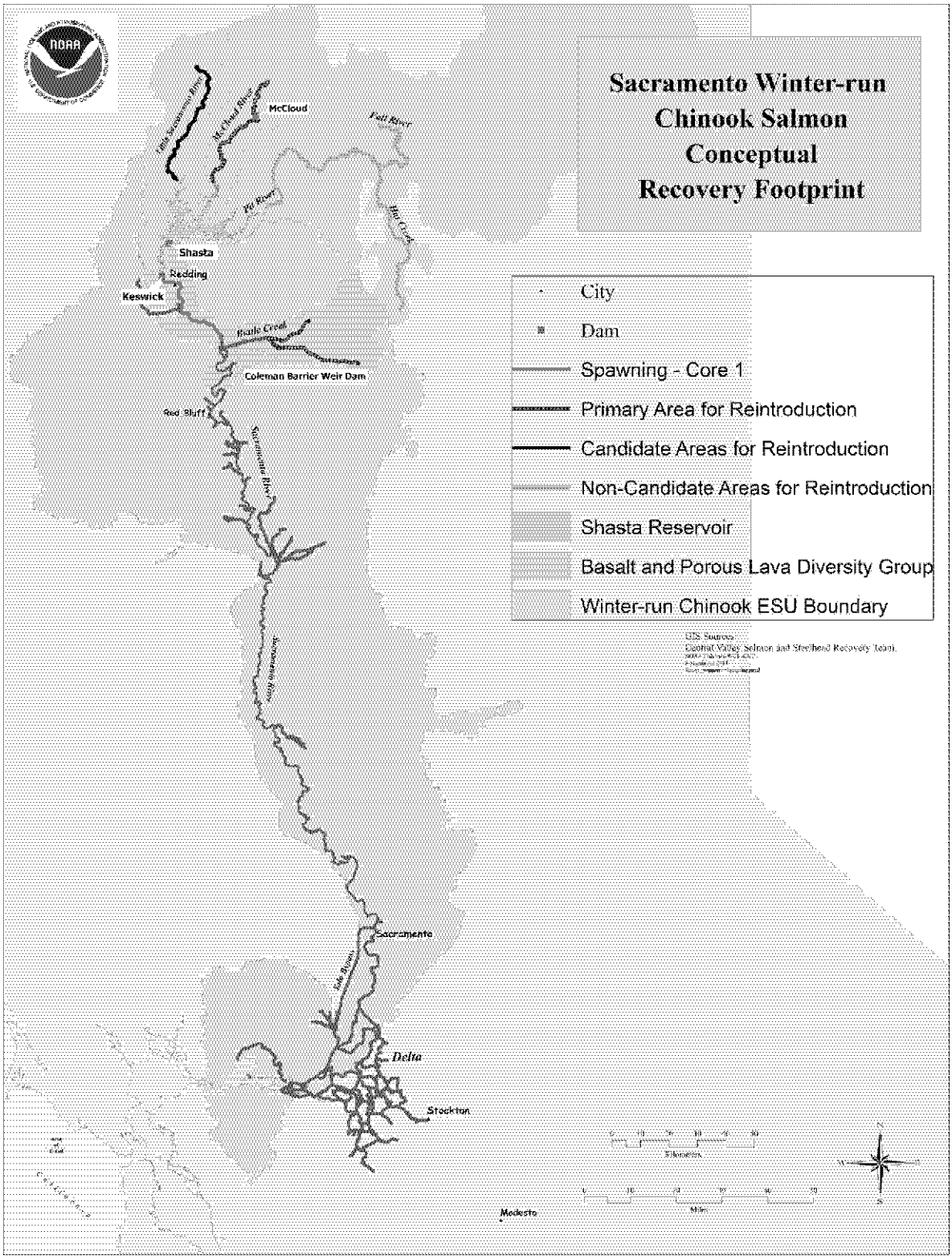


Figure 3-4. Sacramento River Winter-run Chinook Salmon Recovery Footprint. The primary and candidate areas for reintroduction depicted on this map are areas where, although dams block access, the primary constituent elements that are necessary to support freshwater migration, holding, spawning and rearing still exist or could be restored.

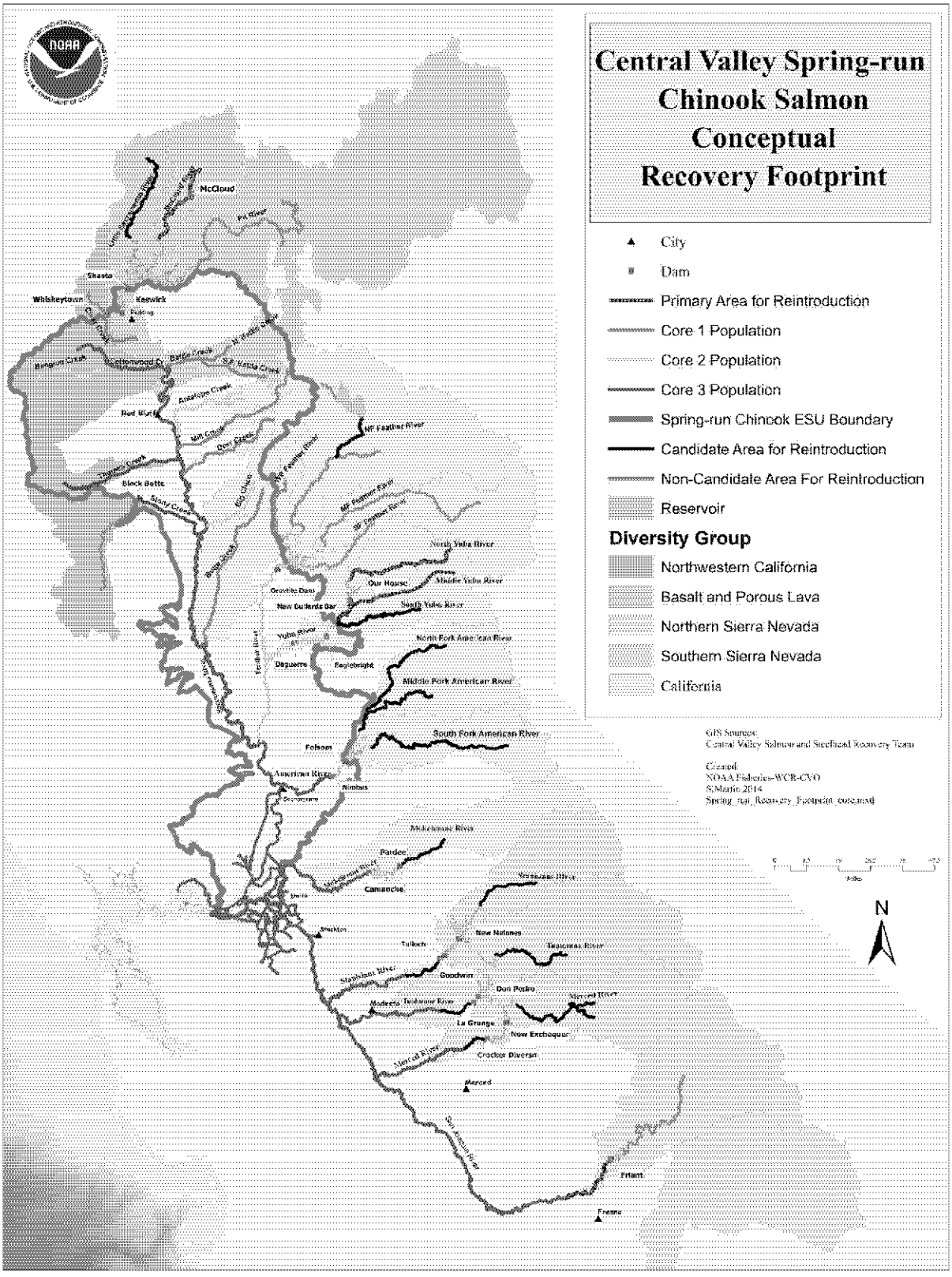


Figure 3-5. Central Valley Spring-run Chinook Salmon Recovery Footprint. The primary and candidate areas for reintroduction depicted on this map are areas where, although dams block access, the primary constituent elements that are necessary to support freshwater migration, holding, spawning and rearing still exist or could be restored.

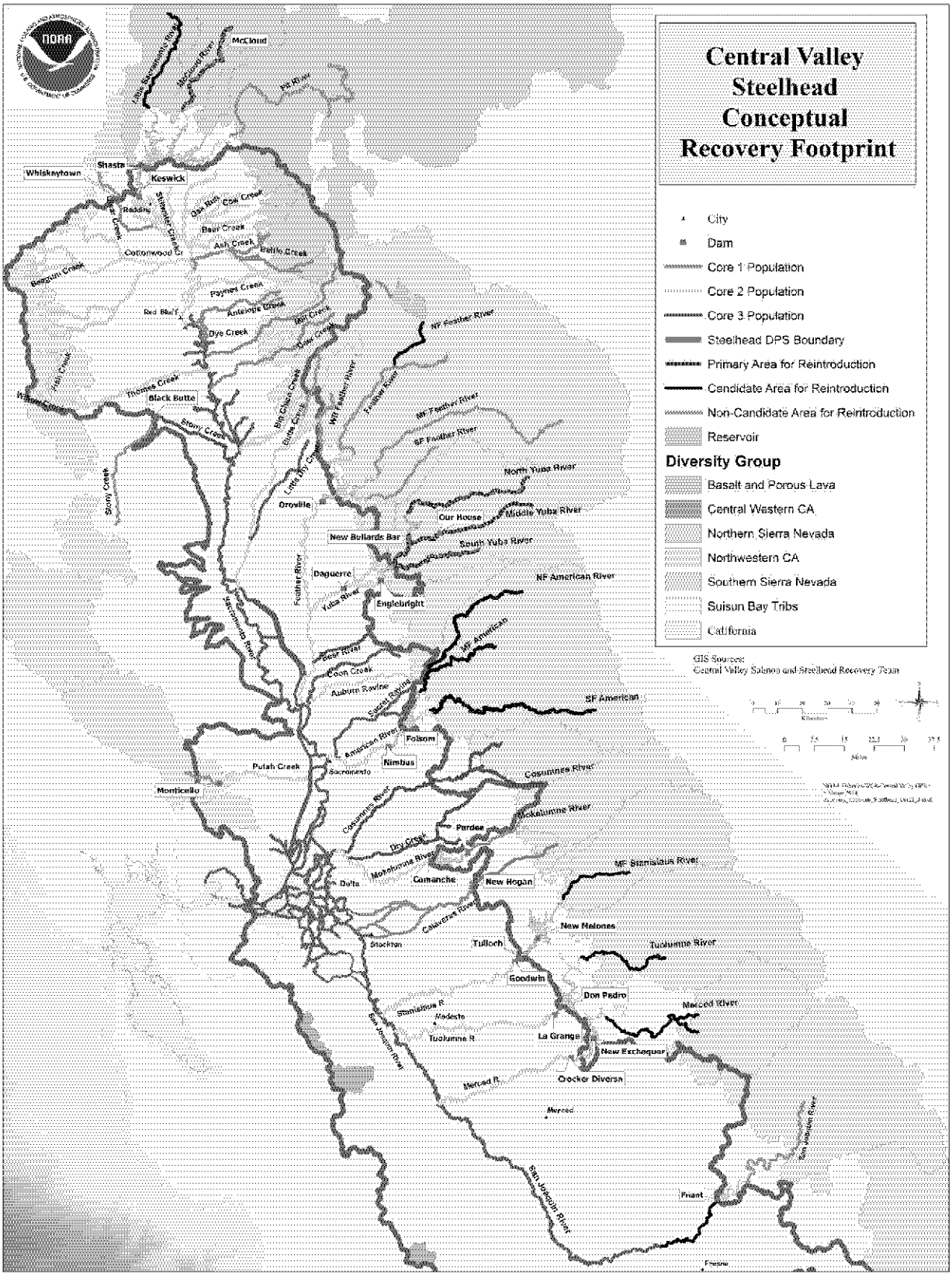


Figure 3-6. California Central Valley Steelhead DPS Recovery Footprint. The primary and candidate areas for reintroduction depicted on this map are areas where, although dams block access, the primary constituent elements that are necessary to support freshwater migration, holding, spawning and rearing still exist or could be restored.

Re-introduction of anadromous fishes to historic habitats will require a new approach to watershed management, especially in regard to the operation and licensing of hydroelectric projects. Many of the keystone passage impediments to upstream habitat are regulated by the Federal Energy Regulatory Commission (FERC). In many watersheds, FERC also regulates upstream hydroelectric projects and facilities, and in most cases the licenses issued by FERC expire on different schedules, making the necessary, coordinated ecosystem-wide approach to relicensing difficult. Numerous hydroelectric licenses will come up for renewal in the next 20 years. Re-introduction of fish to historic habitats will require concerted watershed-scale approaches by FERC and other involved parties to align license schedules, develop new stream flow regimes, and facilitate comprehensive fish passage plans. This approach is especially necessary in the McCloud, upper Yuba, upper American, and other watersheds where hydroelectric projects influence areas identified for re-introduction, and affect downstream habitats that are essential for recovery. Re-introduction will require improved resource agency coordination, including joint filings under FERC proceedings, aligning regulatory schedules and products, and sharing biological, technical, and policy expertise on high priority projects.

The Sacramento River winter-run Chinook salmon ESU currently has one population, and that population spawns outside the species historic spawning range. For that reason, introductions into historically occupied habitat are necessary to meet requirements for redundancy. Re-introduction in the McCloud Rivers has the highest probability of success. Priority for the third population in the Diversity Group is introduction of the species in Battle Creek, which has suitable habitat for the species.

As with winter-run Chinook salmon, spring-run Chinook salmon will require re-introductions into historically occupied or currently suitable habitat in the Basalt and Porous Lava, Northern Sierra Nevada, and Southern Sierra Nevada Diversity Groups, in order to meet requirements for distribution and redundancy. Primary areas for spring-run Chinook salmon re-introduction into historic habitat include upstream of Shasta Dam in the Basalt diversity group and the Yuba River above Englebright Dam in the Northern Sierra Nevada. In the Southern Sierra Nevada, the strategy calls for reintroduction of spring-run Chinook salmon in the San Joaquin River below Friant Dam, and in one additional watershed in the Southern Sierra Nevada (Table 3-5).

Reintroductions of steelhead to historically occupied or currently suitable habitat will be necessary to meet objectives for distribution and redundancy in the Basalt and Porous Lava, Northern Sierra Nevada, and Southern Sierra Nevada Diversity Groups. Priorities for re-introduction are included in Table 3-6. These priorities include the McCloud River in the Basalt and Porous Lava Group and the Yuba River above Englebright in the Northern Sierra Nevada. Top priority areas for steelhead reintroductions in the Southern Sierra Nevada have yet to be established.

Reintroducing Chinook salmon and steelhead to historic habitats, particularly those habitats upstream of impassable barriers, will be extremely complicated and many questions will need to be answered as the projects progress. A few of the most important biological questions include:

- which donor populations should be used?;

- how will donor fish be collected, how many will be needed, and what life stages should be used?;
- how and where will juveniles produced upstream of a barrier be collected, and how will they be transported downstream of the barrier?; and
- where and when will adults and juveniles be released?

In addition to those questions, which apply to all three species, re-introducing steelhead upstream of impassable barriers comes with unique complications and associated questions. First, because steelhead are iteroparous (i.e., they spawn multiple times in their lifetime), the question of what to do with the adult steelhead that spawn upstream of the barrier arises. Assuming those adults should be allowed to carry out their natural life history strategy by returning to the ocean after spawning, an effective collection method will need to be implemented.

Another important issue related to steelhead re-introductions deals with the occurrence of resident *O.mykiss* upstream of the barriers, which, in some Central Valley locations, contain genetic material representative of ancestral *O.mykiss* (Garza and Pearse 2008). This adds additional considerations to the donor stock selection question raised above – should the ancestral stock be used or a below barrier stock? This question and others associated with integrating below and above barrier populations will need to be addressed.

Lastly, reintegrating *O.mykiss* below and above barriers does not guarantee an increase in steelhead abundance, at least in the short-term while the selection regime favors residency. There are more resident *O.mykiss* than anadromous *O.mykiss* in the Central Valley (McEwan 2001), indicating selection pressure in the favor of the resident form. If selection pressures on the anadromous and resident form were equal, then one would expect their relative abundances to be somewhat equal and likely biased to anadromous *O.mykiss* because anadromous fish attain a much larger size than resident fish, and thus are able to outcompete the resident fish for quality spawning habitat and are much more fecund, producing twice as many eggs per body weight (Moyle 2002). Hypotheses for why there are more resident than anadromous *O.mykiss* in the Central Valley include: (1) low survival of *O.mykiss* through the Delta; (2) cold water releases from dams providing thermally survivable habitat for *O.mykiss* to live in year-round; and (3) a combination of 1 and 2. Achieving a better understanding of the factors influencing the selection between anadromous and resident life history strategies is an important step for efforts to expand steelhead habitat upstream of impassable barriers.

In the face of all of the complications and questions related to anadromous salmonid reintroductions in the Central Valley, it is important to recognize that recovering winter-run Chinook salmon, spring-run Chinook salmon, and steelhead is highly unlikely without significant habitat expansion (Lindley *et al.* 2007; Cummins *et al.* 2008; Moyle *et al.* 2008).

Role of Hatcheries in Securing Existing Populations and Reintroducing Populations in Historically Occupied or Suitable Habitat

The principal strategy of salmonid conservation and recovery continues to be through the protection and restoration of the healthy ecosystems upon which they depend, in line with the ESA's stated purpose to conserve "the ecosystems upon which endangered and threatened species

depend" (ESA section 2(b)). However, a natural recovery of local extinctions depends on one or more recolonization events, a process that operates on an indefinite timescale. Likewise, the viability of a depressed population, characterized by small size, fragmented structure, and impacted genetics (e.g., bottlenecks, inbreeding, outbreeding depression, etc.), may be so compromised that its response to restored or increased availability of habitat is not sufficient to prevent imminent extinction. Either case may demand management intervention to attain viable salmonid populations. Conservation hatcheries may provide an appropriate means for establishing new populations and for allowing existing populations to recover. Two relevant examples from the Central Valley are the development of a conservation hatchery to help re-establish spring-run Chinook salmon in the San Joaquin River and the ongoing operation of the winter-run Chinook salmon conservation program at the Livingston Stone National Fish Hatchery.

There is considerable uncertainty regarding the ability of artificial propagation to increase population viability over the long-term, and it cannot be assumed that artificial augmentation will reduce extinction risk. There is a risk to natural recovery from increasing dependency on hatchery production. Conservation hatcheries must therefore monitor the effects of their programs on the natural population using criteria which would trigger modification to or cessation of the conservation program.

3.4 ADAPTIVE MANAGEMENT AND MONITORING

Successful adaptive management relies on accurate data provided by effective long-term monitoring programs. Past and current CV salmonid monitoring programs have suffered from inconsistent and/or inadequate funding. For successful species recovery and effective use of limited resources, a funding mechanism for long term effective monitoring of CV salmonids should be a fundamental top priority in the recovery plan.

Implementation of the Recovery Strategy will involve actions throughout the ESUs and DPS, conducted by a variety of agencies and stakeholders, addressing a multitude of site specific and systematic issues. These efforts are complicated by uncertainties, which include the actual abundance and distribution of the listed species, interactions between the species and their habitat, and the design and effectiveness of recovery actions. An effective means of gathering and sharing information on the condition of the resources, and the lessons learned during implementation of actions, is essential to bring accountability and efficiency to the process, and to allow for informed revisions to the recovery approach.

Adaptive management and monitoring will provide a framework to obtain the appropriate types and amounts of data to evaluate the effectiveness of recovery actions and progress toward recovery. The plan, outlined below, includes an approach to coordination of the numerous monitoring and research tasks required for implementation of the strategy.

Track Performance

This effort will document that recovery actions are implemented, as well as determine if they were implemented as intended and designed.

Monitor effectiveness of implemented actions

The goal of this component of the plan is to determine if actions, once implemented, meet their objectives. Because priority for future restoration efforts will be given to actions shown to be effective, this information will lead to adjustments in priority for actions. At the site level, it will assist in project design, to take advantage of lessons learned.

Review progress in meeting recovery criteria

This information is needed to assess progress toward the goal of delisting, and includes three parts: viability in each Diversity Group (population distribution and abundance), habitat monitoring, and evaluation of threats.

Viability

Existing adult salmonid escapement monitoring programs in the Central Valley are currently inadequate to estimate population status and evaluate population trends in a statistically valid manner for the following management purposes: (1) providing a sound basis for assessing recovery of listed stocks; (2) monitoring the success of restoration programs; (3) evaluating the contribution of hatchery fish to Central Valley populations; and (4) managing sustainable ocean and inland harvest (Allen 2005).

Numerous programs are underway to collect information on anadromous fish species in the Central Valley. Although each of these programs and monitoring activities provides important information about the overall status of the specific resources and their habitats in the Central Valley and Bay/Delta, they are generally implemented on a project-by-project basis. Other streams and associated populations within the Chinook salmon ESUs and the steelhead DPS within the Central Valley Domain have no existing monitoring surveys or programs. Clearly, a more coordinated and comprehensive system-wide watershed and population monitoring system is needed.

As previously noted, there is great need for the development and implementation of a comprehensive monitoring plan for steelhead populations throughout the Central Valley Domain. The Central Valley Domain TRT was unable to assess the status of the California Central Valley steelhead DPS because nearly all of its approximately 80 historic populations are classified as data-deficient, with a few exceptions that are closely associated with a hatchery (Lindley *et al.* 2007).

In addition to population status and trend evaluation, accurate estimation of adult Chinook salmon and steelhead spawner escapement is necessary for harvest management. Age and run-specific escapement data in the Central Valley are necessary to utilize more accurate models associated with ocean harvest management.

Habitat

Watershed-level monitoring, including selected habitat variables, is necessary to evaluate the effectiveness of multiple restoration actions. Watershed-specific monitoring evaluations will contribute to the assessment of threat abatement and population responses. Additionally, the long-term effects of habitat restoration actions need to be assessed throughout the Central Valley Domain. Components that require monitoring include long-term changes in the characteristics of targeted recovery/restoration components such as aquatic habitat, riverine channel

configuration, riparian vegetation, and floodplain structure and function.

Long-term habitat monitoring will also include parameters useful in tracking trends of climate change effects, such that necessary modifications to recovery objectives can be made.

Evaluation of Threats

Actions included in the strategy are intended to address threats to the listed species and their habitats. Monitoring implementation and effectiveness of actions will help track progress and provide information necessary to guide adaptive management. This data, along with monitoring of watershed and habitat conditions outlined above, will provide the information necessary to evaluate the degree to which threats have been eliminated or reduced as well as to identify any new threats.

Coordination research and monitoring targeted to address information gaps

Recovering the Chinook salmon ESUs and steelhead DPS will require numerous investigations and studies. The majority of these will address a specific question (e.g., gravel movement) at a particular site, while some are fairly broad questions (e.g., assess reintroduction potential above a group of impoundments). Also necessary are the system wide habitat and population monitoring programs outlined above. Coordination of these efforts is necessary so that questions are addressed in a priority sequence, and so that information and approaches are shared and efforts are not duplicated. A consistent framework for research and monitoring will directly inform recovery objectives and goals.

Reporting

There is a need to effectively share information with the public, stakeholders, and cooperators. To this end, NOAA is in the process of developing an internet-based recovery action tracking system. The reporting will support the annual reporting for the Government Performance and Results Act, Bi-Annual Recovery Reports to Congress, and the 5-Year Status Review.

4.0 Recovery Goals, Objectives and Criteria

"Merely increasing a species' numbers, range and abundance does not ensure its long-term health and sustainability; only by alleviating threats can lasting recovery be achieved."

- Interim Endangered and Threatened Species Recovery Planning Guidance (NMFS 2010b)

This chapter describes the goals of this Recovery Plan and includes a brief discussion of the biological basis for meeting those goals for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead. This chapter also explains the objectives and criteria to be used to determine when recovery of the listed species has been achieved. Two main types of criteria are presented. First, biological criteria pertaining to both ESU/DPS and population viability are described. Next, threat abatement criteria are covered to determine when the threats that led to listing of the species have been eliminated or adequately reduced.

4.1 Recovery Goals

The overarching goal of this Recovery Plan is the removal of the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead DPS from the Federal List of Endangered and Threatened Wildlife (50 CFR 17.11; 50 CFR 224.101; 50 CFR 223.102). Because recovery plans are not regulatory documents, successful implementation and recovery of listed species will require the support, efforts and resources of many entities, from Federal and State agencies to individual members of the public. Another goal will be to encourage and support effective partnerships with regional stakeholders to meet the objectives and criteria of the Recovery Plan. The objectives and criteria to accomplish the overarching goal of species delisting build upon the technical input and guidance provided by the Central Valley TRT, and other information provided during public workshops and co-manager reviews. Much of the technical recovery discussion in this section is taken directly from information developed by the TRT (Lindley *et al.* 2004; 2006; 2007).

The Endangered and Threatened Species Recovery Planning Guidance (NMFS 2010b) describes the recovery planning goal as recovery and long-term sustainability of an endangered or threatened species and, therefore, delisting of the species. Further, NMFS (2010b) states that goals usually can be subdivided into discrete component objectives which, collectively, describe the conditions (criteria) necessary for achieving the goal. Simply stated, recovery objectives are the parameters of the goal, and criteria are the values for those parameters. The objectives and related criteria, representing the components of the recovery goal, identify mechanisms for pursuing the goal (including necessary recovery actions) and allow confirmation when the goal has been reached.

According to NMFS (2010b), recovery and long-term sustainability of an endangered or threatened species require:

- Adequate reproduction for replacement of losses due to natural mortality factors (including disease and stochastic events)
- Sufficient genetic robustness to avoid inbreeding depression and allow adaptation
- Sufficient habitat (type, amount, and quality) for long-term population maintenance
- Elimination or control of threats (this may also include having adequate regulatory mechanisms in place).

4.2 Integrating TRT Products into Recovery Objectives and Criteria

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria which, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife; the criteria described herein fulfill that role with regard to the aforementioned species.

Population or demographic parameters are considered through the biological recovery criteria, while the threats criteria consider threats under the five ESA listing factors in ESA section 4(a)(1) (threats criteria). Together, these make up the "objective, measurable criteria" required under section 4(f)(1)(B).

These recovery criteria were derived from the TRT products (Appendix C), and as such, they represent the best scientific analysis incorporating the most current understanding of the ESUs and DPS and their populations.

4.2.1 Biological Basis for Recovery Criteria

For delisting, the ESU/DPS should meet the criteria for populations and diversity groups listed below in Sections 4.3.2 and 4.3.4. Downlisting (endangered to threatened) criteria for winter-run Chinook salmon are provided in Section 4.3.4.1. These delisting and downlisting criteria are based on population- and ESU-level considerations as discussed below in Sections 4.2.1.1 and 4.2.1.2.

Population Level Considerations

This plan includes both population-level and Diversity Group recovery criteria. The population-level criteria are used to determine whether a population is viable or not. A viable population is one with a low extinction risk in the wild over the long-term (McElhany *et al*. 2000).

The Central Valley TRT incorporated the four VSP parameters into assessments of population viability, and two sets of population viability criteria were developed, expressed in terms of extinction risk (Table 4-1). The first set of criteria deal with direct estimates of extinction risk from population viability analysis (PVA) models. If data are available and such analyses exist and are deemed reasonable for individual populations, such PVA assessments may be efficient for assessing extinction risk. The Central Valley TRT assumed that, for PVA results, a 5 percent or less risk of extinction in 100 years is an acceptably low extinction risk for populations (Lindley *et al*. 2007).

The second set of criteria are simpler and do not require PVA modeling results. These simpler extinction risk criteria are the basis of the population-level recovery criteria used in this Recovery Plan, with the low extinction risk levels defining what constitutes a viable population. The simpler criteria from Table 4-1 include population size (and effective population size), population decline, catastrophic rate and effect, and hatchery influence. Estimators for the various viability criteria are presented in Table 4-2.

Population Size (Abundance)

The effective population size criteria (second row of Table 4-1) relate to loss of genetic diversity. Very small populations, for example with *Ne* < 50, suffer severe inbreeding depression (Franklin 1980; Soulé 1980 *in* Lindley *et al.* 2007), and normally outbred populations with such low *Ne* have a high risk of extinction from this inbreeding. Somewhat larger, but still small, populations can be expected to lose variation in quantitative traits through genetic drift faster than it can be replaced by mutation. With future research, it may be possible to better define population size targets that conserve genetic variation and account for migration and genetic structuring within ESUs/DPS.

Census size N can be used if direct estimates of effective population size are not available. Census size is estimated as the product of the mean run size and the average generation time. The average spawning run size is computed as the mean of up to the three most recent generations, if that much data are available.

The general criteria for population size discussed below may be adjusted as further information is developed. Healthy populations should be at or near carrying capacity in most years. As such, a detailed and thorough assessment of each watershed's carrying capacity should be conducted, and the recovery criterion for abundance should be based on that estimated carrying capacity.

As recovery actions are implemented and habitats are restored and expanded, the low extinction risk abundance criterion (i.e., census size>2,500) may be too low for large watersheds or for abundant populations. For example, Butte Creek has supported spring-run Chinook salmon populations with a census size well in excess of 2,500 since 1998, suggesting that the carrying capacity of that system may be greater than that criterion.

Carrying capacity assessments could be accomplished by applying a consistent approach to measure habitat capacity throughout each ESU/DPS and then relating that capacity to assumed spawner density thresholds that correspond to varying levels of extinction risk (Williams *et al.* 2008). Until such population-specific abundance recovery criteria are developed, the low and moderate extinction risk abundance criterion (Table 4-1) serve as benchmarks for the developing population delisting criteria.

Population Decline (Productivity)

This criterion is intended to capture demographic risks. The rationale behind the population decline criteria are fairly straight forward: severe and prolonged declines to small run sizes are strong evidence that a population is at risk of extinction. Population growth (or decline) rate is estimated from the slope of the natural logarithm of spawners versus time for the most recent 10 years of spawner count data.

Catastrophic Rate and Effect (Productivity)

The overall goal of the catastrophe criterion is to capture a sudden shift from a low risk state to a higher risk state. Catastrophes are defined as instantaneous declines in population size due to events that occur randomly in time, in contrast to regular environmental variation. A high risk catastrophic event is one that causes a 90 percent decline in population size over one generation. A moderate risk catastrophic event is one that is smaller but biologically significant, such as a year-class failure.

Hatchery Influence (Diversity)

The spawning of hatchery fish in the wild is a potentially serious threat to the viability of natural populations. Population genetics theory predicts that hatchery fish can negatively impact wild populations when they spawn in the wild. In assessing the genetic impact of immigration on a population, considerations include the source of the immigrants, duration of the impact, the number of immigrants relative to the size of the recipient population, and how genetically divergent the immigrants are from the recipient population. Definitions of the manner in which different immigration scenarios relate to extinction risk for natural populations are summarized in Figure 4-1. Application of these definitions can result in a low-risk classification even with moderate amounts of straying from best-practices hatcheries, as long as other risk measures are acceptable (Lindley *et al.* 2007). The fraction of naturally-spawning hatchery origin fish is the mean fraction over one to four generations.

Table 4-1. Criteria for assessing the Level of Risk of Extinction for Populations of Pacific Salmonids, Applied to the Chinook Salmon ESUs and the Steelhead DPS in the Central Valley Domain (from Lindley et al. 2007).

	Risk of Extinction		
Criterion	High	Moderate	Low
Extinction risk from PVA	> 20% within 20 years	> 5% within 100 years	< 5% within 100 years
	– or any ONE of –	– or any ONE of –	– or ALL of –
Population size[a]	$N_e \leq 50$	$50 < N_e \leq 500$	$N_e > 500$
	–or–	–or–	–or–
	$N \leq 250$	$250 < N \leq 2500$	$N > 2500$
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe, rate and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[e]	not apparent
Hatchery influence[f]	High	Moderate	Low

[a] Census size N can be used if direct estimates of effective size N_e are not available, assuming $N_e/N = 0.2$.
[b] Decline within last two generations to annual run size $\leq$ 500 spawners, or run size > 500 but declining at $\geq$ 10% per year. Historically small but stable population not included.
[c] Run size has declined to $\leq$ 500, but now stable.
[d] Catastrophes occuring within the last 10 years.
[e] Decline < 90% but biologically significant.
[f] See Figure 1 for assessing hatchery impacts.

Table 4-2 Estimation Methods and Data Requirements for Population Metrics. S_t denotes the number of spawners in year t; g is mean generation time, assumed as three years for California salmon (from Lindley et al. 2007).

Metric	Estimator	Data	Criterion
$\hat{S}_t$	$\sum_{i=t-g+1}^{t} S_i/g$	$\geq$ 3 years spawning run estimates	Population decline
N_e	$N \times 0.2$ or other	varies	Population size
N	$\hat{S}_t \times g$	$\geq$ 3 years spawning run estimates	Population size
Population growth rate (% per year)	slope of $\log(S_t)$ v. time $\times 100$	10 years S_t	Population decline
c	$100 \times (1 - \min(N_{t+g}/N_t))$	time series of N	Catastrophe
h	average fraction of natural spawners of hatchery origin	mean of 1-4 generations	Hatchery influence

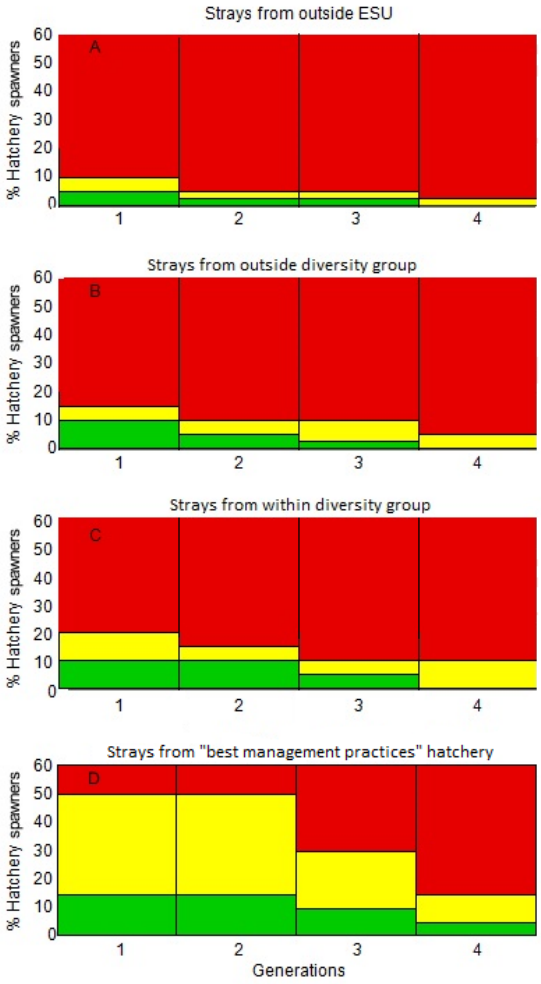


Figure 4-1. Extinction Risk Levels Corresponding to Different Amount, Duration and Source of Hatchery Strays.

Green bars indicate the range of low risk, yellow bars moderate risk, and red areas indicate high risk. Which chart to use depends on the relationship between the source and recipient populations. (A) hatchery strays are from a different ESU than the wild population. (B) Hatchery strays are from the same ESU but from a different diversity group within the ESU. (C) Hatchery strays are from the same ESU and diversity group, but the hatchery does not employ "best management practices." (D) Hatchery strays are from the same ESU and diversity group, and the hatchery employs "best management practices." (from Lindley *et al.* 2007)

Diversity Group and ESU/DPS Considerations

In order to delist the winter-run and spring-run Chinook salmon ESUs and the steelhead DPS, the TRT stated that there must be at least two viable populations in each diversity group (Lindley *et al.* 2007). This ESU/DPS-level recovery goal addresses the representation and redundancy rule for ESU/DPS viability.

The TRT recommendation of at least two viable populations is not applicable to the Northwestern California diversity group for spring-run Chinook salmon and steelhead, because this diversity group did not historically support viable populations. However due to management and restoration activities, the potential exists to support a viable population in Clear Creek.

As previously explained in Section 3.2.1, full steelhead recovery can be achieved without representation from either the Suisun Bay or Central Western California diversity groups.

4.3 Biological Objectives and Criteria at the Population, Diversity Group, and ESU/DPS Level

Implementation of the Recovery Plan is designed to ultimately achieve objectives for the ESUs/DPS at the Diversity Group level, and at the population level (i.e. watershed level) for the four VSP criteria of abundance, productivity, diversity, and spatial structure. Objectives addressing these requirements include demographic parameters, reduction or elimination of threats to the species (the listing factors), and any other particular vulnerability or biological needs inherent to the species.

4.3.1 Population Objectives

In general, viable populations should demonstrate a combination of population abundance, growth rate and genetic integrity that produces an acceptable probability of population persistence. Specifically, viable populations should meet the low extinction

risk levels for the population decline and population size criteria described below in the following section.

4.3.2 Population Level Criteria

Consistent with the strategic approach to achieve recovery, this Recovery Plan establishes the following criteria for the viability of individual populations, similar to NMFS (2005b). The criteria are based on the VSP criteria for productivity and abundance, and diversity outlined in section 4.2.1

Low risk of extinction criteria

- Census population size is >2,500 adults -or- Effective population size is >500
- No productivity decline is apparent
- No catastrophic events occurring or apparent within the past 10 years
- Hatchery influence is low (see Figure 4-1).

Moderate risk of extinction criteria

- Census population size is 250 to 2,500 adults -or- Effective population size is 50 to 500 adults
- Productivity: Run size may have dropped below 500, but is stable
- No apparent decline in population growth rate resulting from catastrophic events within the past 10 years
- Hatchery influence is moderate

4.3.3 ESU/DPS Objectives

ESU/DPS viability depends on the number of populations within the ESU/DPS, their individual status, their spatial arrangement with respect to each other and sources of catastrophic disturbance, and the diversity of the populations and their habitats. In the most general terms, ESU/DPS viability increases with the number of populations (redundancy), the viability of these populations, spatial distribution of the populations, the diversity of the populations, and the diversity of habitats that they occupy.

For the ESUs and DPS to achieve recovery, each of the Diversity Groups should support both viable and dependent populations and meet goals for redundancy and distribution. Thus, an overall goal is to sustain populations in each of the Diversity Groups.

4.3.4 ESU/DPS Criteria

ESU Level Downlisting Criteria for Endangered Winter-run Chinook

Downlisting is the reclassification of a species from endangered to threatened. Two criteria have been identified with regard to downlisting of winter-run Chinook salmon from endangered to threatened:

- One population should meet each of the low extinction risk criteria described in section 4.3.2.; and
- In addition to the one viable population, the ESU should include one other spawning population that meets the moderate extinction risk criteria described in Table 4-1.

These winter-run Chinook salmon downlisting criteria were identified because, when achieved, the species' viability would be notably improved from its current status, but would still be far from recovered (i.e., delisted). Currently, there is one population of winter-run Chinook salmon. In order to achieve the downlisting criteria, the species would need to be composed of two populations – one viable and one at moderate extinction risk. Having a second population would improve the species' viability, particularly through increased spatial structure and abundance, but further improvement would be needed to reach the goal of recovery. As identified in the next section, to delist winter-run Chinook salmon, three viable populations are needed. Thus, the downlisting criteria represent an initial key step along the path to recovering winter-run Chinook salmon.

ESU/DPS Delisting Criteria

In order for the Chinook salmon ESUs and the steelhead DPS to achieve recovery, Diversity Groups should display the following characteristics:

For the Winter-run Chinook salmon ESU:

- Three populations in the Basalt and Porous Lava Diversity Group at low risk of extinction

For the Spring-run Chinook salmon ESU:

- One population in the Northwestern California Diversity Group at low risk of extinction
- Two populations in the Basalt and Porous Lava Diversity Group at low risk of extinction
- Four populations in the Northern Sierra Diversity Group at low risk of extinction
- Two populations in the Southern Sierra Diversity Group at low risk of extinction
- Maintain multiple populations at moderate risk of extinction

For the California Central Valley steelhead DPS:

- One population in the Northwestern California Diversity Group at low risk of extinction
- Two populations in the Basalt and Porous Lava Flow Diversity Group at low risk of extinction
- Four populations in the Northern Sierra Diversity Group at low risk of extinction
- Two populations in the Southern Sierra Diversity Group at low risk of extinction
- Maintain multiple populations at moderate risk of extinction

For context, these ESU/DPS recovery criteria are shown in relation to historic and current conditions in Table 4-3. Although Table 4-3 does show that much improvement in the number and distribution of viable populations is needed, an encouraging take-away point is that these species can be recovered without achieving the historic condition. For example, a recovered spring-run Chinook salmon ESU requires nine viable populations, not the 19 that historically occurred in the Central Valley.

Table 4-3: Number of independent, viable populations of winter-run and spring-run Chinook salmon and steelhead by diversity group under historic and current conditions, relative to the recovery criteria. The recovery criteria also include maintenance of all existing dependent populations.

Diversity Group	Historic, Current and Recovered Independent, Viable Populations - Total By Diversity Group								
	Winter-Run			Spring Run			Steelhead		
	Historic	Current	Recovery Criteria	Historic	Current	Recovery Criteria	Historic	Current	Recovery Criteria
Basalt and Porous Lava	4	0	3	4	0	2	12	Unknown	2
Northwestern California	0	0	0	0	0	1	14	Unknown	1
Northern Sierra	0	0	0	11	1	4	21	Unknown	4
Southern Sierra	0	0	0	4	0	2	26	Unknown	2

4.4 Threat Abatement

The underlying causes of species declines should be controlled prior to delisting. These causes include all threats identified at the time of listing, as well as any new factors identified since listing. Since listing, numerous additional threats have been identified and prioritized for the ocean, migratory corridors, and for each of the Diversity Groups and individual populations of the winter-run and spring-run Chinook salmon ESUs, and the steelhead DPS within the Central Valley Domain (Introduction, Appendix B).

NMFS believes that the condition of habitat in the ESUs/DPS will be directly affected by actions that address threats to the habitat. Therefore, changes to habitat condition will be inferred by monitoring progress and the degree to which threats to habitat are improved or removed, at both the watershed and system scale. Therefore, abatement of threats will also meet these habitat objectives:

- The spatial distribution and productive capacity of freshwater, estuarine, and marine habitats should be sufficient to maintain viable populations identified for recovery;
- The diversity of habitats for recovered populations should provide sufficient resilience and redundancy to withstand expected natural disturbance regimes such as wildfires, floods, droughts and volcanic eruptions. Historic conditions represent a reasonable template for a viable population; the closer the habitat resembles the historic diversity, the greater the confidence in its ability to support viable populations; and
- At a large scale, habitats should be protected and restored, with a trend toward an appropriate range of attributes for salmonid viability. Freshwater, estuarine, and marine habitat attributes should be maintained in a non-deteriorating state.

4.4.1 Threats

Sacramento River Winter-run Chinook Salmon

Several factors have contributed to the decline of winter-run Chinook salmon through degradation of spawning, rearing, and migration habitats. The primary factors included in the listing of winter-run Chinook salmon were blockage of historical habitat by Shasta and Keswick dams, warm water releases from Shasta Dam, juvenile and adult passage constraints at RBDD, water exports in the southern Delta, heavy metal contamination from Iron Mountain Mine, high ocean harvest rates and entrainment in a large number of unscreened or poorly screened water diversions (NMFS 1997). Other factors include smaller water manipulation facilities and dams, loss of rearing habitat in the lower Sacramento River and Delta from levee construction, marshland reclamation, interaction with and predation by introduced species, adverse flow conditions, high summer water temperatures and vulnerability to drought (NMFS 1997). Since listing, some of these threats have been addressed, although numerous additional threats have been identified and prioritized (Appendix B).

Central Valley Spring-run Chinook Salmon

Listing factors and threats to Central Valley spring-run Chinook salmon fall into three broad categories: loss of historical spawning habitat; degradation of remaining habitat; and threats to genetic integrity. The last threat is to wild spawning populations resulting from spawning with FRFH spring-run Chinook salmon and naturally- and hatchery produced fall-run Chinook salmon. A complete prioritized list of the life stage-specific threats to the ESU is presented in Appendix B.

Central Valley Steelhead

Threats to Central Valley steelhead are similar to those for Central Valley spring-run Chinook salmon: loss of historical spawning habitat, degradation of remaining habitat, and threats to the genetic integrity of the wild spawning populations from hatchery steelhead production programs in the Central Valley. A complete prioritized list of life stage-specific threats to the DPS is presented in Appendix B.

4.4.2 Listing Factors

All threats to a species can be categorized into one of the five ESA listing factors:

1. The present or threatened destruction, modification, or curtailment of its habitat or range;
2. Overutilization for commercial, recreational, scientific, or educational purposes;
3. Disease or predation;
4. The inadequacy of existing regulatory mechanisms;
5. Other natural or manmade factors affecting its continued existence.

NMFS proposes that, to determine that the affected ESU/DPS is recovered to the point that it no longer requires the protections of the ESA, these five ESA listing factors should be addressed according to specific criteria identified for each of them in order to ensure that the underlying causes for listing the species are addressed.

It is likely that current threats may diminish or increase in severity due to anthropogenic or natural changes to the environment. Indeed, successful implementation of the actions in this recovery plan will ameliorate threats to the ESUs/DPS. Consequently, NMFS expects that the significance of threats will change over time. It is also

possible that new threats may be identified. To track changes in the threat regime, every five years during the status reviews of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead, NMFS will evaluate whether the five listing factors have substantially changed.

4.4.3 Threat Abatement Criteria

NMFS is providing the specific threat abatement criteria listed below for each of the relevant listing factors to help to ensure that underlying causes of decline have been addressed and mitigated prior to considering a species for delisting. These threat abatement criteria correspond to the listing factors identified for winter- and spring-run Chinook salmon and steelhead in this Recovery Plan, and are related to each of the threats described in Appendix B.

- Populations have unobstructed access to Core 1, 2, and 3 watersheds and assisted access to primary watersheds for reintroduction that are obstructed. Man-made structures (e.g., bridges and water diversions) affecting these watersheds and in migratory habitat should meet NMFS' salmonid passage guidelines for stream crossings and screening criteria for anadromous salmonids (Listing Factors 1, 4, and 5)
- Utilization for commercial, recreational, scientific and educational purposes is managed, such that all core 1 populations meet the low extinction risk categories for abundance, productivity, and diversity (see table 4-1) (Listing Factor 2)
- Hatchery programs are operated so that all core 1 populations meet the low extinction risk criteria for hatchery influence (see table 4-1) (Listing Factors 3 and 5)
- Migration and rearing corridors meet the life-history, water quality and habitat requirements of the listed species, such that the corridor supports multiple viable populations (Listing Factors 1, 3, 4, and 5)

5.0 Recovery Actions

"Once there is a firm commitment and a strategy alternative has been decided upon, the third and final pillar of an effective salmon recovery effort is that a number of specific actions will be required to achieve effective implementation."

- Jeffrey J. Dose. Commitment, Strategy, Action: The Three Pillars of Wild Salmon Recovery *in* Salmon 2100: the future of wild Pacific salmon

This Recovery Plan establishes a strategic approach to recovery, which identifies critical recovery actions for the Central Valley, as well as watershed- and site-specific recovery actions. Watershed-specific recovery actions address threats occurring in each of the rivers or creeks that currently support spawning populations of the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU, or the California Central Valley steelhead DPS. Site-specific recovery actions address threats to these species occurring within a migration corridor (e.g., San Francisco Bay or the Delta).

This Recovery Plan maintains a consistent strategic framework for the establishment of recovery goals and criteria, the identification and prioritization of threats, and the identification of recovery actions. As described in the Recovery Strategy chapter, the framework for ESU or DPS recovery includes goals and criteria directed at the diversity group and population levels. Similarly, the threats assessment framework for each ESU or DPS also was organized by diversity groups and populations. For the winter-run Chinook salmon ESU, threats were prioritized for the one Sacramento River population; for spring-run Chinook salmon and steelhead, threats were prioritized within each diversity group as well as within each population.

Three steps were used to prioritize recovery actions as they are presented in this plan. First, results from the threats assessment and prioritization process (described in Appendix B) were used to guide the identification of watershed- and site-specific recovery actions for each diversity group and population. This step prioritized recovery actions separately for each species. The second step was undertaken through consideration of specific actions that benefit multiple species and populations. Results from the second step included tables of recovery actions listed in descending order of priority by geographic region (e.g., Delta, mainstem Sacramento River, Battle Creek) based on multiple species benefits (see Appendix C). These first two steps were the only steps taken to prioritize recovery actions that were presented in the Co-Manager Review Draft Recovery Plan. Based on feedback from co-managers, it was apparent that the priority with which recovery actions should be undertaken was not clear.

To address this, we implemented a third step and prioritized each of the area- or watershed-specific recovery actions according to three categories. Priority 1 actions address the most important threats within an area (e.g., Pacific Ocean or Delta) or watershed; priority 2 actions address threats of moderate importance, and priority 3 actions are of lower importance to implement[7].

Actions were identified as priority 1, 2, or 3 based on the first two prioritization steps and on the best professional judgment of agency co-managers, including biologists from CDFW, DWR, USFWS, USFS, and NMFS.

A number of ecosystem and/or anadromous fish enhancement plans for the Central Valley, as well as input received from two recovery planning public workshops, held May 22nd and 24th, 2007 in Sacramento and Redding, respectively, have been used to identify recovery actions. These documents include:

- Final Restoration Plan for the AFRP (USFWS 2001)
- AFRP Planning Documents (AFRP Website 2005; AFRP Website 2006a; AFRP Website 2006b)
- Ecosystem Restoration Plan Planning Documents (CALFED 2006; CALFED 2007)
- Summary of Threats and Recovery Actions for Spring-run Chinook Salmon and Winter-run Chinook Salmon Recovery Actions. Sacramento Salmon and Steelhead Recovery Workshop (NMFS 2007c)
- Summary of Threats and Recovery Actions for Steelhead. Sacramento Salmon and Steelhead Recovery Workshop (NMFS 2007a)
- Steelhead Restoration and Management Plan for California (CDFW 1996)
- Lower Yuba River Revised Implementation Plan and Appendices (CALFED and YCWA 2005)
- Ecosystem Restoration Program Plan (ERPP) (CALFED 1999a)
- Restoring Central Valley Streams: A Plan for Action (CDFW 1993)
- Lower Yuba River Fisheries Management Plan (CDFW 1991a)

[7] In NMFS' Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead, October 2009, Appendix C, we described how we applied the recovery action priorities 1-3 described in NMFS recovery planning guidelines (55 FR 24296; June 15, 1990), which are also described in NMFS' Recovery Planning Guidance (NMFS 2010b), in developing recovery actions for each species addressed in this recovery plan. The recovery actions priorities 1-3 described here in this final recovery plan are based on grouping the recovery actions for all three listed species addressed in this recovery plan by area or watershed and prioritizing those actions as described here.

- Initial Fisheries and In-Stream Habitat Management and Restoration Plan for the Lower American River (Water Forum 2001)
- CALFED Bay/Delta Program Multi-Species Conservation Strategy. Final Programmatic EIS/EIR Technical Appendix (CALFED 2000a)
- Potential for Re-establishing a Spring-Run Chinook Salmon Population in the Lower Feather River (MWD 2005)
- Central Valley Salmon – A perspective on Chinook and Steelhead in the Central Valley of California (Williams 2006)
- What caused the Sacramento River fall Chinook stock collapse? (Lindley *et al*. 2009)
- Insights into the Problems, Progress, and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration (Vogel 2011).

The recovery actions for this plan are presented in the tables below according to the following geographic organization:

- Throughout California or the Central Valley
- Pacific Ocean
- San Francisco, San Pablo, and Suisun bays
- Delta
- Mainstem Sacramento River
- Northwestern California Diversity Group
- Basalt and Porous Lava Diversity Group
- Northern Sierra Nevada Diversity Group
- Mainstem San Joaquin River
- Southern Sierra Nevada Diversity Group.

The implementation schedules that follow outline actions for the recovery program for the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU, and the California Central Valley steelhead DPS, as set forth in this recovery plan. The schedules are a guide for meeting the recovery goals outlined in this plan. They indicate action priorities, action numbers, action descriptions, and duration of actions; the parties potentially involved in either funding or carrying out actions; and estimated costs. The listing of a party in an implementation schedule does not require the identified party to implement the action(s) or to secure funding for implementing the action(s).

Cost estimates are provided wherever practicable. In some cases, information essential to the development of even the roughest of estimates is unavailable, as described in detail below:

- There is no available information to estimate, even in the roughest of terms, the appropriate extent of an action:

- The essential quality or quantity of a determinative feature of an action can only be estimated after site-specific investigations are completed; NMFS is unaware of any existing site-specific investigations. This includes:

Gravel Augmentation	Estimate of amount of necessary gravel augmentation (if any) unavailable. Per unit cost is $11 to $72/cubic yard (Appendix D).
Wetland Habitat Restoration	Estimate of amount of habitat to be restored unavailable. Per unit cost is $75 to $100,000/acre (Appendix D Table HI-7).
Riparian Habitat Restoration	Estimate of amount of habitat to be restored unavailable. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive week control are needed.
Floodplain Habitat Restoration	Estimate of amount of habitat to be restored unavailable. Per unit cost is $5,000 to $80,000/acre (Appendix D Table HI-4)
Side Channel Habitat Restoration/Re-connection	Estimate of amount of habitat to be restored unavailable. Per unit cost is $20,000 to $300,000/acre (Appendix D Table HI-5)
Sediment retention projects.	Extent and method of sediment retention unavailable. See Appendix D, tables HU-1 through HU-4 for per unit costs for road de-commissioning, road upgrades, landslide/gully stabilization, and planting in upland areas.
Habitat acquisition/easements	Estimate of amount of habitat for acquisition, lease, or easement unavailable. Land acquisition costs per acre for California are presented by county in Appendix D, Table HA-3, and generally range from $200 to $20,000/acre. Conservation easement costs range from $209 to $730/acre (Appendix D).
Water acquisition for instream flow	Estimate of amount of water to be purchased unavailable. Cost per unit ranges from $43 to $88/af/year for upstream of Delta water purchases (Appendix D)

- With regard to the Delta (DEL-2.31) and San Francisco Bay (SFB-2.4) actions designed to promote nitrification and retention of NH4 through marsh restoration, it is not scientifically practicable to estimate how much restoration is needed to achieve the appropriate NH4 concentrations.

- For the actions calling for projects to minimize predation at weirs, diversions, and related structures outside of the Delta[8], it is impracticable to provide cost estimates given the unknown but likely large number of man-made structures in the bays, and the Sacramento and San Joaquin river systems, many of which will require site-specific studies and adaptive management to identify unique solutions. After initial investigation, it is likely that the solution at one structure may apply to other structures of the same type (e.g., boat docks), in which case the overall cost of identifying and implementing solutions will diminish. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013)[9].
- For actions calling for fish passage improvements at small agricultural diversions on a particular river or creek, the total number of diversions is unknown, making it impracticable to provide a total cost. Per unit cost of providing passage at agricultural diversion dams ranges from $30,000 to $1,356,500 (see Appendix D, page 21, table HB-4).

- Information on the cost of an action is known only to a third party, but such information has not been provided to NMFS by the third party at time of this Recovery Plan's publication;
- The action is so novel that no comparable actions can be identified and the action involves development or application of a new technology for which it is impracticable to provide a reasonable guess at the action's cost;
- The recommended action is based on the broad directives/guidelines of existing government plans and goals, for which no cost-estimate currently exists, but, due to the breadth of the existing directives/guidelines and their lack of specificity, it is impracticable to estimate the cost of their implementation. Two actions that fall into this category are: (1) Implement recommended actions from the National Ocean Council's National Ocean Policy Implementation Plan dated April 2013 [action PAO-2.3]; and (2) Implement the USEPA's Action Plan for addressing water quality concerns in the Bay/Delta [DEL-1.25].

Under the aforementioned circumstances, NMFS is unable to estimate practicably the cost of the action; accordingly, costs are identified as "To Be Determined" ("TBD"). Cost estimates will be determined as the currently unavailable information becomes available. Wherever practicable, NMFS has attempted to identify the following: 1) per-unit costs (particularly where the

[8] The cost of minimizing predation at Delta structures was estimated at $50 million over 50 years (BDCP 2013). A similar type of cost analysis for which to base the cost of minimizing predation in San Francisco, San Pablo, and Suisun bays, and the Sacramento and San Joaquin river systems has not been conducted.

[9] BDCP (2013) estimated the annual cost of predator removal for 17 sites at roughly $640,000, therefore, each site would cost about $38,000 annually ($640,000/17).

unavailable quantum of information is the amount of habitat which must be addressed); 2) the cost of interim activities (including initial studies), which are the only estimable portion of an action and will help to provide the previously unavailable essential information, thereby ultimately leading to the action's ultimate cost estimate; and/or 3) a plan for determining the ultimate cost estimate.

In an effort to identify only the additional cost of species recovery, we considered what is already required under local, State, or Federal regulation, or settlement agreements, to be required actions, and thereby estimated them at $0. For example, the cost of an action required by a Reasonable and Prudent Alternative action which has already been adopted by an action agency is listed as $0. Also, actions were assumed to have no additional cost to recovery if the action would be accomplished under the existing work programs of government agencies and would not require an agency or group to acquire funding beyond their existing budgets. Because several federal and state agencies have significant budgets directed to natural resource protection in general, and anadromous salmonids in particular, many of the actions identified in this recovery plan will be implemented through those existing programs; as such, many actions are identified to cost $0, since the action will not cause agency budgets to expand.

The Southwest Fisheries Science Center (SWFSC) produced a Technical Memorandum providing information on costs associated with restoration activities. To help comply with the requirement to provide estimates of recovery costs, that Technical Memorandum has been appended to this recovery plan (Appendix D). Data from publicly available sources were used to obtain estimates of restoration costs for a variety of restoration activities. All costs described in Appendix D pertain to direct expenditures on restoration and do not include economic opportunity costs (e.g., foregone profits associated with restrictions on livestock grazing, timber harvest and other activities). Appendix D offers ranges of costs applicable at the ESU scale. Actual costs may vary widely from one watershed to another and across the extent of the Central Valley Domain due to potential differences in regional labor costs, property values, availability of expert contractors and materials, and permitting issues, etc. Many cost estimates for restoration activities in the Central Valley are specifically based on CALFED Ecosystem Restoration Program (ERP) implementation and/or contracted costs (most notably fish screening projects, gravel augmentation, channel restoration, bank stabilization, land acquisition, conservation easements, proposed watershed effectiveness monitoring, and a 5-dam decommissioning and removal project), so are specific to the Central Valley and are referenced as such in the Technical Memorandum. Also, levee-related and water purchase/lease activity cost estimates for the Central Valley were included in the report, based on information from DWR, county water agencies, and ERP. Irrigation ditch activity costs, including water control structures, were developed from information from county water agencies in the Central Valley. The rest of Appendix D contains data from the northernmost part of California, Oregon, Washington, and Idaho.

NMFS estimates that recovery for listed Central Valley salmon and steelhead, like for most of the ESA-listed Pacific Northwest salmon and steelhead, could take 50 to 100 years. Because there is an extensive list of actions that need to be undertaken to recover the listed Central Valley salmonids, there are many uncertainties involved in predicting the course of recovery and in estimating total costs and time to recovery. Such uncertainties include biological and ecosystem

responses to recovery actions. Obtaining and evaluating cost estimates for recovery actions can be challenging, and projecting costs into the future becomes increasingly imprecise. NMFS believes it is impracticable to accurately estimate all projected actions and associated costs over 50 to 100 years, given the large number of economic, biological, and social variables involved, and that it is more appropriate to initially focus on the first 25 years of implementation. Because of these variables, cost projections become increasingly inaccurate with time. Most actions can be accomplished within this 25 year time frame. For actions that extend beyond 25 years (these actions are specifically identified in the description of the respective actions below), the cost over the first 25 years is provided, and it is assumed for lack of better information that those costs will continue for the remaining duration of the action. The cost estimates for actions in later years are likely much less accurate than estimates during earlier years of implementation.

The duration of an action in the implementation tables refers to how long the action will take to complete, as opposed to when the action will be initiated. When the exact number of years that it would take to complete an action could not be estimated, more general estimates were provided. The duration for most actions was identified using general estimates as short-term (i.e., roughly 10 years or less) or long-term (i.e., 11 to 25 years in most cases, up to 100 years where specifically noted).

Abbreviations key for the following tables:
ACWA: Association of California Water Agencies
AMR: American River
ANC: Antelope Creek
BAC: Battle Creek
BCC: Big Chico Creek
BLM: U.S. Bureau of Land Management
BUC: Butte Creek
CDFW: California Department of Fish and Wildlife
CEV: Central Valley
CLC: Clear Creek
COR: Cosumnes River
Corps: U.S. Army Corps of Engineers
CVP: Central Valley Project
CVRWQCB: Central Valley Regional Water Quality Control Board
DEC: Deer Creek
DEL: Delta
DRN: Delta Restoration Network
DSC: Delta Stewardship Council
DWR: California Department of Water Resources
FER: Feather River
FERC: Federal Energy Regulatory Commission
GCID: Glenn Colusa Irrigation District
HGMP: Hatchery and Genetic Management Plan
MER: Merced River
MIC: Mill Creek
MID: Merced Irrigation District

MOR: Mokelumne River
NGO: Non-governmental organization
NID: Nevada Irrigation District
NMFS: National Marine Fisheries Service
NFWF: National Fish and Wildlife Foundation
NRCS: Natural Resources Conservation Service
ODFW: Oregon Department of Fish and Wildlife
OID: Oakdale Irrigation District
PCWA: Placer County Water Agency
PG&E: Pacific Gas and Electric
PFMC: Pacific Fishery Management Council
PUC: Putah Creek
SAR: Sacramento River
SJR: San Joaquin River
SRCS: Spring-run Chinook salmon
STR: Stanislaus River
STC: Stony Creek
STE: Steelhead
SWP: State Water Project
SWRCB: State Water Resources Control Board
SWRFSC: NMFS Southwest Region Fisheries Science Center
SYRCL: South Yuba River Citizens League
TBD: To Be Determined
TCCA: Tehama-Colusa Canal Authority
THC: Thomes Creek
TID: Turlock Irrigation District
TNC: The Nature Conservancy
TUR: Tuolumne River
USBR: United States Bureau of Reclamation
USEPA: United States Environmental Protection Agency
USFS: United States Forest Service
USFWS: United States Fish and Wildlife Service
WRCS: Winter-run Chinook salmon
YCWA: Yuba County Water Agency
YUR: Yuba River

5.1 California and Central Valley Recovery Actions

Table 5-1. California and Central Valley Recovery Actions.

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
California	Implement Federal, State, and local initiatives and programs to improve water conservation in order to reduce state-wide water use by 20 percent per capita by 2020. This effort should take into account regional differences and find ways to improve agricultural and urban water use efficiency.	1	CA-1.1	WRCS ,SRCS, STE	Federal, State, County, and local governments	1,4,5	Short-term	TBD	TBD				TBD because the State Conservation Plan for the "20X2020" goal did not include an overall cost of the effort and the cost of the program can reasonably only be estimated by the state; numerous savings associated with investing in water conservation were provided, but an overall cost-benefit analysis was not conducted because of the large number of variables in play (DWR *et al.* 2010).
California	Implement the Global Warming Solutions Act (AB 32), the Sustainable Communities and Climate Protection Act (SB 375) and other smart growth measures to foster	1	CA-1.2	WRCS , SRCS, STE	Federal, State, County, and local governments	1,4,5	Long-term (beyond 25 years)	TBD	TBD	TBD	TBD	TBD	TBD because the number and scope of smart growth projects that will be implemented is indeterminate; it

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
	sustainable land use throughout California.												is assumed that smart growth and sustainable land use practices will need to be implemented in perpetuity in order to delist the species in this plan and keep them delisted.
Central Valley	Develop and implement an ecosystem based management approach that integrates harvest, hatchery, habitat, and water management, in consideration of ocean conditions and climate change (Lindley *et al.* 2009).	1	CEV-1.1	WRCS, SRCS, STE	NMFS, USFWS, CDFW, DWR, PFMC, SWRCB, USBR	1, 2, 5	Long-term	$1,086,360	$1,699,840	$1,965,015	$2,271,558	$2,625,921	$9,648,694
Central Valley	Support programs to provide educational outreach and local involvement in restoration and watershed stewardship, including programs like Salmonids in the Classroom, Aquatic Wild, Adopt a Watershed, school district environmental camps, and other programs teaching the effects of human land and water use on anadromous fish survival.	1	CEV-1.2	WRCS, SRCS, STE	NMFS, USFWS, USBR, USFS, CDFW, DWR	5	Long-term						Cost is provided in the education/outreach actions for specific watersheds.

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Central Valley	Provide additional funding for increased law enforcement to reduce illegal take of anadromous fish, ecologically harmful stream alterations, and water pollution and to ensure adequate protection for juvenile fish at pumps and diversions.	1	CEV-1.3	WRCS, SRCS, STE	CDFW, NMFS	4	Long-term	$12 million	$12 million	$12 million	$12 million	$12 million	$60 million
Central Valley	Implement the recommendations and guidelines of the California Hatchery Scientific Review Group (http://cahatcheryreview.com/).	1	CEV-1.4	WRCS, SRCS, STE	NMFS, USFWS, CDFW, USBR, DWR	5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD[10]
Central Valley	Implement a comprehensive Central Valley steelhead monitoring plan to better understand their abundance and distribution.	1	CEV-1.5	STE	NMFS, USFWS, CDFW, DWR, USBR	1	Long-term	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$7,500,000
Central Valley	Evaluate the relationship between resident and anadromous forms of O. mykiss to better understand the role that resident fish play in species maintenance and persistence.	1	CEV-1.6	STE	NMFS, USFWS, CDFW	1	Short-term	<$500,000	<$500,000				Cost will depend on study methodology, experimental design, number of samples needed, and other factors,

[10] The Hatchery Scientific Review Group Cost (HSRG) did not develop cost estimates for their recommendations and guidelines. To implement the HSRG recommendations, hatchery coordination teams for each hatchery will be established; those teams will identify implementation costs.

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
													but overall it is anticipated to cost <$1,000,000
Central Valley	Implement and evaluate actions to minimize the adverse effects of exotic (non-native invasive) species (plants and animals) on the aquatic ecosystems used by anadromous salmonids.	1	CEV-1.7	WRCS, SRCS, STE	Department of Boating and Waterways	1,2,4	Long-term	$51,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000	$551,000,000
Central Valley	Develop and implement State and National levee vegetation policies to maintain and restore riparian corridors.	1	CEV-1.8	WRCS, SRCS, STE	Corps, DWR, CDFW, NMFS	1,4	Long-term	$0	$0	$0	$0	$0	$0
Central Valley	Incorporate ecosystem restoration including breaching and setting back levees into Central Valley flood control plans (i.e., FloodSafe Strategic Plan and the Central Valley Flood Protection Plan).	1	CEV-1.9	WRCS, SRCS, STE	NMFS, USFWS, Corps, USBR, CDFW, DWR,	1,4	Long-term	$0	$0	$0	$0	$0	$0
Central Valley	Establish partnerships and agreements that promote water transactions, water transfers, shared storage, and integrated operations that benefit both species needs and water supply reliability.	1	CEV-1.10	WRCS, SRCS, STE	SWRCB, NFWF, ACWA, DWR, USBR	1,4,5	Short-term	$2,500,000	$2,500,000	$0	$0	$0	$5,000,000
Central Valley	Annually evaluate the harvest rate of Central Valley spring-run Chinook salmon and Sacramento River winter-run Chinook salmon in the ocean salmon	1	CEV-1.11	WRCS, SRCS	NMFS, PFMC, CDFW, USFWS	2	Long-term	Up to $750,000 for genetic analysis and reporting (Garza	Up to 750,000 for genetic analysis and reporting (Garza	Up to 750,000 for genetic analysis and reporting (Garza	Up to 750,000 for genetic analysis and reporting (Garza	Up to 750,000 for genetic analysis and reporting (Garza	Up to $3,750,000 for genetic analysis and reporting (Garza 2013); Up to $3,450,000 for

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
	fisheries (commercial and recreational) and modify fishing regulations as necessary to ensure that the fisheries impacts allow for the ESUs to recover.							2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program[11]	2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program	2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program	2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program	2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program	sampling assuming two FTEs are needed to expand the existing sampling program
Central Valley	Continue to implement and improve comprehensive Chinook salmon monitoring to assess the viability of winter-run and spring-run.	1	CEV-1.12	WRCS,SRCS	CDFW, USFWS, DWR, USBR, NMFS	5	Long-term	$0	$0	$0	$0	$0	$0
Central Valley	Conduct a Central Valley-wide assessment of anadromous salmonid passage opportunities at large rim dams including the quality and quantity of upstream habitat, passage feasibility and logistics, and passage-related costs.	2	CEV-2.1	WRCS, SRCS, STE	NMFS, USFWS, USBR, USFS, CDFW, DWR	1,5	Short-term	$2,500,000	$2,500,000	$0	$0	$0	$5,000,000
Central Valley	Develop a Fishery Management and Evaluation Plan for inland fisheries to ensure that impacts of those fisheries on winter-run	2	CEV-2.2	WRCS, SRCS, STE	CDFW, NMFS	2	Short-term	$0	$0	$0	$0	$0	$0

[11] Based on the May 2012 State Occupational Employment and Wage Estimates for California provided by the Bureau of Labor Statistics, the mean annual wage for a biologist is $69,000 (http://www.bls.gov/oes/current/oes_ca.htm#19-0000).

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
	Chinook salmon, spring-run Chinook salmon, and steelhead allow for these species to recover.												

5.2 Pacific Ocean Recovery Actions

Table 5-2. Pacific Ocean Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Re-evaluate and modify management measures, annual conservation objectives, harvest forecasting techniques, NMFS consultation standards for ESA listed salmon stocks, and consider implementing an ecosystem-based salmon fishery management plan that considers multi-trophic interactions, ocean currents, upwelling patterns, ocean temperatures, and other relevant factors.	1	PAO-1.1	WRCS, SRCS	NMFS, PFMC, CDFW	1,5	~ 10 years	$1,220,150	$1,410,493	$0	$0	$0	$2,630,643
Enhance water quality in the ocean and along the coast by continuing to promote and implement sustainable practices on land in ways that will improve the health of ocean water quality.	2	PAO-2.1	WRCS, SRCS, STE	NMFS, USFWS, PFMC, CDFW, WDFW, ODFW, county planning	1,5	Long-term	$0	$0	$0	$0	$0	$0
CDFW and National Marine Sanctuary Program should consider the ecological requirements of salmon and steelhead when designating sanctuaries	2	PAO-2.2	WRCS, SRCS, STE	CDFW, NMFS	4	Long-term	$0	$0	$0	$0	$0	$0
Implement recommended actions from the National Ocean Council's National Ocean Policy Implementation Plan dated April 2013	2	PAO-2.3	WRCS, SRCS, STE	NMFS, USFWS, PFMC, CDFW, WDFW, ODFW, county planning	4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, the Ocean Policy Implementation Plan contains broad directives/guidelines, for which no cost-estimate currently exists, but, due to the breadth of the existing

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												directives/guidelines and their lack of specificity, it is impracticable to estimate the cost of their implementation.

5.3 San Francisco, San Pablo, and Suisun Bay Recovery Actions

Table 5-3. San Francisco, San Pablo, and Suisun Bay Reocery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects that improve wastewater and stormwater treatment throughout Suisun, San Pablo, and San Francisco bays and surrounding residential and commercial areas.	1	SFB-1.1	WRCS, SRCS, STE	SWRCB	1,5	Short-term	$1,545,000,000	$1,786,020,000	$0	$0	$0	$3,331,020,000
Protect, enhance, and restore a complex portfolio of habitats throughout Suisun, San Pablo, and San Francisco bays to provide cover and prey resources for migrating salmonids.	1	SFB-1.2	WRCS, SRCS, STE	NMFS, USFWS, Corps, DWR, CDFW	1, 3	Long-term						>$100 million (San Francisco Estuary Partnership 2007)
Improve the timing and extent of freshwater flow to the San Francisco Bay region to the	1	SFB-1.3	WRCS, SRCS, STE	USBR, DWR, CDFW, USFWS, NMFS, SWRCB, DSC	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
benefit of juvenile and adult salmonids by modifying water operations in the Central Valley to support flows that mimic the natural hydrograph.												
Fund and implement San Francisco Estuary Program's Comprehensive Conservation and Management Program aimed at the Estuary's aquatic resources.	1	SFB-1.4	WRCS, SRCS, STE	San Francisco Estuary Partnership	1, 4	Short-and Long-term components						$60-$80 million[12]
Cities, counties, districts, joint powers authority or other political subdivisions of the State involved with water management in Suisun, San Pablo, and San Francisco bays should	2	SFB-2.1	WRCS, SRCS, STE	CVRWQCB, Agriculture industry	1, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on the number of farmed acres that need drainage improvements in order to comply with CVRWQCB regulations. The cost estimates for management

[12] The cost range of $60-$80 million was derived from the 2007 Comprehensive Conservation and Management Plan's Aquatic Resources section. The cost range was identified by summing the cost of actions that were not already covered by actions in this Recovery Plan.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
implement agricultural drainage management projects to treat, store, convey, and/or dispose of agricultural drainage.												practices may range from less than $20/acre to greater than $110/acre per year (CVRWQCB 2012)
Develop a long-term strategy for monitoring and regulating discharges from agricultural lands entering Suisun, San Pablo, and San Francisco bays.	2	SFB-2.2	WRCS, SRCS, STE	SWRCB	1,5	5 Years	$0	$0	$0	$0	$0	$0
Implement projects that would reduce anthropogenic inputs of NH4 to help achieve concentrations below 4 µmol L-1 in order to promote increased primary and secondary production (Dugdale *et al*. 2007).	2	SFB-2.3	WRCS, SRCS, STE	NMFS, USFWS, SWRCB, DWR, CDFW, Local agriculture groups	1,4,5	Long-term						$1 - $2 billion by 2020 to upgrade Sacramento County Regional Water Treatment Plant to reduce discharge limits for nitrogen, ammonia and pathogens[13].

[13] Source: Sacramento Business Journal; http://www.bizjournals.com/sacramento/news/2012/12/05/state-water-sacramento-waste-water-treat.html

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement tidal marsh restoration projects to promote nitrification and retention of NH4 (Dugdale *et al*. 2007).	2	SFB-2.4	WRCS, SRCS, STE	NMFS, USFWS, Corps, CDFW, DWR, Various NGOs	1, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD because it is not scientifically practicable to estimate how much restoration is needed to achieve the appropriate NH4 concentrations
Evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on juvenile salmon and steelhead in Suisun, San Pablo, and San Francisco bays; continue implementation if effective.	2	SFB-2.5	WRCS, SRCS, STE	USFWS, NMFS, USBR, CDFW, DWR, Various NGOs	3	Long-term	$0-$15,000,000[14]	$0-$15,000,000	$0-$15,000,000	$0-$15,000,000	$0-$15,000,000	$0-$75,000,000

[14] If the action is limited to angling regulation changes, the cost is $0; the upper bound ($15,000,000) is based on the cost of the Columbia River pikeminnow bounty program (i.e., $3,000,000/year on average) as identified in NMFS (2011). This recovery plan is not calling for a predator bounty program in the Central Valley, but for the purposes of cost estimation, the Columbia River program's cost is assumed to represent an upper bound for what predator control could cost in the Central Valley.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement studies to develop quantitative estimates of predation on juvenile salmonids by non-native species throughout Suisun, San Pablo, and San Francisco bays.	2	SFB-2.6	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	3	Short-term	$200,000-$400,000	$0	$0	$0	$0	$200,000-$400,000
Implement projects to identify predation "hot spots" throughout Suisun, San Pablo, and San Francisco bays and minimize losses of juvenile salmonids at those locations.	2	SFB-2.7	WRCS, SRCS, STE	DWR, USBR, CDFW, NMFS, USFWS	1,3	Long-term	$5,000-$50,000 for initial hot spot identification ; see total cost for potential site-specific costs	TBD	TBD	TBD	TBD	$5,000-$50,000 for initial hot spot identification. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												(BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Prevent in-bay disposal of contaminated sediments known to be detrimental to aquatic life.	2	SFB-2.8	WRCS, SRCS, STE	NMFS, Corps, USEPA	5	Long-term	$0	$0	$0	$0	$0	$0
Evaluate, and if feasible implement restoration projects that integrate upland, intertidal, and subtidal habitats; consider the following locations (from California State Coastal Conservancy *et al.* 2010): 1) San Pablo Bay: study potential resources and restoration activities in areas offshore from Sears Point, San Pablo	2	SFB-2.9	WRCS, SRCS, STE	California State Coastal Conservancy, CDFW, Corps, NMFS, USFWS	1	Long-term	TBD	TBD	TBD	TBD	TBD	$5,000-$50,000 for initial scoping and feasibility; total project cost TBD based on the type and amount of habitat that is restored. See Appendix D for unit costs.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Bay National Wildlife Refuge and Tubbs Island, and other restoration sites; 2) Corte Madera area: Muzzi Marsh, Corte Madera Ecological Reserve, Heard Marsh: existing wetlands and restored eelgrass, link to living shoreline project; 3) Richardson Bay: wetland restoration linked to existing oyster/eelgrass populations; 4) Breuner Marsh and Point Molate: link to Point San Pablo eelgrass bed; 5) Eastshore State Park: wetland restoration linked with oyster and eelgrass restoration, creek daylighting; 6) Central and North Bay Islands: link rocky habitat with eelgrass												

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
and oyster beds; and 7) South Bay Salt Pond sites; Eden Landing and other sites: link to southernmost eelgrass population, native oyster restoration.												
Develop and implement education and outreach programs to encourage stewardship of Suisun, San Pablo, and San Francisco bay habitats.	2	SFB-2.10	WRCS, SRCS, STE	NMFS, USFWS, CDFW, DWR	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Develop and implement studies to identify the significance and spatial distribution of marine mammal predation on	3	SFB-3.1	WRCS, SRCS, STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1,3	Short-term	$1.5 million - TBD					$1.5 million minimum up to TBD [15].

[15] Based on an internet search, no projects have studied pinniped predation on juvenile salmon; as such there is no cost estimate to base the cost of this action on. The cost of studying pinniped predation on adult salmon is roughly estimated at $300,000 annually (Rub 2013); we assume that studying pinniped predation on juvenile salmon is more complicated than adults and thus will be at least as expensive. If the project were conducted for five years, the cost would be at least $1.5 million.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
adult and juvenile anadromous salmonids in Suisun, San Pablo, and San Francisco bays.												
On an annual basis, update the Office of Oil Spill Prevention and Response's Environmental Sensitivity Index maps and GIS maps to include the most current information on locations of sensitive or valued existing or restored subtidal habitats	3	SFB-3.2	WRCS, SRCS, STE	CDFW	3	Long-term	$0	$0	$0	$0	$0	$0

5.4 Delta Recovery Actions

Table 5-4. Delta Recovery Actions. Adaptively manage these suite of actions to achieve, at a minimum, through-Delta survival objectives of 57% for winter-run, 54% for spring-run, and 59% for steelhead originating from the Sacramento River; and 38% for spring-run and 51% for steelhead originating from the San Joaquin River (NMFS 2012b).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop, implement, and enforce new Delta flow objectives that mimic historic natural flow characteristics, including increased freshwater flows (from both the Sacramento and San Joaquin rivers) into and through the Delta and more natural seasonal and interannual variability.	1	DEL-1.1	WRCS, SRCS, STE	BDCP agencies and stake holders	1	Long-term, beginning in year 5	$0	$0	$0	$0	$0	$0
Reduce hydrodynamic and biological impacts of exporting water through Jones and Banks pumping plants.	1	DEL-1.2	WRCS, SRCS, STE	USBR, DWR, CDFW, NMFS	1	Long-term						$8.6 billion to $14.5 billion in capital costs (Stapler 2013); $85 million/year operating cost (Medellín-Azuara *et. al* 2013)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Provide pulse flows of approximately 17,000 cfs or higher as measured at Freeport periodically during the winter-run emigration season (i.e., December-April) to facilitate outmigration past Chipps Island.	1	DEL-1.3	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, SWRCB	1	Long-term	$0	$0	$0	$0	$0	$0
Conduct landscape-scale restoration of ecological functions throughout the Delta to support native species and increase long-term overall ecosystem health and resilience (Whipple *et al*. 2012).	1	DEL-1.4	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	Long-term						$600 million to $13 billion

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a targeted research and monitoring program to better understand the behavior, movement, and survival of steelhead, spring-run Chinook salmon, and winter-run Chinook salmon emigrating through the Delta from the Sacramento and San Joaquin rivers.	1	DEL-1.5	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	5	Long-term, up to 50 years						$627 million over 50 years[16].

[16] This number is derived from the total estimated cost of monitoring and research as identified in the May 2013 administrative draft of BDCP. It is assumed that the cost estimate provided for BDCP research and monitoring provides a very rough approximation of the cost of action DEL-1.7.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Provide access to new floodplain habitat in the South Delta for migrating salmonids from the San Joaquin system.	1	DEL-1.6	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~20 years						~$950,000,000 [17]
Restore, improve and maintain salmonid rearing and migratory habitats in the Delta and Yolo Bypass to improve juvenile salmonid survival and promote population diversity.	1	DEL-1.7	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	Long-term						Cost of this action is covered by actions DEL – 1.5 and DEL – 1.6.
Restore 17,000 to 20,000 acres of floodplain habitat (NMFS 2009b).	1	DEL-1.8	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0

[17] Assumes relocation of approximately 40 miles of existing lower San Joaquin River area levees over 50 years; cost estimate and associated assumptions taken from BDCP revised administrative draft dated May 2013

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Restore Liberty Island, Cache Slough, and the lower Yolo bypass (NMFS 2009b).	1	DEL-1.9	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0
Enhance floodplain habitat in lower Putah Creek and along the toe drain (NMFS 2009b).	1	DEL-1.10	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0
Implement the Putah Creek Enhancement Project (NMFS 2009b).	1	DEL-1.11	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0
Implement the Lisbon Weir Fish Passage Enhancement Project (NMFS 2009b).	1	DEL-1.12	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0
Implement the Prospect Island Tidal Habitat Restoration Project.	1	DEL-1.13	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$16 million	$16 million				$32 million (Riordan 2013) Cost covered by Fish Restoration Program Agreement between CDFW and DWR.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Chipps Island Tidal Marsh Restoration Project.	1	DEL-1.14	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD	TBD				<= $15 million[18]
Implement the Eastern Decker Island Tidal Marsh Restoration Project.	1	DEL-1.15	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD	TBD				TBD, based on area of restoration and whether cost can be offset by re-use of excavated material[19]

[18] Chipps Island has 732 acres available for restoration; assuming $20,100/acre for tidal marsh restoration, the maximum cost estimate is roughly $15 million.

[19] Decker Island was formed in the early 1900s when dredged material from the Sacramento River was deposited there. As such, the island is one of the highest places above sea level in the Delta. Restoration of Decker Island to provide fish habitat will involve considerable excavation, and there may or may not be value associated with the excavated material.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Southport Floodplain Restoration Project.	1	DEL-1.16	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$55-$160 million (West Sacramento Area Flood Control Agency 2011)					$55-$160 million (West Sacramento Area Flood Control Agency 2011)
Implement the Dutch Slough Tidal Marsh Restoration Project.	1	DEL-1.17	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$25 - $30 million in 2005 dollars (California State Coastal Conservancy 2006)					$25 - $30 million in 2005 dollars (California State Coastal Conservancy 2006)
Minimize the frequency, magnitude, and duration of reverse flows in Old and Middle River to reduce the likelihood that fish will be diverted from the San Joaquin or Sacramento rivers into the southern or central Delta (NMFS 2009b).	1	DEL-1.18	WRCS, SRCS, STE	USBR, DWR	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to evaluate head of Old River barrier operations to identify and then implement the best alternative for maximizing survival of juvenile steelhead and spring-run Chinook salmon emigrating from the San Joaquin River.	1	DEL-1.19	WRCS, SRCS, STE	USBR, DWR	1	Short-term	$0	$0	$0	$0	$0	$0
Modify Delta Cross Channel gate operations and evaluate methods to control access to Georgiana Slough and other migration routes into the Interior Delta to reduce diversion of listed juvenile fish from the Sacramento River and the San Joaquin River into the southern or central Delta (NMFS (2009b).	1	DEL-1.20	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Through additional releases in the San Joaquin River system, augment flows in the southern Delta and curtail exports during critical migration periods (April-May), consistent with a ratio or similar approach.	1	DEL-1.21	WRCS, SRCS, STE	USBR, DWR, MID, Turlock Irrigation District, SWRCB	1	Long-term	$0	$0	$0	$0	$0	$0, no additional cost because additional releases will likely occur via SWRCB water quality objectives; and the export curtailments already occur through the RPA in the CVP/SWP Biological Opinion (NMFS 2009b)
Curtail exports when protected fish are observed at the export facilities to reduce mortality from entrainment and salvage (NMFS (2009b).	1	DEL-1.22	WRCS, SRCS, STE	USBR, DWR	1,5	Year 1 through 25	$0	$0	$0	$0	$0	$0
Improve fish screening and salvage operations to reduce mortality from entrainment and salvage (NMFS (2009b).	1	DEL-1.23	WRCS, SRCS, STE	USBR, DWR	1,5	Year 1 through 25	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Establish a Delta operations technical group to assist in determining real-time operational measures, evaluating the effectiveness of the actions, and modifying them if necessary (NMFS (2009b).	1	DEL-1.24	WRCS, SRCS, STE	USBR, DWR	1,5	Year 1 through 25	$0	$0	$0	$0	$0	$0
Implement the USEPA's Action Plan for addressing water quality concerns in the Bay/Delta (USEPA 2012).	1	DEL-1.25	WRCS, SRCS, STE	USEPA, SWRCB	1,5	Long-term						TBD[20]
Design and implement a project(s) to: (1) allow adult salmonids (and sturgeon) from the Sacramento Deep Water Ship Channel	1	DEL-1.26	WRCS, SRCS, STE	Corps	1	Short-term	TBD; this action requires a yet to be determined unique engineering solution. Initial feasibility	TBD				TBD; this action requires a yet to be determined unique engineering solution. Initial feasibility

[20] The action plan contains seven components, six of which have dedicated funding and would result in no additional cost. A component calling for advanced water quality monitoring and assessment will require some additional funding, but it was not practicable until the multiple entities involved in this component have coordinated to conduct a funding assessment; a funding assessment for this component is planned.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
(SDWSC) to pass the channel gates and enter the Sacramento River (or block adult salmonids from entering the SDWSC); and (2) minimize fish passage from the Sacramento River into the SDWSC.							study is assumed to cost at least $50,000.					study is assumed to cost at least $50,000.
Identify and implement projects designed to improve passage and habitat conditions in the Stockton Deep Water Ship Channel.	1	DEL-1.27	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1	Long-term	$0	$0	$0	$0	$0	$0
Implement projects to minimize predation at weirs, diversions, and related structures in the Delta.	1	DEL-1.28	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	3	Long-term	$5 million	$5 million	$5 million	$5 million	$5 million	$50 million over 50 years (BDCP 2013)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Establish Vernalis flow criteria that incorporate the flow schedules of the San Joaquin River and tributaries in order to increase juvenile salmonid outmigration survival.	1	DEL-1.29	WRCS, SRCS, STE	USBR, DWR, CDFW, NMFS, USFWS, MID, TID, SWRCB	1	Long-term	$0	$0	$0	$0	$0	$0
Implement integrated flood control improvements along McCormack-Williamson Tract that benefit flood management, aquatic and terrestrial habitats, and species and ecological processes.	2	DEL-2.1	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$5,000,000	$5,000,000	$0	$0	$0	$10,000,000
Implement restoration projects for Lindsey and Barker sloughs.	2	DEL-2.2	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$400,000 to $3,400,000 (Solano Land Trust *et al*. 2006)					$400,000 to $3,400,000 (Solano Land Trust *et al*. 2006)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Evaluate the potential effects of reconnecting Elk Slough to the Sacramento River, and if the evaluation suggests that habitat conditions for salmonids would improve, then implement a project to carry out the reconnection (Siegel 2007).	2	DEL-2.3	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$2,600,000	$2,600,000	$0	$0	$0	$5,200,000
Improve habitat for juvenile salmonids in Elk, Sutter, and Steamboat sloughs (Siegel 2007).	2	DEL-2.4	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on type and extent of habitat improvements; initial study is expected to cost at least $50,000.	TBD				TBD, based on type and extent of habitat improvements; initial study is expected to cost at least $50,000.
Re-establish hydrologic connectivity between historical Stone Lakes floodplain and the Sacramento River with a design that minimizes juvenile stranding.	2	DEL-2.5	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD; unaware of similar projects to base cost on; initial feasibility study would cost at least $50,000	TBD				TBD; unaware of similar projects to base cost on; initial feasibility study would cost at least $50,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Restore tidal wetlands and associated habitats at Brannan Island State Park, northeast tip of Sherman Island, along Seven-Mile slough, and the southwest tip of Twitchell Island.	2	DEL-2.6	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on type and extent of habitat improvements; initial study is expected to cost at least $50,000.	TBD				TBD, based on type and extent of habitat improvements; initial study is expected to cost at least $50,000.
Implement the Grizzly Slough Floodplain and Riparian Habitat Restoration Project.	2	DEL-2.7	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years						$250,000 - $4,000,000[21]

[21] DWR website identifies 50 additional acres for floodplain restoration at Grizzly Slough (http://www.water.ca.gov/floodsafe/fessro/environmental/dee/grizzlyslough.cfm).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Meins Landing Tidal Habitat Restoration Project.	2	DEL-2.8	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.	TBD				TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.
Implement the Hill Slough Tidal Habitat Restoration Project.	2	DEL-2.9	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.	TBD				TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.
Implement the Tule Red Restoration Project.	2	DEL-2.10	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.	TBD				TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Rush Ranch Tidal Habitat Restoration Project.	2	DEL-2.11	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.	TBD				TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.
Evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on juvenile salmon and steelhead in the Delta.	2	DEL-2.12	WRCS, SRCS, STE	CDFW, Sport fishing community	3	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Modify existing water control structures to maintain flows through isolated ponds in the Yolo Bypass to minimize fish stranding, particularly following the cessation of flood flows over the Fremont Weir.	2	DEL-2.13	WRCS, SRCS, STE	TCCA, USBR, DWR, CDFW, NMFS, USFWS	1	Short-term	TBD, based on type and number of modifications; initial study is expected to cost at least $50,000.	TBD				TBD, based on type and number of modifications; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Modify Reclamation District 2068 levees to provide rearing and predator refuge habitat for juvenile salmonids.	2	DEL-2.14	WRCS, SRCS, STE	Corps	1	~10 years	TBD	TBD				TBD based on the amount and type of habitat to be restored.
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap.	2	DEL-2.15	WRCS, SRCS, STE	Corps	1	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement to stop illegal rip rap applications in the Delta.	2	DEL-2.16	WRCS, SRCS, STE	CDFW, NMFS, Corps	1,4	Long-term						Cost is covered under action # COC-2.9 ($1,750,000)
Curtail further development in active Delta floodplains through zoning restrictions, county master plans and other Federal, State, and county planning and regulatory processes, and land protection agreements.	2	DEL-2.17	WRCS, SRCS, STE	Contra Costa, Solano, Yolo, Sacramento, and San Joaquin counties. DRN, DSC	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Prioritize and screen Delta diversions.	2	DEL-2.18	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS, local counties	1	Long-term	$100,000 for monitoring program; screening costs for Delta Diversions are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Implement management actions for addressing invasive aquatic species including those described in the California Aquatic Invasive Species Management Plan.	2	DEL-2.19	WRCS, SRCS, STE	Department of Boating and Waterways	1	Long-term	$51,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000	$551,000,000
Implement projects that improve wastewater and stormwater treatment throughout the Delta and surrounding residential and commercial areas.	2	DEL-2.20	WRCS, SRCS, STE	NMFS, USFWS, SWRCB, CVRWCB, DWR, CDFW, Local governments	1, 5	Long-term						Cost is covered under action SFB-2.3 ($1 - $2 billion by 2020 to upgrade Sacramento County Regional Water Treatment Plant to reduce discharge limits for

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												nitrogen, ammonia and pathogens[22]).
Review and potentially update the through-Delta survival rate objectives included in this recovery plan as new information is obtained.	2	DEL-2.21	WRCS, SRCS, STE	NMFS, CDFW, DSC, USFWS	1	Long-term	$0	$0	$0	$0	$0	$0
Develop regional agreements on geographic boundaries for estimating through-Delta survival, and appropriate technologies for collecting the required empirical data.	2	DEL-2.22	WRCS, SRCS, STE	NMFS, CDFW, DSC, USFWS	5	Long-term	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development

[22] Source: Sacramento Business Journal; http://www.bizjournals.com/sacramento/news/2012/12/05/state-water-sacramento-waste-water-treat.html

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Explore and support the development of existing or innovative approaches and tools for centralized tracking of restoration efforts in the Delta.	2	DEL-2.24	WRCS, SRCS, STE	Delta Conservancy, DWR, USBR, CDFW, NMFS Delta land owners	1,5	Long-term	$0	$0	$0	$0	$0	$0
Coordinate efforts to identify and highlight funding needs for restoration planning, monitoring, tracking, synthesis and adaptive management in the near and long term.	2	DEL-2.25	WRCS, SRCS, STE	Delta Conservancy, DWR, USBR, CDFW, NMFS Delta land owners	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop outreach strategies and mechanisms to ensure the Delta community, the legislature, appropriate agencies and the public are regularly updated on actions related to restoration and recovery.	2	DEL-2.26	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, Various NGOs	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement education and outreach programs to encourage river stewardship.	2	DEL-2.27	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, Various NGOs	1,5	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Cities, counties, districts, joint powers authority or other political subdivisions involved with water management should implement agricultural drainage management projects to treat, store, convey, and/or dispose of agricultural drainage.	2	DEL-2.28	WRCS, SRCS, STE	CVRWQCB, Delta farmers	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on the number of farmed acres that need drainage improvements in order to comply with CVRWQCB regulations. The cost estimates for management practices may range from less than $20/acre to greater than $110/acre per year (CVRWQCB 2012)
Continue development of a long-term strategy for monitoring and regulating discharges from agricultural lands to protect waters within the Central Valley, including	2	DEL-2.29	WRCS, SRCS, STE	CVRWQCB	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
enforcing the regulations.												
Increase monitoring and enforcement in the Delta to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants (SWRCB 2007).	2	DEL-2.30	WRCS, SRCS, STE		1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Implement projects that would reduce anthropogenic inputs of NH4 to help achieve concentrations below 4 µmol L-1 in order to promote increased primary and secondary production (Dugdale *et al*. 2007).	2	DEL-2.31	WRCS, SRCS, STE	Sacramento Regional County Sanitation District	1	Long-term						Cost is covered under action SFB-2.3 ($1 to $2 billion by 2020).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to operate the Suisun Marsh Salinity Control Structure with the boat lock open in order to allow fish passage in and out of Suisun Marsh.	3	DEL-3.1	WRCS, SRCS, STE	DWR and USBR	1,5	Long-term	$0	$0	$0	$0	$0	$0

5.5 Mainstem Sacramento River Recovery Actions

Table 5-5. Mainstem Sacramento River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a program to reintroduce winter-run Chinook salmon, spring-run Chinook salmon, and steelhead to historic habitats upstream of Shasta Dam. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.	1	SAR-1.1	WRCS, SRCS, STE	USBR, NMFS, CDFW, DWR, USFWS, PG&E, FERC	1,5	Long-term:	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Restore and maintain riparian and floodplain ecosystems along both banks of the Sacramento River to provide a diversity of habitat types including riparian forest, gravel bars and bare cut banks, shady vegetated banks, side	1	SAR-1.2	WRCS, SRCS, STE	USBR, NMFS, CDFW, DWR, USFWS	1,4	~10 years	$19,532,500	$22,579,570	$0	$0	$0	$42,112,070

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
channels, and sheltered wetlands, such as sloughs and oxbow lakes following the guidance of the Sacramento River Conservation Area Handbook (Resources Agency of the State of California 2003).												
Identify and implement any required projects to assure the M&T Ranch water diversion is adequately screened to protect winter-run Chinook salmon, spring-run Chinook salmon, and steelhead.	1	SAR-1.3	WRCS, SRCS, STE	NMFS, USBR, USFWS, and M&T Ranch	1,5	< 5 years	$9,500,000	$0	$0	$0	$0	$9,500,000
Develop and implement a river flow management plan for the Sacramento River downstream of Shasta and Keswick dams that considers the effects of climate change and balances beneficial uses with the flow and water temperature	1	SAR-1.4	WRCS, SRCS, STE	NMFS, USBR, USFWS, DWR, CDFW	1,5	Short-term	$740,150	$0	$0	$0	$0	$740,150

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
needs of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. The flow management plan should consider the importance of instream flows as well as the need for floodplain inundation (Williams *et al*. 2009).												
Install NMFS-approved, state-of-the-art fish screens at the Tehama Colusa Canal diversion. Implement term and condition 4c from the biological opinion on the Red Bluff Pumping Plant Project, which calls for monitoring, evaluating, and adaptively managing the new fish screens at the Tehama Colusa Canal diversion to ensure the screens are working properly and impacts to listed species are minimized (NMFS	1	SAR-1.5	WRCS, SRCS, STE	DWR, USBR, TCCA	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
2009c).												
Develop and implement a long-term gravel augmentation plan consistent with CVPIA to increase and maintain spawning habitat for winter-run Chinook salmon, spring-run Chinook salmon, and steelhead downstream of Keswick Dam.	1	SAR-1.6	WRCS, SRCS, STE	CDFW, NMFS, USBR, USFWS	1,5	Long-term	$380,000	$439,280	Up to ~$500,000	Up to ~$500,000	Up to ~$500,000	Up to ~$2,319,280
Develop and implement a secondary fish trapping location for the Livingston Stone NFH winter-run Chinook salmon supplementation	1	SAR-1.7	WRCS, SRCS, STE	NMFS, USFWS, USBR	1,5	Long-term						Up to $27,400,000 to build secondary facility[23]; Assuming the facility will require two to ten FTE's, operational costs

[23] The Minto Salmon and Steelhead Collection Facility on western Oregon's North Santiam River was rebuilt at a cost of $27,400,000 (http://www.cbbulletin.com/426310.aspx).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
program to provide increased opportunity to capture a spatially representative sample and target numbers of broodstock.												will range from approximately $138,600 to $693,000 per year[24]
Study the merits and investigate feasibility of modifying the altered channel morphology at Turtle Bay in Redding to eliminate the gravel "sink" created by historic gravel mining activities. If the study suggests that it is feasible to modify the channel morphology such that it is beneficial to spawning gravel augmentation efforts, then implement the channel modification project.	1	SAR-1.8	WRCS, SRCS, STE	USFWS, NMFS, DFG, USBR	1	Long-term	>$110,000					>$110,000[25]

[24] Based on the May 2012 State Occupational Employment and Wage Estimates for California provided by the Bureau of Labor Statistics, the mean annual wage for a biologist is $69,000 (http://www.bls.gov/oes/current/oes_ca.htm#19-0000).

[25] A channel morphology study on the Yuba River was estimated at between $110,000 and $150,000; because action SAR-1.8 calls for studying the channel morphology and potentially modifying the channel, the Turtle Bay action will be at least as expensive as the Yuba project.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Investigate mechanisms to influence/stimulate anadromy in *O. mykiss* in the upper Sacramento River.	1	SAR-1.9	STE	NMFS SWRFSC, CDFW	1,5	~5 years	$100,000 - $1,000,000	$0	$0	$0	$0	$100,000 - $1,000,000
Operate and maintain temperature control curtains in Lewiston and Whiskeytown Reservoirs to minimize warming of water from the Trinity River and Clear Creek.	1	SAR-1.10	WRCS, SRCS, STE	USBR	1,5	Long-term	$150,000 for inspections. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$150,000 for inspection. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$150,000 for inspection. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$150,000 for inspection. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$150,000 for inspection. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$750,000 for inspection; repair costs TBD based on inspections. Whiskeytown curtain was replaced in 2012 at a cost of $3.5 million. Replacement needed roughly every 15 years. Lewiston curtain is less susceptible to damage than Whiskeytown, but if it needs to be replaced, cost would be ~$1.5 million.
Avoid full power peaking at Trinity and Carr Power plants during sensitive periods for water temperatures to reduce water temperatures in the Sacramento River. Evaluate impacts of power	1	SAR-1.11	WRCS, SRCS, STE	USBR, USFWS, NMFS	5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD; NMFS is in the process of obtaining the information from USBR.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
peaking operations in the Trinity River, Sacramento River and Clear Creek.												
In an adaptive management context, implement short- and long-term solutions to minimize the loss of adult Chinook salmon and steelhead in the Yolo bypass, and Colusa and Sutter-Butte basins. Solutions include: • Re-operating, to the extent feasible, the Knights Landing outfall gates to help prevent listed fish from entering the Colusa Basin (short-term); • Monitoring the Colusa and Sutter-Butte basins during winter and spring for adult salmon presence, and conducting fish rescues as necessary (short-term);	1	SAR-1.12	WRCS, SRCS, STE	CDWF, DWR, USFWS, NMFS, USBR, GCID, RD 108	1	Short- and long-term components	If fish rescues are needed, cost is estimated at ~$100,000 based on the 2013 rescue. Providing and/or improving fish passage through the Yolo Bypass and Sutter Bypass is required by the 2009 CVP/SWP biological opinion and therefore is estimated at $0. NMFS is in the process of obtaining cost information for this	Same as for FY1-5.	Same as for FY1-5.	Same as for FY1-5.	Same as for FY1-5.	If fish rescues are needed, cost is estimated at ~$100,000 based on the 2013 rescue. Providing and/or improving fish passage through the Yolo Bypass and Sutter Bypass is required by the 2009 CVP/SWP biological opinion and therefore is estimated at $0. NMFS is in the process of obtaining cost information for this action from DWR

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
• Evaluating other potential Colusa Basin Drain entry points for adult salmon along the Sacramento River above Knights Landing, and implementing fish exclusion solutions if necessary (short-term); • Providing and/or improving fish passage through the Yolo Bypass and Sutter Bypass allowing for improved adult salmonid re-entry into the Sacramento River (long-term); and • Installing fish exclusion devices at strategic locations to reduce migration of listed, adult salmonids into the Colusa Basin Drain complex (long-term); locations include,							action from DWR					

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
but are not limited to: • in the Yolo Bypass Tule Canal or Knights Landing Ridge Cut, downstream of Wallace Weir; • just upstream of the Knights Landing outfall gates (Colusa Basin side), provided that the reoperation of the Knights Landing outfall gates and/or the exclusionary device downstream of Wallace Weir fail to block migration of adults into the Colusa Basin Drain; and • at the Knights Landing outfall gates (Sacramento River side), provided that the reoperation of the Knights Landing outfall gates is ineffective.												
Identify management targets for Yolo and Sutter bypass inundation timing,	1	SAR-1.13	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR,	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
frequency, magnitude, and duration that will maximize the growth and survival of juvenile winter-run Chinook salmon and spring-run Chinook salmon; and then manage the bypasses to those targets.				SWRCB								
Ensure that river bank stabilization projects along the Sacramento River utilize bio-technical techniques that restore riparian habitat, rather than solely using the conventional technique of adding rip rap.	2	SAR-2.1	WRCS, SRCS, STE	Corps, USBR, NMFS, USFWS, DWR, CDFW,	1,5	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active Sacramento River floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	SAR-2.2	WRCS, SRCS, STE	Corps, NMFS, USFWS, DWR, CDFWS, Local governments	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement to minimize illegal streambank alterations along the Sacramento River.	2	SAR-2.3	WRCS, SRCS, STE	Corps, SWRCB, CDFW	1,5	Long-term						Cost is covered under action # COC-2.9
Develop and implement education and outreach programs to encourage river stewardship along the Sacramento River. Implement outreach projects to educate the public regarding the salmon life cycle including how to identify a salmon redd.	2	SAR-2.4	WRCS, SRCS, STE	USBR, NMFS, USFWS, CDFW, DWR, Various NGOs	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Improve wastewater and stormwater treatment in residential, commercial, and industrial areas within the Sacramento River watershed.	2	SAR-2.5	WRCS, SRCS, STE	NMFS, USFWS, SWRCB, CVRWCB, DWR, CDFW, Local governments	1, 5	Long-term						Cost partially covered in DEL-2.20 ($1-$2 billion). Other costs TBD based on site-specific evaluations, each of which could range up to $100,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants entering the Sacramento River.	2	SAR-2.6	WRCS, SRCS, STE	Corps, SWRCB, USBR, CDFW	4,5	Long-term	$350,000[26]	$350,000	$350,000	$350,000	$350,000	$1,750,000
Develop a long-term strategy for reducing water quality impacts to the Sacramento River from agricultural lands. The strategy should include incentive-based projects to promote implementation of best management practices as well as enforcement actions to ensure compliance with existing regulations.	2	SAR-2.7	WRCS, SRCS, STE	SWRCB, CVRWQCB, USEPA	5	Long-term	$0	$0	$0	$0	$0	$0

[26] Assuming 1 new full time equivalent at $70,000/year, based on the average salary for a California Fish and Game warden as identified on the Bureau of Labor statistics website (http://www.bls.gov/oes/current/oes_ca.htm#19-0000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects that promote native riparian (e.g., willows) species including eradication projects for non-native species (e.g., Arundo, tamarisk).	2	SAR-2.8	WRCS, SRCS, STE	NMFS, USBR Districts, DWR, Corps	5	Long-term	$0	$0	$0	$0	$0	$0
Implement studies designed to quantify the amount of predation on winter-run Chinook salmon, spring-run Chinook salmon, and steelhead by non-native species in the Sacramento River. If the studies identify predator species and/or locations contributing to low salmonid survival, then evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on juvenile salmon and steelhead in	2	SAR-2.9	WRCS, SRCS, STE	NMFS SWRFSC, CDFW	2	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
the Sacramento River; continue implementation if effective.												
Implement projects to minimize predation at weirs, diversions, and related structures in the Sacramento River.	2	SAR-2.10	WRCS, SRCS, STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover in the Sacramento River for salmonids to minimize predatory opportunities for striped bass and other non-native predators.	2	SAR-2.11	WRCS, SRCS, STE	USCOE, DWR, NMFS	1,3,4	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.	TBD	TBD	TBD	TBD	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop an incentive-based entrainment monitoring program in the Sacramento River designed to work cooperatively with diverters to develop projects or actions in order to minimize pumping impacts.	2	SAR-2.12	WRCS, SRCS, STE	USFWS, USBR, Family Alliance, DWR, CDFW, farmers, local govt, Northern California Water Association	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop and apply alternative diversion technologies that reduce entrainment.	2	SAR-2.13	WRCS, SRCS, STE	USBR and agricultural interests	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. •This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.
Maintain remedial actions to reduce heavy metal containments from Iron Mountain Mine.	2	SAR-2.14	WRCS, SRCS, STE	USEPA, NMFS, DFG, USBR	5	Long-term	$0	$0	$0	$0	$0	$0
Restore the current Lake Red Bluff footprint to riparian habitat, consistent with flood control needs.	2	SAR-2.15	WRCS, SRCS, STE	USFS, USBR, USFWS	1	Short-term	$5,000-$6,750,000, depending on whether just a small portion or the entire footprint is restored.	$0	$0	$0	$0	$5,000-$6,750,000, depending on whether just a small portion or the entire footprint is restored.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop criteria and a process for phasing out the Livingston Stone winter-run Chinook salmon hatchery program as winter-run recovery criteria are reached. This hatchery program is expected to play a continuing role as a conservation hatchery to help recover winter-run Chinook salmon.	2	SAR-2.16	WRCS, SRCS, STE	USFWS, NMFS, CDFW	5	Short-term	$0	$0	$0	$0	$0	$0
Evaluate and reduce stranding of juvenile Chinook in side channels in the reach from Keswick Dam to Colusa, due to flow reductions from Keswick Reservoir, by increasing or stabilizing releases from the reservoir.	2	SAR-2.17	WRCS, SRCS, STE	USBR, USFWS, DFG	1,5	Short-term	$0	$0	$0	$0	$0	$0
Using an adaptive approach and pilot studies, determine if instream habitat for juvenile rearing is limiting salmonid populations, by placing juvenile-rearing-enhancement	2	SAR-2.18	WRCS, SRCS, STE	NMFS SWRFSC, DFG, USFWS	1	Short-term	TBD based on the scope of pilot and full studies; pilot study is assumed to cost at least $50,000; overall cost	TBD	$0	$0	$0	TBD based on the scope of pilot and full studies; pilot study is assumed to cost at least $50,000; overall cost will also depend on the amount and type of instream habitat that is

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
structures in the Sacramento River. If found to be limiting, add large woody debris / coarse organic material to the upper, middle and lower reaches of Sacramento River to increase the quantity and quality of juvenile rearing habitat.							will also depend on the amount and type of instream habitat that is restored, if any.					restored, if any.
Assess the impacts to development, migration, and predation on juvenile salmonids from artificial light sources (e.g., Sundial Bridge) and take appropriate action based on the findings.	2	SAR-2.19	WRCS, SRCS, STE	DFG, local govt.	1,5	Short-term	$0	$0	$0	$0	$0	$0

5.6 Northwestern California Diversity Group Recovery Actions

5.6.1 Clear Creek Recovery Actions

Table 5-6. Clear Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Operate the Clear Creek segregation weir to create reproductive isolation between fall-run Chinook salmon and spring-run Chinook salmon.	1	CLC-1.1	SRCS STE	USFWS	1,4	Long-term	$0	$0	$0	$0	$0	$0
Develop a new spawning gravel budget and implement a long-term gravel augmentation plan in Clear Creek, including acquisition of a long-term gravel supply (per CVPIA and RPA action I.1.3 of the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).	1	CLC-1.2	SRCS STE	USBR, USFWS	1,5	Long-term	$0	$0	$0	$0	$0	$0
Manage releases from Whiskeytown Dam with instream flow schedules and criteria to provide suitable water temperatures for all life stages, reduce stranding and isolation, protect incubating eggs from being dewatered, and promote habitat quality and availability as described in RPA action I.1.6 of the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).	1	CLC-1.3	SRCS STE	USBR, USFWS, Clear Creek Technical Team	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Develop water temperature models to improve Clear Creek water temperature management as described in RPA action I.1.5 of the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).	1	CLC -1.4	SRCS STE	USBR, USFWS, NMFS	5	Short-term	$0	$0	$0	$0	$0	$0
Adaptively manage Whiskeytown Reservoir releases and water temperatures to evaluate whether anadromy in *O. mykiss* can be increased, without causing adverse impacts to other species.	1	CLC -1.5	STE	USBR, USFWS, NMFS	1	Long-term	$0	$0	$0	$0	$0	$0
Implement channel maintenance flows in Clear Creek called for in the CVP/SWP biological opinion (NMFS 2009b, Action I.1.2).	1	CLC -1.6	SRCS STE	USBR, USFWS, NMFS	1	Long-term	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Clear Creek by identifying and implementing projects that would reduce the potential for, and magnitude of wildfires, including projects to restore meadows and forested areas.	2	CLC -2.1	STE	NMFS, USFWS, USBR, CDFW, BLM	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Implement the Clear Creek pulse flows called for in the CVP/SWP biological opinion (NMFS 2009b, Action I.1.1), utilizing adaptive management to adjust pulse timing, magnitude, and/or duration, as needed, to be most effective at attracting adult spring-run Chinook salmon.	2	CLC -2.2	SRCS STE	USBR and Clear Creek Technical Team	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Implement floodplain restoration projects, potentially including the Lower Clear Creek Floodway Rehabilitation Project (Phase 3C).	2	CLC-2.3	SRCSSTE	Shasta Resource Conservation District, BLM, Lower Clear Creek Watershed Group, City of Redding	1,5	Part of the Lower Clear Creek Floodway Rehabilitation Project has been completed. Additional projects could occur over the next 10 years.	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.	TBD	$0	$0	$0	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Clear Creek.	2	CLC-2.4	SRCSSTE	NMFS, Corps, USBR, Resource Conservancy, CDFW, DWR, BLM, Landowners, Local governments, NGOs	1,4,5	Short-term	$62,400	$0	$0	$0	$0	$62,400
Develop programs and implement projects for Clear Creek that promote natural river processes, including projects that restore floodplain habitat (e.g., Cloverview project and Paige Bar floodplain lowering project), add riparian habitat and instream cover, and control non-native invasive plant species.	2	CLC-2.5	SRCSSTE	Corps, USFWS, DWR, CDFW, BLM, Local agencies, NGOs	1,5	Long-term	<$5,000,000	<$5,000,000	<$5,000,000	<$5,000,000	$0	<$20,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Develop education and outreach programs to encourage river stewardship in Clear Creek.	2	CLC-2.6	SRCSSTE	USFWS, USFS, USEPA, Resource Conservation District, BLM, CDFW, Landowners	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Continue to minimize sources of sediment delivered to Clear Creek from roads and other near stream development by out-sloping roads, constructing diversion prevention dips, replacing under-sized culverts and applying other erosion prevention guidelines.	2	CLC-2.7	SRCSSTE	NMFS, USFWS, USFS, CDFW, BLM	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop a long-term operation and maintenance agreement for the segregation weir in Clear Creek.	2	CLC-2.8	SRCSSTE	NMFS, USFWS, SWRCB, BLM, CDFW, Local governments	1,5	Short-term	$0	$0	$0	$0	$0	$0
Ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met in Clear Creek for all potential pollutants.	3	CLC-3.1	SRCSSTE	SWRCB, CVRWQCBs, Local agriculture groups	1,4	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Utilize bio-technical techniques that integrate riparian restoration into bank stabilization projects that may be implemented in the future, instead of conventional rip rap.	3	CLC-3.2	SRCSSTE	Corps, USBR, NMFS, USFWS, BLM, CDFW, CBDA	1,5	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active Clear Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	3	CLC-3.3	SRCSSTE	Corps, NMFS, USFWS, USFS, BLM, CDFW, Local governments	1,4,5	Long-term	$0	$0	$0	$0	$0	$0
Permanently protect Clear Creek riparian and floodplain habitat through easements and/or land acquisition.	3	CLC-3.4	SRCSSTE	County, BLM,. CDFW, Tribal, Local owners	1,5	Long-term	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Monitor and evaluate the sport fishing regulations for Clear Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead. Work with the Fish and Game Commission to modify the regulations as needed.	3	CLC-3.5	SRCSSTE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Negotiate agreements with Federal and State agencies to provide additional instream flows in Clear Creek.	3	CLC-3.6	SRCSSTE	NMFS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)

5.6.2 Cottonwood/Beegum Creek Recovery Actions

Table 5-7. Cottonwood/Beegum Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
Enhance watershed resiliency in Beegum Creek and the greater Cottonwood watershed by identifying and implementing projects that would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade.	2	CBC-2.1	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Develop and implement a spawning gravel augmentation plan in Beegum Creek.	2	CBC-2.2	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Protect/enhance existing riparian habitat and corridors in Beegum Creek and the greater Cottonwood watershed .	2	CBC-2.3	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1	Long-term	$5,000-$50,000 for initial scoping; habitat protection costs TBD	TBD	TBD	TBE	TBD	$5,000-$50,000 for initial scoping; habitat protection costs TBD, based on amount of habitat protected or enhanced. As identified in Appendix D, per unit

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
												costs vary depending on whether fencing, planting, irrigation, or invasive weed control are needed.
Apply NMFS gravel mining criteria to all gravel mining projects in Beegum Creek and the greater Cottonwood watershed.	2	CBC-2.4	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1,5	Long-term	$0	$0	$0	$0	$0	$0
Integrate riparian habitat restoration into bank protection and other stream side development projects in Beegum Creek and the greater Cottonwood watershed.	2	CBC-2.5	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1	Long-term	$0	$0	$0	$0	$0	$0
Implement a non-native plant (e.g. Arundo) eradication plan in Beegum Creek and the greater Cottonwood watershed.	3	CBC-3.1	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Beegum Creek and the greater Cottonwood watershed.	3	CBC-3.2	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active Beegum and the greater Cottonwood watershed floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	3	CBC-3.3	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in the Beegum and the greater Cottonwood Creek watershed.	3	CBC-3.4	SRCS STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners, Cottonwood Creek Watershed Group	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
Permanently protect Cottonwood and Beegum Creek riparian habitat through easements and/or land acquisition	3	CBC-3.5	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1,5	Long-term	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Cottonwood and Beegum watersheds.	3	CBC-3.6	SRCS STE	NMFS, USFWS, USFS, CDFW, Cottonwood Creek Watershed Group	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop cooperative water use agreements with landowners and Federal and State agencies to provide additional instream flows or purchase water rights in Cottonwood Creek.	3	CBC-3.7	SRCS STE	NMFS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)
Develop a baseline monitoring program for Beegum Creek to evaluate water quality throughout the watershed to identify areas of concern.	3	CBC-3.8	SRCS STE	NMFS, USFWS, SWRCB, DWR, CDFW, Local governments	1,5	3 Years	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
Encourage voluntary landowner participation in Beegum Creek in educational opportunities such as water quality short courses, field demonstrations and distribution of water quality "Fact Sheets".	3	CBC-3.9	SRCS STE	NMFS, USFWS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners	2	Long-term	$32,260	$32,260	$32,260	$32,260	$0	$129,040
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Beegum Creek.	3	CBC-3.10	SRCS STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Landowners	1,5	Short-term	$62,400	$0	$0	$0	$0	$62,400
Implement projects to minimize predation at weirs, diversion dams, and related structures in Cottonwood/Beegum Creek.	3	CBC-3.11	SRCS STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
												identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in Cottonwood/Beegum Creek to minimize predatory opportunities for striped bass and other non-native predators.	3	CBC-3.12	SRCS STE	NMFS, USFWS, CDFW, DWR	1,3	Short-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects.	$0	$0	$0	$0	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects.
Implement projects to increase floodplain habitat availability in Beegum Creek and the greater Cottonwood watershed to improve juvenile rearing habitat	3	CBC-3.13	SRCS STE	NMFS, USFWS, CDFW, DWR	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored. $5,000-$50,000 for initial scoping study.

5.6.3 Thomes Creek Recovery Actions

Table 5-8. Thomes Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Conduct a feasibility study on potential channel modifications that would improve upstream migration conditions in Thomes Creek.	3	THC-3.1	STE, SRCS	NMFS, USFWS, CDFW	1,5	5 Years	$50,000-$200,000					$50,000-$200,000
Design and implement a Thomes Creek anadromous fish passage study.	3	THC-3.2	STE, SRCS	NMFS, USFWS, CDFW	1,5	5 Years	$0	$0	$0	$0	$0	$0
Evaluate and improve passage at the Corning Canal siphon and at the two small seasonal push-up diversion dams near Paskenta and Henlyville.	3	THC-3.3	STE, SRCS	NMFS, USFWS, CDFW, DWR, Irrigation districts	1	5 years	$80,000-$382,000/project (CDFW 2004b)					$80,000-$382,000/project (CDFW 2004b)
Flow consolidation through reduction of braided channels in Thomes Creek.	3	THC-3.4	STE, SRCS	NMFS, USFWS, CDFW	1,5	Short-term	$5,000-$50,000 for initial scoping and feasibility; full project cost TBD based on initial study.					$5,000-$50,000 for initial scoping and feasibility; full project cost TBD based on initial study.
Enhance watershed resiliency in Thomes Creek by identifying and implementing projects that	3	THC-3.5	STE, SRCS	NMFS, USFWS, CDFW	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade.												
Develop and implement a spawning gravel augmentation plan in Thomes Creek.	3	THC-3.6	STE, SRCS	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Conduct West Tehama riparian and floodplain conditions inventory.	3	THC-3.7	STE, SRCS	NMFS, USFWS, Tehama County Resource Conservation Districts, CDFW	1	Complete	$0	$0	$0	$0	$0	$0
Implement projects to increase floodplain habitat availability in Thomes Creek to improve juvenile rearing habitat	3	THC-3.8	STE, SRCS	NMFS, USFWS, CDFW	1,4	Long-term	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Re-establish natural channel morphology in Thomes Creek by: (1) applying NMFS gravel mining criteria to all gravel mining projects; (2) integrating natural morphological	3	THC-3.9	STE, SRCS	NMFS, USFWS, Resource Conservation Districts, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0

features and functions into bank protection and other stream side development projects; and (3) implementing non-native plant (e.g. Arundo) eradication plan.												
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Thomes Creek watershed.	3	THC-3.10	STE, SRCS	NMFS, USFWS, USFS, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0

5.6.4 Stony Creek Recovery Actions

Table 5-9. Stony Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Enhance watershed resiliency in Stony Creek by identifying and implementing projects that would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade.	3	STC-3.1	STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Develop and implement a spawning gravel augmentation plan in Stony Creek, which includes habitats above Black Butte Dam after passage is provided.	3	STC-3.2	STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Evaluate water releases from Black Butte Dam, water exchanges with the Tehama-Colusa Canal and interim and long term water diversion solutions at RBDD.	3	STC-3.3	STE	Yolo Basin Working Group	1,5	5 years	$0					$0
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Stony Creek watershed.	3	STC-3.4	STE	NMFS, USFWS, USFS, CDFW	1	Long-term	$0	$0	$0	$0	$0	$0
Develop a baseline monitoring program for Stony Creek to evaluate water quality throughout the	3	STC-3.5	STE	NMFS, USFWS, USFS, CDFW	1	Short-term	$0	$0	$0	$0	$0	$0

watershed to identify areas of concern.												
Encourage voluntary landowner participation in Stony Creek in educational opportunities such as water quality short courses, field demonstrations and distribution of water quality "Fact Sheets".	3	STC-3.6	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, CHS, DWR, CDFW	2	Long-term	$76,140	$76,140	$76,140	$76,140	$0	$304,560
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Stony Creek.	3	STC-3.7	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, CHS, DWR, CDFW	1	Short-term	$62,400	$0	$0	$0	$0	$62,400
Improve water temperature conditions in Stony Creek by identifying and implementing projects that would increase stream flows and increase shaded riverine habitat.	3	STC-3.8	STE	NMFS, USFWS, CDFW, DWR	1,4	Short-term	TBD	$0	$0	$0	$0	TBD based on the amount of water acquired and/or the amount of shaded habitat restored. Estimate of amount of water to be purchased unavailable. Cost per unit ranges from $43 to $88/af/year for upstream of Delta water purchases (Appendix D). Estimate of amount shaded habitat to be restored unavailable. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive week control are needed. Initial scoping study to determine project details estimated at $5,000-$50,000.

Implement projects to increase floodplain habitat availability in Stony Creek to improve juvenile rearing habitat.	3	STC-3.9	STE	NMFS, USFWS, CDFW, DWR	1,4	Long-term	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Install water temperature recorders at select locations in Stony Creek; develop recommendations for minimum instream flow based on temperature needs.	3	SCT-3.10	STE	NMFS, USFWS, CDFW, DWR	1	5 Years	$0					$0
Monitor and evaluate sport-fishing impacts in Stony Creek to ensure that the fishery allows for the recovery of steelhead; modify regulations as necessary.	3	STC-3.11	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

5.6.5 Putah Creek Recovery Actions

Table 5-10. Putah Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Conduct an anadromous fish passage feasibility study in Putah Creek that assesses upstream habitat conditions and operational alternatives.	2	PUC-2.1	STE	NMFS, USFWS, USFS, CDFW, DWR, Yolo Basin Working Group	1,5	5 Years	$25,000-$200,000					$25,000-$200,000
Develop a cooperative program to provide water for target flows in Putah Creek from additional Lake Berryessa releases or reductions in water diversions at Solano Diversion Dam and in the creek downstream of the dam.	2	PUC-2.2	STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0
Implement actions specified by the Putah Creek Council directed at restoring instream and riparian habitat.	2	PUC-2.3	STE	NMFS, USFWS, CDFW, DWR	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of habitat restored. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive weed control are needed.
Permanently protect Putah Creek riparian habitat through	2	PUC-2.4	STE	NMFS, USFWS, CDFW, DWR, NRCS	1,5	Long-term	TBD, based on specific easements and	TBD	TBD	TBD	TBD	TBD, based on specific easements and land

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
easements and/or land acquisition							land acquisitions; initial study is expected to cost at least $50,000.					acquisitions; initial study is expected to cost at least $50,000.
Implement projects that improve wastewater and stormwater treatment throughout the Putah Creek watershed.	2	PUC-2.5	STE	NMFS, USFWS, USEPA, SWRCB, DWR, CDFW, Local governments	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water to be treated and whether existing treatment facilities need to be upgraded or new facilities are required.. $5,000-$50,000 for initial evaluation.
Implement projects to maintain and increase floodplain habitat availability in Putah Creek to improve juvenile rearing habitat	2	PUC-2.6	STE	NMFS, USFWS, USBR, CDFW, DWR, Yolo Basin Working Group	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Develop and implement a spawning gravel augmentation plan in Putah Creek.	2	PUC-2.7	STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD (based on gravel augmentation costs)
Increase monitoring and enforcement in Putah Creek to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin	2	PUC-2.8	STE	SWRCB, RWQCBs, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Plan) are met throughout the Putah Creek watershed for all potential pollutants (SWRCB 2007).												
Monitor and evaluate sport-fishing impacts in Putah Creek to ensure that the fishery allows for the recovery of steelhead; modify regulations as necessary.	3	PUC-3.1	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Evaluate whether predator control measures can be effective at minimizing predation of juvenile steelhead in Putah Creek; implement measures found to be effective.	3	PUC-3.2	STE	USFWS, NMFS, USBR, CDFW, DWR, Various NGOs	1,3,4	Long-term	TBD	TBD	TBD	TBD	TBD	Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects to minimize predation at weirs, diversion dams, and related structures in Putah Creek.	3	PUC-3.3	STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in Putah Creek to minimize predatory opportunities for striped bass and other non-native	3	PUC-3.4	STE	USFWS, NMFS, USBR, CDFW, DWR	1,3	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and	TBD	TBD	TBD	TBD	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
predators.							placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.					method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects.
Encourage voluntary landowner participation in Putah Creek in educational opportunities such as water quality short courses, field demonstrations and distribution of water quality "Fact Sheets".	3	PUC-3.5	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, DWR, CDFW, Landowners	2	Long-term	$76,140	$76,140	$76,140	$76,140	$0	$304,560
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Putah Creek.	3	PUC-3.6	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, DWR, CDFW, Landowners	1,5	Short-term	$62,400	$0	$0	$0	$0	$62,400

5.7 Basalt and Porous Lava Diversity Group Recovery Actions

5.7.1 Cow Creek Recovery Actions

Table 5-11. Cow Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement actions to reduce or eliminate passage impediments in Cow Creek.	2	COC-2.1	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1	5 Years	TBD based on the number and type of impediments. Per unit cost of providing passage at agricultural diversion dams ranges from $30,000 to $1,356,500 (see Appendix D, page 21, table HB-4). Initial evaluation of passage impediments estimated to cost up to $50,000.	$0	$0	$0	$0	TBD based on the number and type of impediments. Per unit cost of providing passage at agricultural diversion dams ranges from $30,000 to $1,356,500 (see Appendix D, page 21, table HB-4). Initial evaluation of passage impediments estimated to cost up to $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Install water temperature recorders at select locations in Cow Creek; develop recommendations for minimum instream flow based on temperature needs.	2	COC-2.2	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1	5 Years	$0	$0	$0	$0	$0	$0
Conduct a Cow Creek diversion mapping study and install screens and ladders at agricultural diversions where necessary.	2	COC-2.3	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	5 Years	$50,000 for mapping study; Per unit cost of providing passage at agricultural diversion dams ranges from $30,000 to $1,356,500 (see Appendix D, page 21, table HB-4)	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Develop and apply alternative diversion technologies that eliminate entrainment in Cow Creek.	2	COC-2.4	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Enhance watershed resiliency in Cow Creek by identifying and implementing projects that would reduce the potential for, and magnitude of, a catastrophic wildfire, and restore forested areas within the watershed including riparian areas.	2	COC-2.5	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Implement actions specified in the Cow Creek Watershed Management Plan directed at restoring riparian habitat.	2	COC-2.6	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,4	Long-term	~$235,000 for restoring 10 acres and developing best management practices	$300,000 for monitoring and identification of new restoration sites; if new sites are identified, each is estimated to cost ~$213,000 /10 acres.	$300,000 for monitoring and identification of new restoration sites; if new sites are identified, each is estimated to cost ~$213,000 /10 acres.	$300,000 for monitoring and identification of new restoration sites; if new sites are identified, each is estimated to cost ~$213,000 /10 acres.	$300,000 for monitoring and identification of new restoration sites; if new sites are identified, each is estimated to cost ~$213,000 /10 acres.	>~$1,435,000
Identify stream reaches in Cow Creek that have been most altered by anthropogenic factors and reconstruct a natural channel geometry scaled to current channel forming flows.	2	COC-2.7	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	Long-term	$4,217,625	$0	$0	$0	$0	$4,217,625

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Curtail further development in the active Cow Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	COC-2.8	STE	NMFS, USFWS, Corps, CDFW, DWR, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement of illegal rip rap applications in Cow Creek.	2	COC-2.9	STE	Corps, SWRCB	1,5	Long-term	$350,000[27]	$350,000	$350,000	$350,000	$350,000	$1,750,000
Develop education and outreach programs to encourage river stewardship in Cow Creek, such as water quality short courses, field demonstrations and distribution of water quality "Fact Sheets".	2	COC-2.10	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

[27] Assuming 1 new full time equivalent at $70,000/year, based on the average salary for a California Fish and Game warden as identified on the Bureau of Labor statistics website (http://www.bls.gov/oes/current/oes_ca.htm#19-0000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Cooperatively negotiate long-term agreements with local landowners to maintain and restore riparian communities along lower reaches of Cow Creek (CALFED 2000).	2	COC-2.11	STE	NMFS, USFWS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Permanently protect Cow Creek riparian habitat through easements and/or land acquisition	2	COC-2.12	STE	NMFS, USFWS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments	1,5	Long-term	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Develop and implement a spawning gravel augmentation plan in Cow Creek.	2	COC-2.13	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,4	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD (gravel augmentation costs)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor, evaluate, and adaptively manage the Cow Creek rainbow trout stocking program to minimize the potential for adverse impacts to steelhead.	2	COC-2.14	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	3 Years	$0	$0	$0	$0	$0	$0
Implement projects to increase floodplain habitat availability in Cow Creek to improve juvenile rearing habitat	2	COC-2.15	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1	Long-term	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Implement projects to increase flows in Cow Creek and tributaries.	2	COC-2.16	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, SWRCB, Cow Creek Watershed Management Group	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD because the estimate of amount of water to be purchased is unavailable. Cost per unit for upstream of Delta water purchases ranges from $43 to $88/af/year (Appendix D). Cost of an initial study to determine the amount of water needed is at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the water quality action options described in the Cow Creek Watershed Management Plan.	2	COC-2.17	STE	USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Cow Creek Watershed Management Group	1	Long-term	$0	$0	$0	$0	$0	$0
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Cow Creek watershed.	2	COC-2.18	STE	NMFS, USFWS, USFS, CDFW, Cow Creek Watershed Management Group	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop a baseline monitoring program for Cow Creek to evaluate water quality throughout the watershed to identify areas of concern.	2	COC-2.19	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Cow Creek Watershed Management Group	1	2 Years	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Cow Creek.	2	COC-2.20	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Landowners, Cow Creek Watershed Management Group	1,5	Short-term	$62,400	$0	$0	$0	$0	$62,400
Decommission the Kilarc-Cow Creek hydroelectric project (FERC Project No. 606).	2	COC-2.21	STE	PG&E, FERC, NMFS, CDFW, Cow Creek Watershed Management Group	1	Short-term	$0					$0
Monitor and evaluate sport-fishing impacts in Cow Creek to ensure that the fishery allows for the recovery of steelhead; modify regulations as necessary.	2	COC-3.1	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

5.7.2 Battle Creek Recovery Actions

Table 5-12. Battle Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Fully fund and implement the Battle Creek Restoration Project through Phase 2	1	BAC-1.1	WRCS, SRCS, STE	USBR, CDFW, NMFS, PG&E, USFWS	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a winter-run Chinook salmon reintroduction plan to re-colonize historic habitats made accessible by the Battle Creek Restoration Project.	1	BAC-1.2	WRCS	CDFW, USFWS, NMFS, watershed stakeholders, USBR	1,5	15	$1,000,000-$1,333,333	$1,000,000-$1,333,333	$1,000,000-$1,333,333	$0	$0	$3,000,000-$3,999,999
Implement the Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan.	1	BAC-1.3	WRCS, SRCS, STE	CDFW, USFWS, NMFS, watershed stakeholders, USBR	1,5	Short-term	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Battle Creek by developing a strategy to identify and prioritize vegetation and fuels treatments that would reduce the potential extent and/or the magnitude of high severity wildfires.	1	BAC-1.4	WRCS, SRCS, STE	USBR, NMFS, USFWS, CDFW	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Ensure that timber cutting operations on private lands in the Battle Creek watershed follow the State Forest Practice rules.	1	BAC-1.5	WRCS, SRCS, STE	USBR, NMFS, USFWS, FERC, CDFW, SWRCB, SPI	1,5	Long-term	$0	$0	$0	$0	$0	$0
Implement a water quality monitoring program throughout the Battle Creek watershed to identify areas of concern. The program should monitor for sediment loading and include detection of chemical/nutrient inputs from illegal plant cultivation operations.	1	BAC-1.6	WRCS, SRCS, STE	USBR, NMFS, USFWS, FERC, CDFW, SWRCB	1,5	5	$0	$0	$0	$0	$0	$0
Develop an Adaptive Management Plan for Coleman National Fish Hatchery and continue to integrate hatchery operations with Battle Creek Salmon and Steelhead Restoration Project activities.	1	BAC-1.7	WRCS, SRCS, STE	CDFW, USFWS, NMFS, watershed stakeholders, USBR	1,4,5	Short-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Evaluate the scientific merits of moving Coleman National Fish Hatchery operations for the production of steelhead and late-fall Chinook salmon to minimize adverse impacts to listed species. If warranted, then follow with an assessment of the feasibility of moving the programs.	1	BAC-1.8	WRCS, SRCS, STE	CDFW, USFWS, NMFS, watershed stakeholders, USBR	1,3,5	Short-term evaluation; long-term implementation	TBD	TBD	TBD	TBD	TBD	TBD; The cost of the evaluation and, if necessary, the feasibility assessment will be identified by the Coleman Hatchery Coordination Team that will be formed according to the recommendation from the Hatchery Scientific Review Group.
Finalize the Biological Opinion for the artificial propagation at Coleman National Fish Hatchery.	1	BAC-1.9	WRCS, SRCS, STE	FWS, NMFS	1,5	1 year	$0	$0	$0	$0	$0	$0
Evaluate the need to upgrade PG&E facilities in order to reduce the potential for outages and harmful flow fluctuations. If outages and flow fluctuations are important stressors after completion of the Battle Creek Salmon and Steelhead Restoration	1	BAC-1.10	WRCS, SRCS, STE	Corps, USFWS, NMFS, CDFW, PG&E	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on whether or not facilities need to be upgraded. Evaluation of facilities estimated to cost up to $100,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Project, then PG&E facilities should be upgraded.												
Develop and utilize the Battle Creek Fisheries Management Plan.	1	BAC-1.11	WRCS, SRCS, STE	CDFW, USFWS, NMFS	1,5	Short-term	$0	$0	$0	$0	$0	$0
Improve fish passage at natural (rock or wood) fish barriers in the watershed including the ones immediately upstream and downstream of Eagle Canyon, and at the mouth of Digger Creek.	1	BAC-1.12	WRCS, SRCS, STE	CDFW, USFWS, NMFS	1,5	Short-term	$500,000					$500,000
Develop and apply alternative water diversion technologies that eliminate entrainment in Battle Creek.	2	BAC-2.1	WRCS, SRCS, STE	FWS, CDFW	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.
Implement a study designed to evaluate the impact of predation on spring-run Chinook salmon and steelhead in	2	BAC-2.2	WRCS, SRCS, STE	FWS, CDFW, NMFS	1,3,5	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Battle Creek. If the study suggests that predation is an important stressor in Battle Creek, then implement projects to minimize predation, potentially including predator removal and/or harvest management.												
Implement projects to minimize predation at weirs, diversion dams, and related structures in Battle Creek.	2	BAC-2.3	WRCS, SRCS, STE	NMFS, CDFW, DWR, USFWS, USBR, Corps, PG&E	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												site will cost about $38,000 annually (BDCP 2013).
The Corps, DWR, CDFW, BLM, USFWS, NMFS, private land owners, and Resource Conservation Districts should continue to focus on retaining, restoring and creating continuous riparian corridors within their jurisdictions in Battle Creek in order to improve natural river function and provide predator refuge habitat.	2	BAC-2.4	WRCS, SRCS, STE	DWR, BLM, TNC, USFWS, CDFW	1,5	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 -$675000
Increase monitoring and enforcement in order to eliminate/minimize illegal plant cultivation operations and anadromous fish poaching in the Battle Creek watershed.	2	BAC-2.5	WRCS, SRCS, STE	CDFW	1,5	Long-term						Cost is covered under action # COC-2.9
Permanently protect Battle Creek riparian habitat through	2	BAC-2.6	WRCS, SRCS, STE	DWR, BLM, TNC, USFWS, CDFW	1,5	Long-term	TBD, based on specific easements and land	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
easements and/or land acquisition.							acquisitions; initial study is expected to cost at least $50,000.					study is expected to cost at least $50,000.
Ensure through the FERC process and monitoring that the hydroelectric project at Lassen Lodge on the South Fork of Battle Creek avoids or minimizes any adverse impacts to listed anadromous salmonids.	2	BAC-2.7	WRCS, SRCS, STE	FERC, USFS, NMFS, CDFW	1,3,5	Short-term	$0	$0	$0	$0	$0	$0
Utilize bio-technical techniques for river bank stabilization instead of conventional rip rap in Battle Creek.	3	BAC-3.1	WRCS, SRCS, STE	Corps, USFWS	1,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement to minimize illegal streambank alterations in Battle Creek.	3	BAC-3.2	WRCS, SRCS, STE	CDFW, Corps, USFWS	1,5	Long-term						Cost is covered under action # COC-2.9

5.8 Northern Sierra Nevada Diversity Group Recovery Actions

5.8.1 Antelope Creek Recovery Actions

Table 5-13. Antelope Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Restore instream flows during upstream and downstream migration periods through water exchange agreements and provide alternative water supplies to Edwards Ranch and Los Molinos Mutual Water Company in exchange for instream fish flows.	1	ANC-1.1	SRCS, STE	NMFS, USFWS, CDFW, Edwards Ranch, Los Molinos Mutual Water Company	1	Long-term	$0	$0	$0	$0	$0	$0
Restore connectivity of the migration corridor during upstream and downstream migration periods by implementing Edwards and Penryn fish passage and entrainment improvement projects and identify and	1	ANC-1.2	SRCS, STE	CDFW, Edwards Ranch	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
construct a defined stream channel for upstream and downstream fish migration												
Create and restore side channel habitats to increase the quantity and quality of off-channel rearing (and spawning) areas in Antelope Creek.	2	ANC-2.1	SRCS, STE	NMFS, CDFW	1	Short-term	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.
Federal, State, and local agencies should use their authorities to develop and implement programs and projects that focus on retaining, restoring and creating riparian and floodplain habitat in Antelope Creek.	2	ANC-2.2	SRCS, STE	NMFS, USFWS, CDFW, DWR, Irrigation districts	1	Short-term	TBD based on type and amount of habitat restored; initial study is expected to cost at least $50,000.	TBD	$0	$0	$0	TBD based on type and amount of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Improve passage conditions at Paynes crossing to allow upstream passage during low flows.	2	ANC-2.3	SRCS, STE	NMFS, USFWS, USFS, CDFW, DWR	1	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement of illegal rip rap applications in Antelope Creek.	2	ANC-2.4	SRCS, STE	Corps, SWRCB	1	Long-term						Cost is covered under action # COC-2.9
Develop education and outreach programs to encourage river stewardship in Antelope Creek.	2	ANC-2.5	SRCS, STE	NMFS, USFWS, USFS, CDFW, DWR, NGOs	5	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Evaluate the quality and quantity of spawning habitat in Antelope Creek and rehabilitate spawning habitat as needed.	2	ANC-2.6	SRCS, STE	NMFS, USFWS, CDFW, DWR	1	Long-term	$50,000 for plan development; rehabilitation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Develop and implement TMDL's for all pollutants in Antelope Creek	2	ANC-2.7	SRCS, STE	NMFS, USFWS, USFS, CDFW	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement in the Antelope Creek watershed to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.	2	ANC-2.8	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	1	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Develop a baseline monitoring program in Antelope Creek to evaluate water quality throughout the watershed to identify areas of concern.	2	ANC-2.9	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1	3 Years	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Antelope Creek by developing a strategy to identify and prioritize vegetation and fuels treatments that would reduce the potential extent and/or the	2	ANC-2.10	SRCS, STE	NMFS, USFWS, USFS, CDFW	1	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
magnitude of high severity wildfires.												
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Antelope Creek watershed.	2	ANC-2.11	SRCS, STE	NMFS, USFWS, USFS, CDFW	1	Long-term	$0	$0	$0	$0	$0	$0
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Antelope Creek.	2	ANC-2.12	SRCS, STE	NMFS, USFWS, Corps, USBR, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Implement projects that cooperatively work with landowners to modify existing diversions in Antelope Creek so that fish do not become entrained in agricultural fields.	2	ANC-2.13	SRCS, STE	NMFS, USFWS, CDFW, DWR, Landowners, Irrigation districts	1,5	Short-term	TBD	TBD	$0	$0	$0	TBD, based on the type of diversion modification. If a fish screen is the solution, the cost will generally range from $2 to $10 thousand per cfs (Appendix D). $5,000-$50,000 for initial evaluation.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for Antelope Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead, and work with the Fish and Game Commission to modify the regulations as needed.	2	ANC-3.1	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	2	Long-term	$0	$0	$0	$0	$0	$0

5.8.2 Mill Creek Recovery Actions

Table 5-14. Mill Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Modify Ward, Upper, and Cemetery Ditch Siphon diversions and associated structures in Mill Creek in order to minimize entrainment and provide unimpeded passage for adult and juvenile Chinook salmon and steelhead. The modifications should meet the fish passage design criteria developed by NMFS as well as the criteria developed by CDFW.	1	MIC-1.1	SRCS, STE	NMFS, CDFW, Los Molinos Mutual Water Company, DWR, USFWS, Mill Creek Conservancy, TNC	1,5	Short-term	$2,672,672	$0	$0	$0	$0	$2,672,672
Analyze previous Mill Creek flow studies (i.e., Alley 1996; Harvey-Arrison 2009) to identify the flow regime in the flow control reach (i.e., downstream of Upper Diversion to the confluence with the Sacramento River) that best supports the life stages of spring-run Chinook salmon and steelhead that occur in that reach; conduct an additional flow study if necessary.	1	MIC-1.2	SRCS, STE	NMFS, CDFW, Los Molinos Mutual Water Company, DWR, USFWS, Mill Creek Conservancy, TNC, NFWF	1,5	Short-term	$200,000	$0	$0	$0	$0	$200,000
Develop and implement instream flow agreements with Mill Creek diverters designed to provide flows that best support the life stages of spring-run Chinook salmon and steelhead that occur in the flow control reach (i.e., downstream of Upper Diversion to the confluence with the Sacramento River).	1	MIC-1.3	SRCS, STE	NMFS, CDFW, Los Molinos Mutual Water Company, DWR, USFWS, Mill Creek Conservancy, TNC, NFWF	1,5		TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
The agreements can include approaches such as groundwater exchange, water leases, acquiring water rights, and other water management options.												
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the upper Mill Creek watershed. On National Forest Service (NFS) lands, this action should follow the prioritization criteria and strategies identified in the Long-term Strategy for Anadromous Fish-producing Watersheds in the Lassen National Forest (USFS 2001).	1	MIC-1.4	SRCS, STE	USFS, NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,4,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in order to eliminate/minimize illegal plant cultivation operations and anadromous fish poaching in the Mill Creek watershed.	1	MIC-1.5	SRCS, STE	NMFS, CDFW, SWRCB	2,4							Cost is covered under action # COC-2.9
Conduct real time flow and water temperature monitoring in Mill Creek in order to inform real time management decisions.	1	MIC-1.6	SRCS, STE	CDFW, USGS, DWR, Los Molinos Mutual Water Company	1,5		$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Build partnerships with land owners and/or permittees in the Mill Creek watershed to develop grazing strategies that promote meadow restoration, protect and improve streamside vegetation, and minimize bank disturbance.	2	MIC-2.1	SRCS, STE	NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,5		$47,520	$0	$0	$0	$0	$47,520
Implement a water quality monitoring program throughout the Mill Creek watershed to identify areas of concern.	2	MIC-2.2	SRCS, STE	NMFS, USFWS, CDFW, DWR, SWRCB, USEPA	1,4,5	Long-term	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in Mill Creek. Collaborate with the Mill Creek Watershed Conservancy in watershed management activities and any other public education events related to river stewardship.	2	MIC-2.3	SRCS, STE	CDFW, Mill Creek Conservancy, TNC, USFWS, NMFS, Los Molinos Mutual Water Company	2		$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Ensure that timber cutting operations in the Mill Creek watershed follow the State Forest Practice rules.	2	MIC-2.4	SRCS, STE	CDFW, CalFire, Board of Forestry, NMFS, USFWS, USFS	1,5		$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Mill Creek by developing a strategy to identify and prioritize vegetation and fuels treatments that would reduce the potential extent and/or the magnitude of high severity wildfires.	2	MIC-2.5	SRCS, STE	USFS, CalFire, NMFS, USFWS, , CDFW, Mill Creek Conservancy	1,5	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Investigate whether there are areas in the Mill Creek valley reach where it would be feasible to implement floodplain restoration projects in order to improve habitat conditions for juvenile rearing. If there are floodplain restoration opportunities, those projects should be prioritized and implemented as funding becomes available.	2	MIC-2.6	SRCS, STE	NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,5	Short-term	$50,000 for investigation; cost of floodplain restoration TBD based on amount of habitat to be restored. Per unit cost of floodplain habitat restoration is $5,000 to $80,000/acre (Appendix D Table HI-4)	TBD	$0	$0	$0	$50,000-TBD
Monitor and evaluate the sport fishing regulations for Mill Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead, and modify the regulations as needed. Establish and enforce hook size restrictions intended to allow trout fishing, but minimize angling impacts on salmon.	2	MIC-2.7	SRCS, STE	CDFW, Fish and Game Commission, NMFS	2,4		$0	$0	$0	$0	$0	$0
Identify stream reaches in Mill Creek that have been most altered by anthropogenic factors and develop restoration actions that restore natural river processes.	2	MIC-2.8	SRCS, STE	NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,5		$4,217,625	$0	$0	$0	$0	$4,217,625

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Curtail further development in the active Mill Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	MIC-2.9	SRCS, STE	Local governments, NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,4	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement to minimize illegal streambank alterations in Mill Creek.	2	MIC-2.10	SRCS, STE	CDFW, NMFS, Corps, SWRCB	1,5	Long-term						Cost is covered under action # COC-2.9
Permanently protect riparian habitat along Mill Creek through easements and/or land acquisition.	2	MIC-2.11	SRCS, STE	CDFW, USFWS, NMFS, Mill Creek Conservancy, TNC	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Develop and implement actions to remove feral cows in the Black Rock area of Mill Creek.	2	MIC-2.12	SRCS, STE	CDFW, USFWS, NMFS, Mill Creek Conservancy, TNC	1,5	Short-term	TBD	$0	$0	$0	$0	TBD, based on number of cows. Cost per cow removed is $150 (Bratcher 2013).

5.8.3 Deer Creek Recovery Actions

Table 5-15. Deer Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement instream flow agreements with the Deer Creek Irrigation District and the Stanford-Vina Ranch Irrigation Company designed to provide flows that best support all life stages of spring-run Chinook salmon and steelhead. The agreements can include approaches such as groundwater exchange, water leases, and other water management options.	1	DEC-1.1	SRCS, STE	Corps, SWRCB, DCID, SVRIC	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)
Modify the Cone-Kimball Diversion, Stanford-Vina Dam, and the Deer Creek Irrigation District Dam in order to provide unimpeded passage for adult and juvenile Chinook salmon and steelhead. The modifications should meet the fish passage design criteria developed by NMFS and CDFW.	1	DEC-1.2	SRCS, STE	NMFS, USFWS, USFS, CDFW, DWR, NGOs	1,5	Short-term	$10,925,000	$12,629,300	$0	$0	$0	$23,554,300

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
In coordination with technical advisors from the natural resource agencies, implement the Deer Creek Flood Improvement Project, and other projects to increase Deer Creek floodplain habitat availability.	1	DEC-1.3	SRCS, STE	NMFS, USFWS, CDFW, DWR	1,4	Short-term	$1,860,000	$0	$0	$0	$0	$1,860,000
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the upper Deer Creek watershed. On National Forest Service lands, this action should follow the prioritization criteria and strategies identified in the Long-term Strategy for Anadromous Fish-producing Watersheds in the Lassen National Forest (USFS 2001).	1	DEC-1.4	SRCS, STE	NMFS, USFWS, USFS, CDFW	1,4	Long-term	$0	$0	$0	$0	$0	$0
Conduct an instream flow study to identify the flow regime in lower Deer Creek that best supports migration and rearing of spring-run Chinook salmon and steelhead.	1	DEC-1.5	SRCS, STE	CDFW, Deer Creek Irrigation Company, Stanford-Vina, SWRCB, DWR, Deer Creek Watershed Conservancy	1,5	Long-term	$1,600,000	$0	$0	$0	$0	$1,600,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Based on instream flow study results, develop an adaptive management strategy to provide a flow regime in the lower watershed that best supports spring-run Chinook salmon and steelhead during fish migration and rearing periods.	1	DEC-1.6	SRCS, STE	CDFW, Deer Creek Irrigation Company, Stanford-Vina, SWRCB, DWR, Deer Creek Watershed Conservancy	1,5	Long-term	$0	$0	$0	$0	$0	$0
Conduct real time flow and water temperature monitoring in Deer Creek in order to inform real time management decisions.	1	DEC-1.7	SRCS, STE	NMFS, USFWS, USGS, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0
Implement a Deer Creek monitoring program to identify the abundance and the temporal and spatial distributions of immigrating and holding spring-run Chinook salmon and steelhead. These data would help ensure that suitable flows and water temperatures are being provided when and where the fish are immigrating and holding. Additionally, the data would help estimate the abundance of both species.	1	DEC-1.8	SRCS, STE	CDFW, SPI	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement in order to eliminate/minimize illegal plant cultivation operations and anadromous fish poaching in the Deer Creek watershed.	1	DEC-1.9	SRCS, STE	CDFW, Deer Creek Irrigation Company, Stanford-Vina, Deer Creek Watershed Conservancy	1,4,5	Long-term						Cost is covered under action # COC-2.9
Study feasibility of consolidating diversion points (e.g., Stanford Vina and Cone-Kimball diversions) to minimize the number of diversions on Deer Creek. Based on this study, consolidate diversions where feasible.	2	DEC-2.1	SRCS, STE	NMFS, CDFW, Deer Creek Watershed Conservancy, Deer Creek Irrigation Company, Stanford-Vina, SWRCB, DWR	1,5	10 Years	$50,000	$750,000	$0	$0	$0	$800,000
Assess the feasibility and need for modifying the lower Deer Creek falls fish ladder, to improve its function for allowing upstream passage to the upper six miles of anadromous habitat. Implement modifications as needed.	2	DEC-2.2	SRCS, STE	NMFS, USFWS, USFS, CDFW	1,5	5 Years	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Deer Creek by developing and implementing a strategy to identify and prioritize vegetation and fuels treatments that would reduce the potential extent and/or the magnitude of high severity wildfires.	2	DEC-2.3	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	1,4,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Build partnerships with land owners and/or permittees in the Deer Creek watershed to develop grazing strategies that promote meadow restoration, protect and improve streamside vegetation, and minimize bank disturbance.	2	DEC-2.4	SRCS, STE	NMFS, CDFW, Deer Creek Watershed Conservancy, USFWS	1,5	Long-term	$47,520	$0	$0	$0	$0	$47,520
Maintain an up-to-date Highway 32 Contingency Spill Plan to ensure immediate emergency response strategy and continue to develop alternatives to reduce the potential for hazardous material spills along Deer Creek.	2	DEC-2.5	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	4,5	Long-term	$0	$0	$0	$0	$0	$0
Work with California Department of Transportation (Caltrans) to ensure that proposed changes to the existing Highway 32 road alignment would not contribute to potentially unacceptable effects to anadromous fish and/or their habitat (e.g. increases in fine grained sediment, increased risk of hazardous spills).	2	DEC-2.6	SRCS, STE	NMFS, USFWS, USFS, CDFW	4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop education and outreach programs to encourage river stewardship in Deer Creek. Continue educational outreach and support and assist Deer Creek Watershed Conservancy (DCWC) in watershed management activities (AFRP Website 2005).	2	DEC-2.7	SRCS, STE	NMFS, USFWS, USFS, CDFW	2,5	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Continue implementing a water quality monitoring program throughout the Deer Creek watershed to identify areas of concern. The monitoring program should include detection of chemical/nutrient inputs from illegal plant cultivation operations.	2	DEC-2.8	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1,4	2 Years	$0	$0	$0	$0	$0	$0
To recruit and provide a continuous supply of spawning gravels into Deer Creek, re-design the Highway 32 culvert crossing at the South Fork of Calf Creek to allow for unimpeded bedload transport.	2	DEC-2.9	SRCS, STE	Caltrans, NMFS, CDFW, Deer Creek Watershed Conservancy, Deer Creek Irrigation Company, Stanford-Vina	1,5	Long-term	$50,000	$0	$0	$0	$0	$50,000
Ensure that timber cutting operations on private lands in the Deer Creek watershed follow the State Forest Practice rules.	2	DEC-2.10	SRCS, STE	Board of Forestry, Deer Creek Watershed Conservancy, SPI, Collins Pine Timber Co	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for Deer Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead, and work with the Fish and Game Commission to modify the regulations as needed. Work with CDFW and the Fish and Game Commission to establish and enforce hook size restrictions intended to allow trout fishing, but minimize angling impacts on salmon.	2	DEC-2.11	SRCS, STE	CDFW, NMFS, Deer Creek Watershed Conservancy	2,4	Long-term	$0	$0	$0	$0	$0	$0
Identify stream reaches in Deer Creek that have been most altered by anthropogenic factors and promote development of actions that contribute to the restoration of riparian vegetation and natural river processes.	2	DEC-2.12	SRCS, STE	CDFW, NMFS, Deer Creek Watershed Conservancy, SPI, Collins Pine Timber Co	1,5	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in the active Deer Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	DEC-2.13	SRCS, STE	Local governments, Corps, NMFS, CDFW, grazing interests, Deer Creek Watershed Conservancy	1,4	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement to minimize illegal streambank alterations in Deer Creek.	2	DEC-2.14	SRCS, STE	CDFW, Corps, SWRCG, NMFS	1,4,5	Long-term						Cost is covered under action # COC-2.9
Permanently protect Deer Creek riparian habitat through easements and/or land acquisition.	2	DEC-2.15	STE	NMFS, USFWS, DWR, CDFW	1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Monitor, evaluate, and adaptively manage the upper Deer Creek rainbow trout stocking program to minimize the potential for adverse impacts to spring-run Chinook salmon or steelhead.	2	DEC-2.16	SRCS, STE	CDFW, NMFS	4,5	5 Years	$0	$0	$0	$0	$0	$0
Evaluate the scientific merits of improving the Upper Falls fish ladder on Deer Creek to allow steelhead access to the upper watershed. The existing ladder will remain closed and improvements to it will not be undertaken unless Deer Creek habitat modeling verifies that: (1) steelhead spawning and rearing habitats below the Upper Falls are limiting steelhead recovery; and (2)	2	DEC-2.17	SRCS, STE	CDFW, NMFS, USBR (Shasta Mitigation)	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
spawning and rearing habitats above the Upper Falls are suitable and necessary to recover the Deer Creek steelhead population.												
Ensure that through the FERC relicensing process for the Fire Mountain Lodge Hydroelectric Project, detailed mitigation and design criteria are implemented to reduce the potential for impacts into downstream anadromous habitat.	3	DEC-3.1	SRCS, STE	FERC, NMFS, USFS	1,5	Long-term	$0	$0	$0	$0	$0	$0

5.8.4 Big Chico Creek Recovery Actions

Table 5-16. Big Chico Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement fish passage improvement projects at the recreational pools in Bidwell Park.	1	BCC-1.1	SRCS, STE	NMFS, USFWS, CDFW, DWR, Big Chico Watershed Alliance	1	5 Years	$500,000	$0	$0	$0	$0	$500,000
Re-establish spring-run Chinook salmon and steelhead passage at low and moderate flows through Iron Canyon.	1	BCC-1.2	SRCS, STE	City of Chico, USFWS, CDFW, NMFS, Big Chico Creek Ecological Reserve, Chico State University, Butte County, Sierra Nevada Conservancy	1	5 years	$1,000,000					$1,000,000
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Big Chico Creek watershed.	2	BCC-2.1	SRCS, STE	NMFS, USFWS, USFS, CDFW	1,5	Long-term	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Big Chico Creek by identifying and implementing projects that would reduce the potential for, and magnitude of, a catastrophic wildfire, and restore forested areas within the watershed including riparian areas.	2	BCC-2.2	SRCS, STE	NMFS, USFWS, CDFW, DWR, Big Chico Watershed Alliance	1,5	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							$50,000.					
Implement projects to increase Big Chico Creek floodplain habitat availability to improve habitat conditions for juvenile rearing	2	BCC-2.3	SRCS, STE	NMFS, USFWS, CDFW, DWR, Big Chico Watershed Alliance	1	Long-term	TBD based on amount of habitat restored; initial study is expected to cost at least $50,000. Per unit cost is $5,000 to $80,000/acre (Appendix D Table HI-4)	TBD	TBD	TBD	TBD	TBD based on amount of habitat restored; initial study is expected to cost at least $50,000. Per unit cost is $5,000 to $80,000/acre (Appendix D Table HI-4)
Identify stream reaches in Big Chico Creek that have been most altered by anthropogenic factors and reconstruct a natural channel geometry scaled to current channel forming flows.	2	BCC-2.4	SRCS, STE	NMFS, USFWS, CDFW, DWR, Big Chico Watershed Alliance	1,5	5 Years	$4,217,625	$0	$0	$0	$0	$4,217,625
Curtail further development in the active Big Chico Creek floodplains through zoning restrictions, county master plans, HCPs, and other Federal, State, and county planning and regulatory processes.	2	BCC-2.5	SRCS, STE	NMFS, USFWS, USFS, Corps, CDFW, DWR, Local governments	1,3, 5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement of illegal rip rap applications in Big Chico Creek.	2	BCC-2.6	SRCS, STE	Corps, SWRCB	1,5	Long-term						Cost is covered under action # COC-2.9
Develop education and outreach programs to encourage river stewardship in Big Chico Creek.	2	BCC-2.7	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, Landowners, Local Schools	1	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Increase monitoring and enforcement in Big Chico Creek to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants (SWRCB 2007).	2	BCC-2.8	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Develop a baseline monitoring program to evaluate water quality throughout the watershed to identify areas of concern.	2	BCC-2.9	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, CDFW	1,5	3 Years	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts.	2	BCC-2.10	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, CDFW, DWR, Landowners	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400

5.8.5 Butte Creek Recovery Actions

Table 5-17. Butte Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Identify and establish minimum instream flow requirements for Butte Creek that support all life stages of spring-run Chinook salmon and steelhead.	1	BUC-1.1	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	1	Long-term	$0	$0	$0	$0	$0	$0
Install and maintain real-time flow and water temperature monitoring gages in Butte Creek in order to help make real-time management decisions.	1	BUC-1.2	SRCS, STE	CDFW, DWR, USFWS, NMFS, SWRCB	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop an entrainment monitoring program in Butte Creek to determine the level of take at individual diversions. Prioritize diversions based on this monitoring and screen those	1	BUC-1.3	SRCS, STE	NMFS, USFWS, CDFW, DWR	1,3,5	5 years	$100,000 for monitoring program; costs of screens for Butte Creek TBD	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
that are determined to have substantial impacts.												
Implement projects that consolidate and screen existing diversions in Butte Creek where feasible.	1	BUC-1.4	SRCS, STE	NMFS, USBR, CDFW, DWR, Irrigation districts, Water districts	1,3,5	Long-term	$50,000	$750,000	$0	$0	$0	$800,000
Develop information to better understand the interaction between surface water and groundwater in the Butte Creek watershed in order to evaluate the potential impacts of water management options (e.g., groundwater sales; conjunctive use) in the watershed on the Butte Creek flow regime.	1	BUC-1.5	SRCS, STE	SWRCB, CDFW, DWR Irrigation districts	4,5	Short-term	$0	$0				$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects that improve water temperature management in Butte Creek, including facility modifications to the DeSabla-Centerville Hydroelectric Project.	1	BUC-1.6	SRCS, STE	PG&E, NMFS, CDFW, FERC, SWRCB	1	Short-term	TBD. NMFS is in the process of obtaining the cost from PG&E.					TBD. NMFS is in the process of obtaining the cost from PG&E.
Improve the segregation of Butte Creek spring-run and fall-run Chinook salmon during spawning by development and installation of a more robust separation device or removable weir at or near the Parrott-Phelan diversion dam. The segregation device should allow adult steelhead passage.	1	BUC-1.7	SRCS	CDFW, NMFS, USFWS, PG&E	1	Short-term	< $500,0000					<$500,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement programs and measures designed to control non-native predatory fish in Butte Sink and the Sutter Bypass, including harvest management techniques and programs for non-native predators (e.g., striped bass, largemouth bass, and smallmouth bass).	2	BUC-2.1	SRCS, STE	NMFS, USFWS, CDFW, DWR	2,3	Long-term	TBD	TBD	TBD	TBD	TBD	Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Increase instream cover in Butte Creek in order to minimize predatory opportunities for striped bass and other non-native predators on anadromous salmonids.	2	BUC-2.2	SRCS, STE	Corps, USFWS, NMFS, CDFW	1,3	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects
Implement flow ramping protocols in Butte Creek to protect all life	2	BUC-2.3	SRCS, STE	NMFS, USFWS, CDFW, DWR, PG&E, FERC	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
stages of spring-run Chinook salmon and steelhead.												
Develop and implement a strategy that prioritizes projects with the intent of promoting Butte Creek watershed resiliency and reducing the potential for wildfires.	2	BUC-2.4	SRCS, STE	NMFS, USFWS, CDFW, Butte Creek Watershed Conservancy, PG&E	1,4	Long-term	$0	$0	$0	$0	$0	$0
Identify stream reaches in Butte Creek that have been most altered by anthropogenic factors and develop and implement actions that restore natural river processes; conduct associated public outreach projects. One specific issue that should be addressed by this action is the number of temporary passage	2	BUC-2.5	SRCS, STE	NMFS, USFWS, CDFW, DWR	1	Long-term	$4,217,625	$0	$0	$0	$0	$4,217,625

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
impediments installed to create swimming holes in Butte Creek near Chico.												
Develop and implement programs and projects that focus on maintaining and restoring riparian corridors within the Butte Creek watershed.	2	BUC-2.6	SRCS, STE	NMFS, USFWS, USFS, CDFW, DWR, Local governments	1,4	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 -$675000
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Butte Creek.	2	BUC-2.7	SRCS, STE	Corps, USBR, NMFS, USFWS, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active Butte Creek floodplains through zoning restrictions, county master plans, and	2	BUC-2.8	SRCS, STE	Corps, NMFS, USFWS, DWR, CDFW, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
other Federal, State, and county planning and regulatory processes.												
Develop education and outreach programs to encourage river stewardship in the Butte Creek watershed.	2	BUC-2.9	SRCS, STE	NMFS, USFWS, CDFW, DWR, CSU Chico, Landowners, schools	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Permanently protect riparian habitat in Butte Creek through easements and/or land acquisition	2	BUC-2.10	SRCS, STE	CDFW, Landowners, USFWS	1	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Increase monitoring and enforcement in order to minimize illegal streambank alterations in Butte Creek, including high bank gold mining.	2	BUC-2.11	SRCS, STE	Corps, DWR, SWRCB	1,4,5	Long-term						Cost is covered under action # COC-2.9

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase water quality monitoring and enforcement in Butte Creek to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants (SWRCB 2007).	2	BUC-2.12	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Butte Creek.	2	BUC-2.13	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Dist, SWRCB, DWR, CDFW, Landowners	5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Implement projects to increase Butte Creek floodplain habitat availability to improve habitat	2	BUC-2.14	SRCS, STE	NMFS, USFWS, CDFW, DWR	1,4	Long-term	TBD based on amount of habitat restored; initial study is expected to cost at least $50,000. Per unit cost is $5,000 to $80,000/acre (Appendix D Table	TBD	TBD	TBD	TBD	TBD based on amount of habitat restored; initial study is expected to cost at least $50,000. Per unit cost is $5,000 to $80,000/acre (Appendix D Table

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
conditions for juvenile rearing							HI-4).					HI-4).
Monitor and evaluate the sport fishing regulations for Butte Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead, and work with the Fish and Game Commission to modify the regulations as needed.	2	BUC-2.15	SRCS, STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Develop, implement and evaluate a Butte Creek water management option for the PG&E DeSabla-Centerville Hydroelectric Project to determine the flow conditions that optimize coldwater holding habitat and spawning	2	BUC-2.16	SRCS, STE	CDFW, PG&E, FERC, NMFS	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
distribution for spring-run Chinook salmon.												
Maintain state-of-the-art fish passage facilities at diversions in Butte Creek and DWR weir 2 to meet NMFS and CDFW fish passage criteria.	2	BUC-2.17	SRCS, STE	Irrigation districts, DWR	1,4	Long-term	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000 over 25 years; ~$20,000 for each year after that. Estimate of $20,000/year is based on DWR (2004b).
Implement projects to minimize predation at weirs, diversion dams, and related structures in Butte Creek.	3	BUC-3.1	SRCS, STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).

5.8.6 Feather River Recovery Actions

Table 5-18. Feather River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Establish reproductive isolation between fall-run Chinook salmon and spring-run Chinook salmon naturally spawning in the Feather River.	1	FER-1.1	SRCS	DWR, USFWS, NMFS, CDFW, FERC	1	Long-term	$0	$0	$0	$0	$0	$0 because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.
Develop and implement hatchery and genetic management plans for the spring-run Chinook salmon, steelhead, and fall-run Chinook salmon hatchery programs at the Feather River Fish Hatchery.	1	FER-1.2	SRCS, STE	DWR, USFWS, NMFS, CDFW, SWRCB, CVRWQCB, FERC	1,5	Long-term	$0	$0	$0	$0	$0	$0 because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.
Identify and implement actions intended to minimize straying of Feather River Hatchery salmon and steelhead.	1	FER-1.3	SRCS, STE	DWR, YCWA, USFWS, NMFS, CDFW, SWRCB, CVRWQCB, and FERC	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	The cost of hatchery measures are included in FER-1.2; the cost of any flow management measures are TBD in FERC licensing proceedings for projects on the Feather and Yuba Rivers.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop a spawning gravel budget, identify gravel depleted areas, and implement an augmentation plan in the Feather River.	1	FER-1.4	SRCS, STE	DWR, CDFW, USFWS, NMFS, SWRCB, and FERC	1	Long-term	$0	$0	$0	$0	$0	$0 because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.
Implement and maintain projects to increase side channel habitats in order to improve steelhead spawning habitat availability and quality.	1	FER-1.5	STE	DWR, CDFW, USFWS, NMFS, and FERC	1,4	Long-term	$0	$0	$0	$0	$0	$0 because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.
Operate the Feather River Hatchery programs for spring-run Chinook salmon and steelhead as conservation hatchery programs, and develop criteria and a process for phasing out the programs as recovery criteria are reached.	1	FER-1.6	SRCS, STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects to minimize predation at weirs, diversion dams, and related structures in the Feather River.	1	FER-1.7	SRCS, STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Implement the lower Feather River Corridor Management Plan and other projects that promote natural river processes (e.g., floodplain and riparian restoration). Federal, State, and local agencies should	1	FER-1.8	SRCS, STE	DWR, CDFW, Corps	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. NMFS is in the process of obtaining the cost information from DWR.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
use their authorities to develop and implement programs and projects that focus on retaining, restoring and creating active floodplain and riparian corridors within their jurisdiction in the Feather River watershed.												
Implement projects to improve near shore refuge cover for salmonids in the Feather River to minimize predatory opportunities for striped bass and other non-native predators.	1	FER-1.9	SRCS, STE	DWR, CDFW, Corps	1,3,4	Short-term	TBD	TBD				TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects
Manage releases from Oroville Dam with instream flow schedules and criteria to provide suitable water temperatures for all life	1	FER-1.10	SRCS, STE	NMFS, USFWS, CDFW, DWR, SWRCB, FERC	1,5	Long-term	$0	$0	$0	$0	$0	$0, because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
stages, reduce stranding and isolation, protect incubating eggs from being dewatered, and promote habitat availability.												
Implement a habitat expansion plan that meets the criteria of the Habitat Expansion Agreement, or develop and implement a program to reintroduce spring-run Chinook salmon and steelhead to historic habitats upstream of Oroville Dam in the North Fork Feather River. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term	2	FER-2.1	SRCS, STE	NMFS, USFWS, CDFW, DWR, PG&E, USFS, FERC	1,5	Long-term	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000 (Cost estimate is for reintroducing spring-run Chinook salmon and steelhead to the North Fork Feather River.)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
reintroduction program.												
Implement a habitat expansion plan that meets the criteria of the Habitat Expansion Agreement, or implement actions to enhance habitat conditions and improve access within the north fork Feather River upstream of Oroville Dam, including increasing minimum flows, providing passage at upstream dams, and assessing feasibility of passage improvement at natural barriers.	2	FER-2.2	SRCS, STE	NMFS, USFWS, CDFW, DWR, PG&E, USFS, FERC	1,4,5	Long-term	TBD	TBD	TBD	TBD	TBD	$50,000 for habitat evaluation and identification of specific enhancement actions; cost of actions TBD
Implement a study designed to develop quantitative estimates of	2	FER-2.3	SRCS, STE	NMFS, USFWS, CDFW, DWR	3,4	5 Years	$200,000-$400,000	$0	$0	$0	$0	$200,000-$400,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
predation on spring-run Chinook salmon and steelhead in the Feather River.												
Implement programs and measures designed to minimize predation on juvenile salmonids in the Feather River, including harvest management techniques and programs for non-native predators (e.g., striped bass, largemouth bass, and smallmouth bass).	2	FER-2.4	SRCS, STE	NMFS, USFWS, CDFW, DWR	2,3,4	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Curtail further development in the active Feather River floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	FER-2.5	SRCS, STE	Corps, NMFS, USFWS, DWR, CDFW, Local governments	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Utilize fish friendly designs (e.g., levee setbacks, inclusion of riparian vegetation) for levee construction and maintenance.	2	FER-2.6	SRCS, STE	Corps, SWRCB	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in the Feather River, including how to identify and avoid damaging salmon and steelhead redds.	2	FER-2.7	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, DWR, CDFW, CSU Chico, Landowners, schools, Feather River Nature Center	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Permanently protect Feather River riparian and floodplain habitat through easements and/or land acquisition.	2	FER-2.8	SRCS, STE	NMFS, CDFW, DWR, Corps	1,5	Long-term	TBD based on amount specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on amount specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Monitor and evaluate the sport fishing regulations for the Feather River to ensure they are consistent with the recovery of	2	FER-2.9	SRCS, STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
spring-run Chinook salmon and steelhead.												
Negotiate agreements with landowners and Federal and State agencies to provide additional instream flows or purchase water rights in the Feather River.	2	FER-2.10	SRCS, STE	USFWS, NMFS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)
Evaluate pulse flow benefits in the Feather River for adult immigration and juvenile outmigration during peak migration periods for years with low water availability; if pulse flows are determined to be effective for attracting adult spring-run Chinook salmon and steelhead or for improving survival during juvenile	2	FER-2.11	SRCS, STE	DWR, USFWS, NMFS, CDFW, FERC, YCWA, PG&E, NID	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in FERC license proceedings.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
outmigration, implement the most beneficial pulse flow regime.												
Develop an entrainment and predator monitoring program in the Feather River to determine the level of take at individual diversions and screen those with the highest take level relative to screen cost.	2	FER-2.12	SRCS, STE	NMFS, CDFW, Irrigation districts, Water districts	1,3,5	5 years	$100,000 for monitoring program; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Modify Sunset Pumps to provide unimpeded upstream passage of adult steelhead and Chinook salmon (and sturgeon) and to minimize predation of juveniles moving downstream.	2	FER-2.13	SRCS, STE	DWR	1,3,5	Short-term	$50,000 to identify and design a preferred modification; cost of modification TBD after the initial study.	$0	$0	$0	$0	$50,000 to identify and design a preferred modification; cost of modification TBD after the initial study.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop a baseline monitoring program in the Feather River to evaluate water quality throughout the watershed to identify areas of concern and disseminate the information to resource managers.	2	FER-2.14	SRCS, STE	DWR, CDFW	1,5	3 Years	$0	$0	$0	$0	$0	$0
Develop and apply alternative diversion technologies that eliminate entrainment in the Feather River.	3	FER-3.1	SRCS, STE	NMFS, CDFW, Irrigation districts, Water districts	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.
Implement pollution control programs and projects to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met in the Feather River for all potential pollutants.	3	FER-3.2	SRCS, STE	SWRCB, CVRWQCB, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to prepare plans and implement best-management practices to reduce water quality impacts in the Feather River watershed.	3	FER-3.3	SRCS, STE	USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400

5.8.7 Yuba River Recovery Actions

Table 5-19. Yuba River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a program to reintroduce spring-run Chinook salmon and steelhead to historic habitats upstream of Englebright Dam. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.	1	YUR-1.1	SRCS, STE	NMFS, USFWS, USFS, CDFW, Corps, PG&E, NIC, YCWA, FERC	1, 4	Long-term: Evaluations beginning in year 1 , Pilot	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Improve spawning habitat in the Englebright Dam Reach (Englebright Dam [RM 24] downstream to the Deer Creek confluence	1	YUR-1.2	SRCS, STE	NMFS, USFWS, Corps, CDFW	1	Long-term	$5.9 million for spawning rehabilitation (DWR and PG&E 2010)	$800,000 for maintenance	$800,000 for maintenance	$800,000 for maintenance	$800,000 for maintenance	$9, 900,000 over 25 years; $800,000 for each additional 5-year block.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
[RM 23]) through habitat rehabilitation and a long-term gravel injection program (Pasternack 2009).												
Develop programs and implement projects that promote natural river processes, including projects that add riparian habitat and instream cover.	1	YUR-1.3	SRCS, STE	YCWA, Corps, CDFW, SYRCL, USFS, USFWS	1	Long-term	$4,217,625	$0	$0	$0	$0	$4,217,625
Modify Daguerre Point Dam to provide unobstructed volitional upstream passage of adult steelhead and Chinook salmon (and sturgeon) and to minimize predation of juveniles moving downstream.	1	YUR-1.4	SRCS, STE	YCWA, Corps, CDFW, SYRCL, USFWS	1,4	Long-term	Cost estimates for fish passage alternatives range from $2.5 million to construct an engineered channel to $97 million to remove the dam (DWR and Corps 2003).	Operation and maintenance costs range from $50,000 to $2,000,000 per year (DWR and Corps 2003)	Operation and maintenance costs range from $50,000 to $2,000,000 per year (DWR and Corps 2003)	Operation and maintenance costs range from $50,000 to $2,000,000 per year (DWR and Corps 2003)	Operation and maintenance costs range from $50,000 to $2,000,000 per year (DWR and Corps 2003)	$3.5 million to $137 million based on DWR and Corps (2003) estimates, and assuming construction during years 1-5 and operation and maintenance costs during years 6-25.
Develop and implement a large woody material restoration	2	YUR-2.1	SRCS, STE	NMFS, USFWS, Corps, USBR, DWR, CDFW	1	Long-term	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$3,750,000 - $10,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
program along the lower Yuba River utilizing sources of wood that enter upstream reservoirs.												
Increase floodplain habitat availability in the lower Yuba River.	2	YUR-2.2	SRCS, STE	CDFW, USFWS, NMFS, YCWA	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on several factors including: (1) how much floodplain habitat is to be restored; (2) the amount of material that needs to be removed; (3) whether the removed material can be sold and at what price; and (4) whether the newly available floodplain is planted or vegetation is allowed to colonize naturally. Initial evaluation to address these factors estimated at up to $200,000.
Curtail further development in active Yuba River floodplains through zoning restrictions, county master plans, and other Federal, State, and	2	YUR-2.3	SRCS, STE	YCWA, Corps, CDFW, SYRCL, USFS, FERC, USFWS	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
county planning and regulatory processes.												
Create and restore side channel habitats to increase the quantity and quality of off-channel rearing and spawning areas in the Yuba River.	2	YUR-2.4	SRCS, STE	YCWA, Corps, CDFW, SYRCL, USFS, FERC, USFWS	1	Short-term	TBD	TBD				TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). Initial evaluation estimated at $5,000-$50,000
Federal, State, and local agencies should use their authorities to develop and implement programs and projects that focus on retaining, restoring and creating river riparian corridors within their jurisdiction in the Yuba River watershed.	2	YUR-2.5	SRCS, STE	NMFS, USWS, FERC, CDFW, DWR, YCWA	1	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 - $675000
Permanently protect Yuba River riparian and floodplain habitat through easements and/or land	2	YUR-2.6	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, Yuba Watershed Council	1	Long-term	TBD based on specific easements and land acquisitions; initial study is expected	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
acquisition.							to cost at least $50,000.					
Implement flow fluctuation and ramping rates found to be protective of embryos and juveniles.	1	YUR-2.7	SRCS, STE	YCWA, NMFS, USFWS, Corps, CDFW, DWR, PG&E, NID, SYRCL, Yuba Watershed Council	1	Long-term	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings
Implement programs and measures designed to minimize predation by non-native fish in the Yuba River, including harvest management techniques and programs for non-native predators (e.g., striped bass, largemouth bass, and smallmouth bass).	2	YUR-2.8	SRCS, STE	NMFS, USFWS, CDFW, DWR, YCWA, South Yuba and Brophy Water Districts	2,3	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Improve efficiency of screening devices at Hallwood-Cordua and Brophy-South Yuba water diversions, and	2	YUR-2.9	SRCS, STE	NMFS, CDFW, YCWA, South Yuba and Brophy Water Districts	1,4	Short-term	$200,000	$0	$0	$0	$0	$200,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
construct screens at unscreened diversions												
Evaluate whether salmonid straying between the Feather and Yuba rivers can be minimized through flow management.	2	YUR-2.10	SRCS, STE	NMFS, USFWS, Corps, DWR, YCWA	1,4	Short-term	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the evaluation is TBD based on the initial study.	TBD	TBD	TBD	TBD	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the evaluation is TBD based on the initial study.
Monitor and evaluate the sport fishing regulations for the Yuba River to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead.	2	YUR-2.11	SRCS, STE	NMFS, CDFW,SYRCL, Yuba Watershed Council	2	Short-term	$0	$0	$0	$0	$0	$0
Relocate the riverside motocross recreation area outside of the Yuba River's active floodplain.	3	YUR-3.1	SRCS, STE	CDFW, Yuba County, Yuba Watershed Council	2	5 Years	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in the Yuba River.	3	YUR-3.2	SRCS, STE	NMFS, USFWS, USBR, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Identify the benefits, risks, and costs associated with various techniques and locations for spatially segregating spring-run Chinook salmon and fall-run Chinook salmon during spawning in the Yuba River. If the benefits sufficiently outweigh the risks and costs, then implement a project to segregate spring- and fall-run Chinook salmon.	3	YUR-3.3	SRCS, STE	NMFS, CDFW, YCWA, Yuba Watershed Council, PG&E	1	Short-term	$10,000 for benefit, risk, and cost evaluation. Cost of segregation TBD based on the evaluation.	$0	$0	$0	$0	$10,000 for benefit, risk, and cost evaluation. Cost of segregation TBD based on the evaluation.

5.8.8 Dry Creek Recovery Actions

Table 5-20. Dry Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Conduct an anadromous fish passage assessment in Dry Creek and implement projects to fix any obstructions.	3	DRC-3.1	STE	NMFS, USFWS, USFS, CDFW, DWR, Yuba Watershed Council, Bear River Watershed Group	1	5 Years	$50,000-$200,000, fish passage project(s) cost TBD by the assessment.	$0	$0	$0	$0	$50,000-$200,000, fish passage project(s) cost TBD by the assessment.
Enhance watershed resiliency in Dry Creek by identifying and implementing projects that would reduce the potential for, and magnitude of, a catastrophic wildfire, and restore forested areas within the watershed including riparian areas.	3	DRC-3.2	STE	NMFS, USFWS, USFS, CDFW, DWR, Yuba Watershed Council, Bear River Watershed Group	1	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Dry Creek watershed.	3	DRC-3.3	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in Dry Creek.	3	DRC-3.4	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Dry Creek watershed.	3	DRC-3.5	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Develop a long-term strategy for monitoring and regulating discharges from agricultural lands in the Dry Creek watershed to protect waters within the Central Valley, including enforcing the regulations.	3	DRC-3.6	STE	SWRCB, NRCS, Placer County	1,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in Dry Creek to ensure that the water quality criteria established in the Central	3	DRC-3.7	STE	SWRCB, CVRWQCB, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.												
Conduct a hydrologic analysis of the Dry Creek watershed that explores conjunctive use opportunities to reduce water allocations that are dependent on surface water.	3	DRC-3.8	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1	Long-term	$275,550	$0	$0	$0	$0	$275,550
Evaluate gravel resources on Dry Creek and provide gravel at any identified locations.	3	DRC-3.9	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1,5	Short-term	$5,000-$50,000 for evaluation; gravel augmentation costs TBD based on the evaluation.	$0	$0	$0	$0	$5,000-$50,000 for evaluation; gravel augmentation costs TBD based on the evaluation.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Curtail further development in the active Dry Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	3	DRC-3.10	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1,5	Long-term	$0	$0	$0	$0	$0	$0
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Dry Creek.	3	DRC-3.11	STE	NMFS, USFWS, Corps, USBR, CDFW, DWR, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Permanently protect Dry Creek riparian habitat through easements and/or land acquisition	3	DRC-3.12	STE		1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for Dry Creek to ensure they are consistent with the recovery of steelhead.	3	DRC-3.13	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Implement programs and measures designed to control non-native predatory fish in Dry Creek (NMFS 2007b), including harvest management techniques and programs for non-native predators (e.g., striped bass, largemouth bass, and smallmouth bass).	3	DRC-3.14	STE	NMFS, USFWS, CDFW, DWR	1,3	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Implement projects to minimize predation at weirs, diversion dams, and related structures in Dry Creek.	3	DRC-3.15	STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							site-specific costs.					specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in Dry Creek to minimize predatory opportunities for striped bass and other non-native predators.	3	DRC-3.16	STE	NMFS, USFWS, CDFW, DWR	1,3	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.	TBD	TBD	TBD	TBD	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects

5.8.9 Auburn Ravine Recovery Actions

Table 5-21. Auburn Ravine Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Install a fish ladder at Gold Hill Dam and screen the diversion canal.	2	AUR-2.1	SRCS, STE	SWRCB, CVRWQCB, Local farmers, SARSAS	1,5	5 Years	<$1 million	$0	$0	$0	$0	<$1 million
Develop an entrainment monitoring program in Auburn Ravine and Coon Creek to determine the level of take at individual diversions. Prioritize diversions based on this monitoring and screen those that are determined to have substantial impacts at the population level.	2	AUR-2.2	STE	NMFS, USFWS, CDFW, DWR, Placer County, Irrigation districts, SARSAS	1,3,5	5 years	$100,000 for monitoring program; screening costs for Auburn Ravine are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Develop and apply alternative diversion technologies that eliminate entrainment in Auburn Ravine and Coon Creek.	2	AUR-2.3	STE	NMFS, USFWS, CDFW, DWR, Placer County, Irrigation districts, SARSAS	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. •This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects that consolidate and screen existing diversions in Auburn Ravine and Coon Creek where feasible.	2	AUR-2.4	STE	NMFS, USBR, CDFW, DWR, Irrigation districts, Water districts, SARSAS	1,3,5	Long-term	$200,000	$200,000	$0	$0	$0	$400,000
Conduct a hydrologic analysis of the Auburn/Coon Creek watershed that explores conjunctive use opportunities to reduce water allocations that are dependent on surface water.	2	AUR-2.5	STE	NMFS, USFWS, Corps, USBR, CDFW, DWR, SARSAS, PCWA	5	Long-term	$275,550	$0	$0	$0	$0	$275,550
Enhance watershed resiliency in Auburn Ravine and Coon Creek by identifying and implementing projects that would reduce the potential for, and magnitude of, a catastrophic wildfire, and restore forested areas within the watershed including riparian areas.	2	AUR-2.6	STE	NMFS, USFWS, USFS, CDFW, DWR, Placer County, SARSAS, PCWA	1	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the	2	AUR-2.7	STE	NMFS, USFWS, USFS, CDFW, Placer County, SARSAS	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Auburn Ravine and Coon Creek watershed.												
Develop a baseline monitoring program in Auburn Ravine and Coon Creek to evaluate water quality throughout the watershed to identify areas of concern.	2	AUR-2.8	STE	NMFS, USFWS, USEPA, SWRCB, DWR, CDFW, Placer County, SARSAS	5	3 Years	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in the Auburn Ravine/Coon Creek watershed.	2	AUR-2.9	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Landowners, Placer County, SARSAS, PCWA	2	Long-term	$76,140	$76,140	$76,140	$76,140	$0	$304,560

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Auburn Ravine/Coon Creek watershed.	2	AUR-2.10	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Placer County, Local farmers	5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Develop a long-term strategy for monitoring and regulating discharges from agricultural lands in the Auburn Ravine/Coon Creek watershed to protect waters within the Central Valley, including enforcing the regulations.	2	AUR-2.11	STE	SWRCB, Local farmers	5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in Auburn Ravine and Coon Creek to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met (SWRCB 2007).	2	AUR-2.12	STE	SWRCB, CVRWQCB, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Identify stream reaches in Auburn Ravine and Coon Creek that have been most altered by anthropogenic factors and reconstruct a natural channel geometry scaled to current channel forming flows.	2	AUR-2.13	STE	NMFS, USFWS, CDFW, DWR, SARSAS	5	5 Years	$4,217,625	$0	$0	$0	$0	$4,217,625
Curtail further development in the active Auburn Ravine and Coon Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	AUR-2.14	STE	NMFS, USFWS, Corps, USFS, DWR, CDFW, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop State and national levee vegetation policies to maintain and restore riparian corridors in Auburn Ravine and Coon Creek (Corps vegetation management policy and FloodSAFE).	2	AUR-2.15	STE	NMFS, USFWS, Corps, USBR, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement programs and projects that focus on retaining, restoring and creating river riparian corridors within their jurisdiction in the Auburn Ravine/Coon Creek watershed.	2	AUR-2.16	STE	NMFS, USFWS, Corps, USBR, USFS, DWR, CDFW, Local agencies, NGOs	1,5	Short-term	TBD	TBD	$0	$0	$0	TBD based on amount of riparian habitat to be restored. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive week control are needed. Initial scoping study estimated to cost $5,000-$50,000.
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Auburn Ravine and Coon Creek.	2	AUR-2.17	STE	NMFS, USFWS, Corps, USBR, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Permanently protect Auburn and Coon Creek riparian habitat through easements and/or land acquisition	2	AUR-2.18	STE	NMFS, USFWS, CDFW, DWR, SARSAS	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Implement programs and measures in Auburn Ravine and Coon Creek designed to control non-native predators.	2	AUR-2.19	STE	NMFS, USFWS, CDFW, DWR, SARSAS	1,3	Long-term	Cost covered by the cost of SFB-2.5 ($0-$75,000,000).	TBD	TBD	TBD	TBD	Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects to minimize predation at weirs, diversion dams, and related structures in Auburn Ravine and Coon Creek.	2	AUR-2.20	STE	NMFS, CDFW, DWR, USFWS, USBR, Corps, SARSAS	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs. P	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in Auburn Ravine and Coon Creek to help minimize predation.	2	AUR-2.21	STE	NMFS, USFWS, CDFW, DWR, SARSAS	1,3	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.	TBD	TBD	TBD	TBD	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for Auburn Ravine and Coon Creek to ensure they are consistent with the recovery of steelhead.	3	AUR-3.1	STE	NMFS, CDFW	1,2	Long-term	$0	$0	$0	$0	$0	$0

5.8.10 American River Recovery Actions

Table 5-22. American River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a steelhead reintroduction plan to re-colonize historic habitats above Nimbus and Folsom Dams: Conduct feasibility study; Conduct habitat evaluations; Conduct 3-5 year pilot testing program; and Implement long-term fish passage.	1	AMR-1.1	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, FERC, PG&E, PCWA	1,5	Long-term: Evaluations beginning in year 1	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Implement physical and structural modifications to the American River Division of the CVP in order to improve water temperature management (See RPA action II.3 in the 2009 Biological Opinion for the long-term operations of the CVP and SWP) (NMFS 2009b).	1	AMR-1.2	STE	NMFS, USFWS, Corps, USBR, DWR, CDFW, CBDA, Water Forum	1,4	Long-term	$0	$0	$00	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop an annual water temperature management plan for the lower American River (NMFS 2009b).	1	AMR-1.3	STE	USFWS, USBR, CDFW, DWR, Water Forum	1,5	Long-term	$0	$0	$0	$0	$0	$0
Implement the flow management related actions (i.e., RPA actions II.1 and II.4) identified in the reasonable and prudent alternative from the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).	1	AMF-1.4	STE	USFWS, USBR, CDFW, DWR, Water Forum	1,4	Long-term	$0	$0	$0	$0	$0	$0
Implement a long-term gravel management program in the lower American River to provide suitable spawning habitat per CVPIA.	1	AMR-1.5	STE	USFWS, USBR, Water Forum	1,4	Long-term	$1,000,000[28]	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$5,000,000
Implement a long-term wood management program to provide habitat	1	AMR-1.6	STE	USFWS, USBR, CDFW, Water Forum	1,4,5	Long-term)	$100,000	$200,000	$250,000	$300,000	$300,000	$1,150,000

[28] Based on cost of 2013-2016 CVPIA funded gravel augmentation project for the American River.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
complexity and predator refuge habitat.												
Implement the recommendations of the 2012 California Hatchery Scientific Review Group Report regarding the steelhead program at Nimbus Hatchery.	1	AMR-1.7	STE	USBR, CDFW	4,5	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a HGMP for the steelhead program at Nimbus Hatchery (NMFS 2009b).	1	AMR-1.8	STE	USBR, CDFW	2,5	Long-term	$0	$0	$0	$0	$0	$0
Develop a baseline monitoring program in the American River watershed to evaluate water quality throughout the watershed to identify areas of concern.	2	AMR-2.1	STE	NMFS, USFWS, USEPA, SWRCB, DWR, CDFW	1,5	3 Years	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in the American River watershed to ensure that the water quality	2	AMR-2.2	STE	SWRCB, CVRWQCB	1,4	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.												
Implement projects that improve wastewater and stormwater treatment in residential, commercial, and industrial areas throughout the American River watershed.	2	AMR-2.3	STE	NMFS, CDFW, SWRCB, Water Forum, Sacramento County and cities germane to this issue.	4,5	Long-term	TBD	TBD	TBD	TBD	TBD	Cost partly covered in DEL-2.20 ($1-$2 billion). Other costs TBD based on site-specific evaluations, each of which could range up to $100,000.
Develop education and outreach programs to encourage river stewardship in the American River watershed.	2	AMR-2.4	STE	Corps, NMFS, USFWS, DWR, CDFW, American River Conservancy, Local government, Water Forum	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Develop and implement programs and projects that focus on retaining, restoring and creating river riparian corridors within their	2	AMR-2.5	STE	NMFS, USFWS, Corps, USBR, USFS, DWR, CDFW, Local agencies, NGOs	1,4	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 -$675,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
jurisdiction in the American River watershed.												
Permanently protect American River riparian habitat through easements and/or land acquisition	2	AMR-2.6	STE	Local govt, Corps, SAFCA, CDFW	1,5	short-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in the American River.	2	AMR-2.7	STE	Corps, USBR, NMFS, USFWS, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active American River floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	AMR-2.8	STE	Corps, NMFS, USFWS, USFS, DWR, CDFW, Local governments	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Inventory locations on the American River for creating shallow inundated floodplain habitat for multi-species benefits and implement where suitable opportunities are available (Water Forum 2001).	2	AMR-2.9	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR, Water Forum	1	Long-term	$0	$0	$0	$0	$0	$0
Modify sport-fishing regulations to minimize "take" of wild steelhead and to minimize hatchery influence in the lower American River. This could include increased information in the regulations about not wading through redds and increasing the bag and possession limit for hatchery steelhead.	3	AMR-3.1	STE	NMFS, CDFW	2,5	short-term	$0	$0	$0	$0	$0	$0

5.8.11 Mokelumne River Recovery Actions

Table 5-23. Mokelumne River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Adaptively manage water releases in the Mokelumne River in consideration of the spatial and temporal distribution of steelhead life stages in the Mokelumne River.	1	MOR-1.1	STE	NMFS, USFWS, CDFW, DWR, Landowners, Irrigation districts	1	Long-term	$0	$0	$0	$0	$0	$0
Manage cold water pools in Camanche and Pardee reservoirs to provide suitable water temperatures in the Mokelumne River for all steelhead life stages.	1	MOR-1.2	STE	NMFS, USFWS, USBR, CDFW, EBMUD	1	Long-term	$278,030 for evaluation of alternative reservoir management practices; cost of any operational changes TBD based on the evaluation.	TBD	TBD	TBD	TBD	$278,030 for evaluation of alternative reservoir management practices; cost of any operational changes TBD based on the evaluation.
Implement the recommendations of the 2012 California Hatchery Scientific Review Group Report regarding the steelhead program at Mokelumne Hatchery.	1	MOR-1.3	STE	NMFS, USFWS, CDFW, DWR	4, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD; Specific actions to be taken and associated costs will be identified by the Mokelumne River Hatchery Coordination Team that will be formed according to the recommendation from the Hatchery Scientific Review Group.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to develop and implement a spawning gravel augmentation plan for the Mokelumne River.	2	MOR-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Conduct feasibility studies for allowing steelhead access to habitat above Camanche and Pardee dams, including assessing habitat suitability and fish passage logistics.	2	MOR-2.2	STE	NMFS, USFWS, USBR, DWR, PG&E, FERC	1	Short-term	$720,000	$0	$0	$0	$0	$720,000
If the feasibility studies suggest that fish passage can be successful, then design and conduct an experimental fish passage program evaluating adult distribution, survival, spawning, and juvenile production in habitats above Camanche and Pardee dams.	2	MOR-2.3	STE	NMFS, USFWS, USBR, DWR	1	Short-term	$0	$9,000,000	$0	$0	$0	$9,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
If the experimental fish passage program demonstrates that passage above Camanche and Pardee dams can substantively contribute to the long-term viability of the DPS, then develop and implement long-term fish passage programs.	2	MOR-2.4	STE	NMFS, USFWS, USBR, DWR	1	Long-term	$0	$0	$3,500,000	$3,500,000	$3,500,000	10,500,000
Evaluate the adequacy of the existing flow regime through SWRCB processes, and dedicate flows as necessary.	2	MOR-2.5	STE	NMFS, USFWS, CDFW, SWRCB	1,5	Long-term	$0	$0	$0	$0	$0	$0
Negotiate agreements with landowners, water districts, and Federal and State agencies to provide additional instream flows or purchase water rights, and/or restore riparian habitat to promote shading in the Mokelumne River.	2	MOR-2.6	STE	USFWS, NMFS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water Districts, Landowners, Local governments, NGOs	1, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on : (1) amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D); and (2) amount of habitat restored. As identified in Appendix D, per unit costs for riparian restoration vary depending on whether fencing, planting, irrigation, or invasive weed control are needed. Evaluation of water available for acquisition and riparian habitat

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												restoration opportunities could range up to $100,000.
Evaluate pulse flow benefits for steelhead attraction and passage in the Mokelumne River; if pulse flows are determined to be effective for attracting steelhead, implement the most beneficial pulse flow regime.	2	MOR-2.7	STE	NMFS, USFWFS, USBR, CDFW, DWR	1	Long-term	$0	$0	$0	$0	$0	$0
Monitor and evaluate sport-fishing regulations to ensure that angling impacts on steelhead in the Mokelumne River are consistent with recovery.	2	MOR-2.8	STE	NMFS, CDFW	1, 2	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement outreach projects in the Mokelumne River basin to educate the public regarding the steelhead life cycle and watershed stewardship.	2	MOR-2.9	STE	NMFS, USFWS, USBR, CDFW, DWR	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Mokelumne River.	2	MOR-2.10	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners	1, 5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Increase monitoring and enforcement in the Mokelumne River to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.	2	MOR-2.11	STE	SWRCB, CVRWQCB, Local agriculture	1, 5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Work with local land owners to restore riparian habitats in the Mokelumne River.	2	MOR-2.12	STE	NMFS, USFWS, Resource Conservation Districts, CDFW, DWR	1, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of habitat restored. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive weed control are needed.$5,000-$50,000 for initial scoping evaluation.
Permanently protect Mokelumne River riparian habitat through easements and/or land acquisition	2	MOR-2.13	STE	NMFS, USFWS, Resource Conservation Districts, CDFW, DWR	1, 5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Conduct research and monitoring to better understand the factors affecting the survival of steelhead downstream of Woodbridge Dam.	2	MOR-2.14	STE	EBMUD, CDFW, USFWS, NMFS	1,5	Short-term	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the research and monitoring is TBD based on the initial study.	TBD	$0	$0	$0	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the research and monitoring is TBD based on the initial study.
Implement projects to minimize predation in the Mokelumne River.	2	MOR-2.15	STE	EBMUD, CDFW, USFWS, NMFS	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							for potential site-specific costs.					details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Implement projects to minimize entrainment in the Mokelumne River.	2	MOR-2.16	STE	EBMUD, CDFW, USFWS, NMFS	1	Short-term	TBD based on number of diversions and site specific factors affecting screening costs. $5,000-$50,000 for initial scoping evaluation.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.8.12 Cosumnes River Recovery Actions

Table 5-24. Cosumnes River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop cooperative water use agreements (e.g., groundwater exchange agreements) with local water users to provide flows in the Cosumnes River.	3	COR-3.1	STE	CDFW, USFWS, NMFS, water districts	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)
Implement projects to minimize predation in the Cosumnes River	3	COR-3.2	STE	CDFW, USFWS, NMFS	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												assumed that each site will cost about $38,000 annually (BDCP 2013).
Implement projects to minimize entrainment in the Cosumnes River.	3	COR-3.3	STE	CDFW, USFWS, NMFS, water districts	1,5	Short-term	TBD based on number of diversions and site specific factors affecting screening costs. $5,000-$50,000 for initial scoping evaluation.	TBD	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.9 Mainstem San Joaquin River Recovery Actions

Table 5-25. San Joaquin River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Exhibit B hydrographs providing interim and restoration flows as outlined in the San Joaquin River Stipulation of Settlement (available at http://www.restoresjr.net/).	1	SJR-1.1	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a spring-run Chinook salmon reintroduction strategy as outlined in paragraph 14 of the San Joaquin River Stipulation of Settlement (available at http://www.restoresjr.net/).	1	SJR-1.2	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Implement channel modifications as outlined in the San Joaquin River Stipulation of Settlement, including increasing the channel capacity to accommodate restoration flows up to 4,500 cfs (available at http://restoresjr.net/).	1	SJR-1.3	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Minimize entrainment and fish losses to both adult and juvenile life stages to non-viable migration pathways as outlined in the San Joaquin River Stipulation of Settlement, including, placing temporary barriers at Mud and Salt Sloughs and other potential sources of adult entrainment, screening	1	SJR-1.4	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Arroyo Canal and other riparian diversions as they are identified, and modifying and screening the Chowchilla Bypass Bifurcation Structure (available at http://www.restoresjr.net/).												
Provide fish passage at existing structures as outlined in the San Joaquin River Stipulation of Settlement (available at http://restoresjr.net/) including: (1) modifications to the Sand Slough Control Structure; (2) modification of the Reach 4B head gate; (3) reconstruction of Sack Dam to ensure unimpeded fish passage; (4) construction of a Mendota Pool Bypass; (5) modifications to structures in the Eastside and Mariposa Bypasses channels; and (6) fixing other passage impediments including road crossings, drop structures, and others as identified in the DWR Passage Report (DWR 2012) for the San Joaquin River Restoration Area.	1	SJR-1.5	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Manage juvenile salmonid predation risk by filling and/or isolating high priority gravel pits as identified in paragraph 11(b) of the San Joaquin River Stipulation of Settlement (available at http://www.restoresjr.net/).	1	SJR-1.6	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement an ecologically based San Joaquin River flow regime to help restore natural river processes and support all life stages of steelhead and spring-run Chinook salmon (Poff *et al.*1997).	1	SJR-1.7	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, SWRCB	1,4	Long-term	$4,217,625	$4,217,625	$4,217,625	$4,217,625	$0	$16,870,500
Implement projects that improve wastewater and stormwater treatment in residential, commercial, and industrial areas throughout the San Joaquin River watershed to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.	1	SJR-1.8	SRCS, STE	NMFS, USFWS, CDFW, DWR, SWRCB, Local governments	1,4,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on amount of water to be treated and whether existing treatment facilities need to be upgraded or new facilities are required.. Site-specific evaluations could range up to $100,000 each.
Develop a long-term strategy for monitoring and regulating discharges from agricultural lands in the San Joaquin River basin to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan)	1	SJR-1.9	SRCS, STE	SWRCB	1,5	5 Years	TBD	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
are met for all potential pollutants.												
Complete Total Maximum Daily Load projects for all Clean Water Act Section 303(d) listed pollutants entering the San Joaquin River.	1	SJR-1.10	SRCS, STE	SWRCB	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a spawning gravel augmentation plan in the San Joaquin River.	1	SJR-1.11	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1	Long-term	$0	$0	$0	$0	$0	$0; covered under San Joaquin River Restoration Program
Develop and implement a program to reestablish steelhead upstream of Friant Dam. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot phase prior to implementation of the long-term program.	2	SJR-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the San Joaquin River.	2	SJR-2.2	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, SWRCB, Landowners	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop education and outreach programs and coordinate with local governments, communities, and conservation districts to encourage river stewardship in the San Joaquin River basin.	2	SJR-2.3	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, SWRCB	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Permanently protect San Joaquin River riparian and floodplain habitat through easements and/or land acquisition.	2	SJR-2.4	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Implement projects to protect and restore riparian and floodplain habitats along the San Joaquin River, such as projects underway at the San Joaquin River National Wildlife Refuge to restore riparian habitat, expand the refuge, and breach deauthorized levees in order to increase floodplain habitat.	2	SJR-2.5	SRCS, STE		1,4	Long-term	TBD based on type and amount of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on type and amount of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Coordinate with county and other local planning processes to encourage protection of floodplain habitat along the San Joaquin River.	2	SJR-2.6	SRCS, STE	NMFS, USFWS, Corps, CDFW, DWR, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement of illegal stream bank alterations and monitor permitted alterations in the San Joaquin River.	2	SJR-2.7	SRCS, STE	Corps, SWRCB	1,4	Long-term						Cost is covered under action # COC-2.9
Compile available data and/or conduct new habitat analyses to determine if instream cover is lacking in the San Joaquin River, and add instream cover as necessary.	2	SJR-2.8	SRCS, STE	NMFS, USFWS, CDFW	1	5 years	$0	$0	$0	$0	$0	$0
Implement studies designed to quantify the impact of predation on steelhead in the San Joaquin River and identify specific locations where predation is a problem.	2	SJR-2.9	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,3,4	5 Years	$200,000-$400,000	$0	$0	$0	$0	$200,000-$400,000
Conduct studies to evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on steelhead and spring-run Chinook salmon in the San Joaquin River; continue implementation if effective.	2	SJR-2.10	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,3,4	5 Years						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement habitat enhancement or augmentation actions designed to minimize predation on steelhead in the San Joaquin River.	2	SJR-2.11	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, Various NGOs	1,3,4	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement design criteria and projects to minimize predation at weirs, diversion dams, and related structures in the San Joaquin River.	2	SJR-2.12	SRCS, STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1,3,5	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												$38,000 annually (BDCP 2013).
Monitor and evaluate the sport fishing regulations for the San Joaquin River to ensure they are consistent with the recovery of steelhead and spring-run Chinook salmon, and work with the Fish and Game Commission to modify the regulations as needed.	2	SJR-2.13	SRCS, STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Develop information to better understand the interaction between surface water and groundwater in the San Joaquin watershed in order to evaluate the potential impacts of water management options (e.g., groundwater sales; conjunctive use) in the watershed on San Joaquin River flows.	2	SJR-2.14	SRCS, STE	SWRCB, DWR, NMFS, USFWS, USBR, Corps, CDFW,	1.4	Short-term	$0	$0	$0	$0	$0	$0
Develop information to better understand the potential impact of inter basin water management (i.e., Sacramento River water being pumped into and then running off the San Joaquin basin) on the migratory cues and fish response (e.g., straying) for returning adult Chinook salmon and	2	SJR-2.15	SRCS, STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1,4	Short-term	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the research and monitoring is TBD based on the initial	TBD	$0	$0	$0	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the research and monitoring is TBD based on the initial study.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
steelhead.							study.					
Develop an incentive-based entrainment monitoring program in the San Joaquin River designed to work cooperatively with diverters to develop projects or actions in order to minimize pumping impacts.	2	SJR-2.16	SRCS, STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1,4	Short-term	TBD based on number of diversions and site specific factors affecting screening costs. Entrainment monitoring program estimated at up to $300,000 annually.	TBD	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.10 Southern Sierra Nevada Diversity Group Recovery Actions

5.10.1 Merced River Recovery Actions

Table 5-26. Merced River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a program to reestablish steelhead in historic habitat upstream of Crocker-Huffman, Merced Falls, McSwain, and New Exchequer dams. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term program.	1	MER-1.1	STE	NMFS, USFWS, USBR, CDFW, DWR, MID, PG&E, FERC	1,5	Long-term	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Manage releases from New Exchequer Reservoir in order to provide the	2	MER-1.2	STE	NMFS, USFWS, MID, FERC, CDFW, DWR	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
most beneficial flow and water temperatures for all steelhead life stages.												
Supplement flows provided pursuant to the Davis-Grunsky Contract and FERC License Number 2179 with water acquired from willing land owners and water districts to provide additional instream flow.	1	MER-1.3	STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Develop a Merced River steelhead team to help guide collection and evaluation of baseline data to help address hypotheses for why resident O.mykiss are more abundant than anadromous O.mykiss in the Merced River. This information could be used to identify the flow and water	1	MER-1.4	STE	NMFS, USFWS, CDFW, DWR	1,2,3,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
temperature conditions that are most beneficial to anadromous O. mykiss.												
Evaluate whether pulse flows in the Merced River are beneficial to adult steelhead immigration and juvenile steelhead emigration; if pulse flows are determined to be effective, implement the most beneficial pulse flow regime.	1	MER-1.5	STE	NMFS, USFWS, MID, FERC, CDFW, DWR	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process
Identify and implement floodplain and side channel projects to improve river function and increase habitat diversity in the Merced River.	1	MER-1.6	STE	NMFS, USFWS, MID, FERC, CDFW, DWR	1,4,5	Short-term	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to	TBD	$0	$0	$0	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							$300,000/acre.. $5,000-$50,000 for initial scoping evaluation.					
Develop and implement a long-term gravel management plan to increase and maintain steelhead spawning habitat downstream of Crocker-Huffman, Merced Falls, and New Exchequer dams.	1	MER-1.7	STE	NMFS, USFWS, , MID, PG&E, FERC, CDFW, DWR	1,4	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Prioritize Merced River diversions based on their level of entrainment and screen those with the highest benefit to cost ratio.	2	MER-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR, MID	1,3,5	5 years	$50,000 for prioritization; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Work with water rights holders in the Merced River watershed to provide flows that are	2	MER-2.2	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR, NRCS, Family Water Alliance, MID	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
protective of steelhead.												
Develop and implement ramping rate criteria for the Merced River that are protective of anadromous fishes.	2	MER-2.3	STE	NMFS, USFWS, Corps, MID, PG&E, FERC, CDFW, DWR	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process
Continue to supply spawning-sized gravel to landowners for construction and maintenance of wing dam diversion structures in the Merced River; implement the Gravel Mining Reach Phase II projects.	2	MER-2.4	STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on amount of gravel added; Per unit cost is $11 to $72/cubic yard (Appendix D).
Evaluate the potential benefits and feasibility of installing a water temperature control device on New Exchequer Dam in order to most efficiently	2	MER-2.5	STE	NMFS, USFWS, USBR, MID, FERC, CDFW, DWR	1	Short-term	<$50,000	$0	$0	$0	$0	<$50,000 for evaluation and feasibility study.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
utilize the volume of cold water in the reservoir.												
Federal, State, and local agencies should use their authorities to develop and implement programs and projects that focus on retaining, restoring and creating riparian corridors within their jurisdiction in the Merced River watershed.	2	MER-2.6	STE	USFWS, Corps, CDFW, DWR, Local agencies, NGOs	1,4	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 -$675000
Permanently protect Merced River riparian habitat through easements and/or land acquisition	2	MER-2.7	STE	NMFS, USFWS, CDFW, DWR, landowners, Resource Conservation Districts	1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Increase monitoring and enforcement of illegal rip rap applications in the Merced	2	MER-2.8	STE	Corps, SWRCB	1,4,5	Long-term						Cost is covered under action # COC-2.9

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
River.												
Implement studies designed to quantify the impact of predation on steelhead in the Merced River. If the studies identify predator species and/or locations contributing to low steelhead survival, then evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on steelhead in the Merced River; continue implementation if effective.	2	MER-2.9	STE	NMFS, USFWS, CDFW, DWR	1,2,3	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement programs and measures designed to control predation in the Merced River, including actions to isolate "ponded" sections of the river.	2	MER-2.10	STE	NMFS, USFWS, CDFW, DWR	1,3,5	Long-term	$0	$0	$0	$0	$0	$0

5.10.2 Tuolumne River Recovery Actions

Table 5-27. Tuolumne River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Evaluate and, if feasible, develop and implement a steelhead and spring-run Chinook salmon passage program for La Grange and Don Pedro dams. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.	1	TUR-1.1	STE	NMFS, CDFW, Modesto Irrigation District, Turlock Irrigation District, FERC	1,5	Long-term	$720,150	$9,000,000	$3,468,000	$0	$0	$13,188,150

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Manage releases from La Grange and Don Pedro dams to provide suitable flows and water temperatures for all downstream life stages of steelhead.	1	TUR-1.2	STE	NMFS, CDFW, Modesto Irrigation District, Turlock Irrigation District, FERC	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process
Develop a Tuolumne River steelhead team to help guide collection and evaluation of baseline data to help address hypotheses for why resident O.mykiss are more abundant than anadromous O.mykiss in the Tuolumne River. This information could be used to identify the flow and water temperature conditions that are most	1	TUR-1.3	STE	USFWS, CDFW, NMFS	1	Short-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
beneficial to anadromous O. mykiss.												
Evaluate whether pulse flows in the Tuolumne River are beneficial to adult steelhead immigration and juvenile steelhead emigration; if pulse flows are determined to be effective, implement the most beneficial pulse flow regime.	1	TUR-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR, Modesto and Turlock Irrigation Districts, FERC	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process
Continue to implement projects to increase the availability and quality of spawning and rearing habitat in the Tuolumne	2	TUR-2.2	STE	NMFS, USFWS, USBR, CDFW, DWR, Modesto and Turlock Irrigation Districts	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on the amount of spawning gravel to be added and the type and amount of rearing habitat restored. Per unit cost for gravel augmentation is $11 to $72/cubic yard (Appendix D). See Appendix D for per unit costs of restoring various

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
River.												types of rearing habitats (e.g., riparian, floodplain, instream cover. $5,000-$50,000 for initial scoping of rearing habitat restoration opportunities and gravel needs.)
Evaluate the feasibility of moving water diversions lower in the Tuolumne River in order to provide higher flows in the upstream reaches. If feasible and cost effective, move water diversions lower in the Tuolumne River.	2	TUR-2.3	STE	NMFS, USFWS, USBR, CDFW, DWR, Modesto and Turlock Irrigation Districts	1	Long-term	<$200,000 for evaluation; cost of moving diversions TBD based on information obtained during the evaluation.	TBD	TBD	TBD	TBD	<$200,000 for evaluation; cost of moving diversions TBD based on information obtained during the evaluation.
Develop and implement flow fluctuation criteria for the Tuolumne River that are protective of anadromous	2	TUR - 2.4	STE	NMFS, USFWS, Corps, CDFW, DWR, Modesto and Turlock Irrigation Districts, FERC	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
fishes.												
Work with State and Federal water acquisition programs to dedicate instream water in the Tuolumne River.	2	TUR - 2.5	STE	NMFS, USFWS, USBR, CDFW, DWR, Modesto and Turlock Irrigation Districts	1	Long-term	$0	$0	$0	$0	$0	$0
Evaluate modifying current operation plans (e.g., flood control curves) for Don Pedro with the Corps and irrigation districts to reallocate instream flows for salmonids.	2	TUR - 2.6	STE	Corps, Modesto and Turlock Irrigation Districts, NMFS, USFWS, CDFW	1	Short-term	$0	$0	$0	$0	$0	$0
Identify and implement floodplain and side channel projects to improve river function and	2	TUR - 2.7	STE	NMFS, USFWS, CDFW, Modesto and Turlock Irrigation Districts	1	Short-term	TBD	TBD	$0	$0	$0	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
increase habitat diversity in the Tuolumne River.												4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre. $5,000-$50,000 for initial scoping of restoration opportunities.
Update the 2006 Water Quality Control Plan for the Bay-Delta in order to improve flow conditions for steelhead in the Tuolumne River.	2	TUR - 2.8	STE	SWRCB, CDFW, USFWS, NMFS, Modesto and Turlock Irrigation Districts	1,4	Long-term	$0	$0	$0	$0	$0	$0
Restore riparian habitat to promote shading and habitat diversity in the Tuolumne River.	2	TUR - 2.9	STE	Corps, Modesto and Turlock Irrigation Districts, NMFS, USFWS, CDFW, CV Flood Protection Board	1		TBD	TBD	TBD	TBD	TBD	TBD, based on amount of habitat restored. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive weed control are needed. $5,000-$50,000 for initial scoping of restoration opportunities.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects to minimize predation at weirs, diversion dams, and related structures in the Tuolumne River.	2	TUR - 2.10	STE	NMFS, CDFW, DWR, USFWS, Modesto and Turlock Irrigation Districts	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in the Tuolumne River to minimize predatory opportunities for striped bass and other non-native	2	TUR - 2.11	STE	NMFS, USFWS, CDFW, DWR	1,3	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those	TBD	TBD	TBD	TBD	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
predators.							issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.					projects
Develop a baseline monitoring program for the Tuolumne River to evaluate water quality throughout the watershed to identify pollutants to be included on the Clean Water Act section 303(d) list.	2	TUR - 2.12	STE	SWRCB, CDFW, USFWS, NMFS, Modesto and Turlock Irrigation Districts	1,5	Short-term	$0	$0	$0	$0	$0	$0
Complete Total Maximum Daily Load projects for all Clean Water Act Section 303(d) listed pollutants entering the Tuolumne	2	TUR - 2.13	STE	SWRCB	1	Short-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
River.												
Encourage voluntary landowner participation in the Tuolumne River watershed in educational opportunities such as water quality short courses, field demonstrations and distribution of water quality "Fact Sheets".	2	TUR - 2.14	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners	2	Long-term	$76,140	$76,140	$76,140	$76,140	$0	$304,560
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Tuolumne River.	2	TUR - 2.15	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, CDFW, DWR, SWRCB	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement in the Tuolumne River to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants excluding water temperature.	2	TUR - 2.16	STE	SWRCB, CVRWQCB, Local agriculture groups	1,4	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Evaluate Tuolumne River O.mykiss genetics to inform management in the anadromous reach as well as planning for potential reintroductions to the upper river.	3	TUR - 3.1	STE	CDFW, USFWS, NMFS	1,5	Short-term	$25,000 - $50,000	$0	$0	$0	$0	$25,000 - $50,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Prioritize lower Tuolumne River diversions based on their level of entrainment and screen those with the highest benefit to cost ratio	3	TUR - 3.2	STE	CDFW, USFWS, NMFS, USBR, DWR, Modesto and Turlock Irrigation Districts	1,5	5 years	$50,000 for prioritization; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.10.3 Stanislaus River Recovery Actions

Table 5-28. Stanislaus River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Evaluate and, if feasible, develop and implement a steelhead passage program for Tullock, Goodwin, and New Melones dams. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.	1	STR-1.1	STE	NMFS, USFWS, USBR, CDFW, OID, South San Joaquin Irrigation District, TriDam, PG&E, FERC	1,5	Long-term	$720,150	$9,000,000	$3,468,000	$0	$0	$13,188,150

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Manage releases from Tulloch, Goodwin, and New Melones dams to provide suitable water temperatures and flows for all steelhead life stages. Suitable water temperatures for the Stanislaus River are specified on page 621 of the biological opinion for the long-term operations of the CVP/SWP (NMFS 2009b). Suitable minimum instream flow schedules for the Stanislaus River are described in Appendix 2-E of the biological opinion	1	STR-1.2	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR, OID, South San Joaquin Irrigation District, Tridam	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
(NMFS 2009b).												
Develop a Stanislaus River steelhead team to help guide collection and evaluation of baseline data to help address hypotheses for why resident O.mykiss are more abundant than anadromous O.mykiss in the Stanislaus River. This information could be used to identify the flow and water temperature conditions that are most beneficial to anadromous O. mykiss.	1	STR-1.3	STE	NMFS, USFWS, USBR, CDFW	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to implement projects to increase the availability and quality of spawning and rearing habitat in the Stanislaus River.	2	STR-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Evaluate whether pulse flows in the Stanislaus River are beneficial to adult steelhead immigration and juvenile steelhead emigration; if pulse flows are determined to be effective, implement the most beneficial pulse flow regime.	2	STR-2.2	STE	NMFS, USFWS, USBR, CDFW, DWR, Stanislaus River Fish Group, OID, South San Joaquin Irrigation District, TriDam, PG&E, FERC	1,5	Long-term	$0	$0	$0	$0	$0	$0. Pulse flows are required under the 2009 biological opinion for the long-term operations of the CVP/SWP.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Work with State and Federal water acquisition programs to dedicate instream water in the Stanislaus River.	2	STR-2.3	STE	NMFS, USFWS, USBR, CDFW, DWR, Stanislaus River Fish Group	1	Long-term	$0	$0	$0	$0	$0	$0
Negotiate agreements with landowners, water districts, and Federal and State agencies to provide additional instream flows or purchase water rights in the Stanislaus River.	2	STR-2.4	STE	NMFS, USFWS, USBR, Corps, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $162 - $246/af/year for south of Delta water purchases (Appendix D)
Utilize the SWRCB regulatory process of updating the 2006 Water Quality Control Plan for the Bay-Delta to	2	STR-2.5	STE	NMFS, SWRCB	1,4	Short-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
improve flow conditions for steelhead in the Stanislaus River.												
Identify and implement floodplain and side channel projects to improve river function and increase habitat diversity in the Stanislaus River.	2	STR-2.6	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1	Short-term	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.	TBD	$0	$0	$0	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.
Work with local land owners to restore riparian habitats along the Stanislaus River.	2	STR-2.7	STE	NMFS, USFWS, USBR, CDFW, DWR, Stanislaus River Fish Group	1,5	Long-term	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre	TBD	$0	$0	$0	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							(Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.					HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.
Permanently protect riparian habitat along the Stanislaus River through easements and/or land acquisition.	2	STR-2.8	STE	NMFS, USFWS, USBR, Corps, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Monitor and evaluate the impact of the sport fishery on Stanislaus River steelhead to ensure the regulations are consistent with steelhead recovery, and work with the Fish and Game Commission to	2	STR-2.9	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
modify the regulations as needed.												
Increase monitoring and enforcement in order to minimize steelhead poaching in the Stanislaus River.	2	STR-2.10	STE	NMFS, CDFW	2,4	Long-term						Cost is covered under action # COC-2.9
Implement outreach projects in the Stanislaus River to educate the public regarding the steelhead life cycle including how to identify steelhead redds. Encourage voluntary landowner participation in the Stanislaus River in educational opportunities such as water	2	STR-2.11	STE	NMFS, USFWS, USBR, CDFW, DWR, Stanislaus River Fish Group	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
quality short courses, field demonstrations and distribution of water quality "Fact Sheets".												
Evaluate programs and measures designed to minimize predation in the Stanislaus River.	2	STR-2.12	STE	NMFS, USFWS, CDFW, DWR, Stanislaus River Fish Group, OID	1,3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												$38,000 annually (BDCP 2013).
Implement projects to minimize predation in the Stanislaus River at mine pits and at deep pools caused by bank stabilization projects.	2	STR-2.13	STE	NMFS, USFWS, CDFW, DWR, Stanislaus River Fish Group	1,3,4	Long-term	Costs covered in action STR-2.12	Costs covered in action STR-2.12	Costs covered in action STR-2.12	Costs covered in action STR-2.12	Costs covered in action STR-2.12	Costs covered in action STR-2.12
Implement projects to increase instream habitat complexity and predator refuge cover in the Stanislaus River, including the addition of large woody material.	2	STR-2.14	STE	NMFS, USFWS, CDFW, DWR, Stanislaus River Fish Group	1,3,4	Long-term	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$3,750,000 - $10,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop a baseline monitoring program for the Stanislaus River to evaluate water quality throughout the watershed to identify areas of concern.	2	STR-2.15	STE	NMFS, USWFS, USEPA, Resource Conservation Districts, CDFW, DWR, SWRCB, Stanislaus River Fish Group	1,5	3 Years	$0	$0	$0	$0	$0	$0
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Stanislaus River.	2	STR-2.16	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Increase monitoring and enforcement in the Stanislaus River to ensure that the water quality criteria	2	STR-2.17	STE	SWRCB, CVRWQCB, Local agriculture groups	1,4,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.												
Complete Total Maximum Daily Load projects for all Clean Water Act Section 303(d) listed pollutants entering the Stanislaus River.	2	STR-2.18	STE	EPA, SWRCB, CVRWQCB, Local agriculture groups	1,5	Long-term	$0	$0	$0	$0	$0	$0
Evaluate Stanislaus River *O.mykiss* genetics to inform management in the anadromous reach as well as planning for potential reintroductions to the upper river.	2	STR-2.19	STE	NMFS, CDFW, Reclamation, USFWS	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop an entrainment monitoring program in the Stanislaus River to determine the level of take at individual diversions. Prioritize diversions based on this monitoring program and screen those that are determined to have substantial impacts.	3	STR-3.1	STE	NMFS, USFWS, CDFW	1,3,5	5 years	$100,000 for monitoring program; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.10.4 Calaveras River Recovery Actions

Table 5-29. Calaveras River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement long-term year-round instream flow schedules and water temperature requirements that are protective of all steelhead life stages, including providing flows for upstream and downstream fish passage.	1	CAR - 1.1	STE	NMFS, USFWS, CDFW	1	Long-term	$594,090	$0	$0	$0	$0	$594,090
Establish a minimum carryover storage level at New Hogan Reservoir that meets the instream flow and water temperature requirements in the lower Calaveras River.	1	CAR - 1.2	STE	NMFS, USFWS, CDFW, Corps	1,5	Long-term	$1,144,240	$0	$0	$0	$0	$1,144,240
Remove or modify all fish passage impediments in the lower Calaveras River to meet NMFS and CDFW fish passage criteria.	1	CAR - 1.3	STE	NMFS, USFWS, CDFW, Corps	1	Long-term	$0	$15,000,000	$0	$0	$0	$15,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor upstream and downstream fish passage through the existing Bellota weir fish ladder and operate the weir based on this monitoring information to provide timely and safe fish passage.	1	CAR-1.4	STE	NMFS, USFWS, USBR, CDFW, DWR, Fishery Foundation of California, Stockton East Water District	1,4	Long-term	$0	$0	$0	$0	$0	$0
Replace Bellota weir incorporating a permanent fish ladder and screened diversion as recommended in the Calaveras River Fish Screen Facilities Feasibility Study.	1	CAR-1.5	STE	NMFS, USFWS, USBR, CDFW, DWR, Fishery Foundation of California, Stockton East Water District	1	Short-term	$8-$10 million	$0	$0	$0	$0	$8-$10 million
Implement a Calaveras River monitoring program to identify the temporal and spatial distributions of migrating and holding steelhead. These data would help ensure that suitable flows, water temperatures, and passage conditions are	1	CAR-1.6	STE	NMFS, USFWS, USBR, CDFW, DWR, Fishery Foundation of California, Stockton East Water District	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
being provided when and where the fish are in the Calaveras River.												
Fully implement the Calaveras River fish passage improvement project in order to provide permanent upstream and downstream passage for salmonids between the mouth of the Calaveras River and Bellota weir.	2	CAR-2.1	STE	DWR, USFWS, USBR, Corps, CDFW, Fishery Foundation of California, Stockton East Water District	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on the number and type of fish passage impediments. NMFS is in the process of obtaining a cost estimate from DWR, the lead agency for the project.
Until year-round permanent fish passage improvements are made to preclude the need for flashboard weirs, operate Bellota and other weirs so that the flashboards are not in place from at least October through June.	2	CAR-2.2	STE	USFWS, USBR, Corps, CDFW, DWR, Fishery Foundation of California, Stockton East Water District	1	Long-term	$0	$0	$0	$0	$0	$0
Prioritize and screen unscreened diversions in the Calaveras River including Bellota weir.	2	CAR-2.3	STE	CDFW, NMFS, Stockton East Water District, Calaveras County Water District	1,3,5	5 years	$50,000 for prioritization; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												estimated at $20 million (San Francisco Estuary Partnership 2007).
Negotiate agreements with landowners, Stockton East Water District (SEWD), Calaveras County Water District (CCWD) and federal and state agencies to provide additional instream flows.	2	CAR-2.4	STE	SEWD, CCWD, NMFS, USFWS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water Districts, Landowners, Local Governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $162 - $246/af/year for south of Delta water purchases (Appendix D)
Purchase water rights from Calaveras River water diverters in order to increase flows.	2	CAR-2.5	STE	NMFS, USFWS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water Districts, Landowners, Local Governments, NGOs	1,5	Short-term	TBD	TBD	$0	$0	$0	TBD based on the amount of water accounted for in the water right. Cost per unit is $162 - $246/af/year for south of Delta water purchases (Appendix D)
Continue implementing the recommendations from the lower Calaveras River Salmonid Life History Limiting Factor Analysis to assess flow requirements for anadromous salmonids and also develop and implement further specific	2	CAR-2.6	STE	NMFS, USFWS, USBR, CDFW, DWR, Stockton East Water District	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
recommendations.												
Evaluate pulse flow benefits for steelhead attraction and passage in the Calaveras River; if pulse flows are determined to be effective for attracting steelhead, implement the most beneficial pulse flow regime.	2	CAR-2.7	STE	NMFS, USFWS, USBR, Corps, DWR, CDFW	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop a baseline monitoring program for the Calaveras River to evaluate water quality throughout the watershed to identify areas of concern.	2	CAR-2.8	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1	3 Years	$0	$0	$0	$0	$0	$0
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water	2	CAR-2.9	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1	Long-term	$62,400	$0	$0	$0	$0	$62,400

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
quality impacts in the Calaveras River.												
Increase monitoring and enforcement in the Calaveras River to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.	2	CAR-2.10	STE	SWRCB, CVRWQCB, Local agriculture groups	1,4	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Complete Total Maximum Daily Load projects for all Clean Water Act Section 303(d) listed pollutants entering the Calaveras River.	2	CAR-2.11	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a spawning gravel augmentation plan in the Calaveras River, including periodic evaluations of spawning gravel quality and quantity.	2	CAR-2.12	STE	NMFS, USFWS, Corps, DWR, CDFW	1	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Curtail further development in active Calaveras River floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	CAR-2.13	STE	NMFS, USFWS, Corps, CDFW, DWR, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in the Calaveras River.	2	CAR-2.14	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement of illegal stream bank alterations and monitor permitted alterations in the Calaveras River.	2	CAR-2.15	STE	Corps, SWRCB	1,4	Long-term						Cost is covered under action # COC-2.9
Develop education and outreach programs to encourage river stewardship in the Calaveras River.	2	CAR-2.16	STE	NMFS, USFWS, USBR, CDFW, DWR, Various NGOs	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for the Calaveras River to ensure they are consistent with the recovery of steelhead, and work with the Fish and Game Commission to modify the regulations as needed.	2	CAR-2.17	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in order to minimize anadromous fish poaching in the Calaveras River.	2	CAR-2.18	STE	CDFW	2	Long-term						Cost is covered under action # COC-2.9
Implement a study designed to quantify the amount of predation on steelhead by non-native species in the Calaveras River. If the study identifies predator species and/or locations contributing to low steelhead survival, then evaluate whether predator control actions (e.g., fishery management or	2	CAR-2.19	STE	NMFS, USFWS, CDFW, DWR	1,2	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
directed removal programs) can be effective at minimizing predation on juvenile steelhead in the Calaveras River; continue implementation if effective.												
Develop and implement design criteria and projects to minimize predation at weirs, diversion dams, and related structures in the in the Calaveras River.	2	CAR-2.20	STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												about $38,000 annually (BDCP 2013).
Improve refuge cover for steelhead in the Calaveras River to minimize predatory opportunities for predators.	2	CAR-2.21	STE	NMFS, USFWS, CDFW, DWR	1,2	Short-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. See Table H1-2 in Appendix D for cost per unit for various projects.	$0	$0	$0	$0	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects
Permanently protect riparian habitat through easements and/or land acquisition.	2	CAR-2.22	STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Examine the potential for re-establishing steelhead in historic habitats upstream of New Hogan Dam by conducting feasibility and habitat evaluations. If	3	CAR-3.1	STE	NMFS, USFWS, CDFW, DWR, Corps	1,5	Long-term	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
these evaluations suggest that re-establishment can be successful, then develop a phased program intended to re-establish steelhead upstream of New Hogan Dam.												

6.0 Climate Change and Recovery of Salmon and Steelhead

"Climate variability plays a large role in driving fluctuations in salmon abundance by influencing their physical environment, the availability of food, the competitors for that food, and the predators that prey on small salmon. The complexity of influences on salmon, both climate and otherwise, combined with the scarcity of observations of factors important to salmon in estuaries and the ocean, make it challenging to identify the links between salmon and climate."

- Climate Impacts Group (2004)

6.1 Overview

The scientific basis for understanding the processes and sources of climate variability has grown significantly in recent years, and our ability to forecast human and natural contributions to climate change has improved dramatically. With consensus on the reality of climate change now established (Oreskes 2004; IPCC 2007), the scientific, political, and public priorities are evolving toward determining its ecosystem impacts, and developing strategies for adapting to those impacts. Climate forces directly influence regional temperature, wind, precipitation, snowpack and streamflow patterns, which may impact the habitat suitability for marine and anadromous species directly or indirectly (Schwing 2009).

Many salmon populations throughout the West Coast are at historically low levels due to stresses imposed by a variety of human activities including dam construction, logging, pollution, and over-fishing. Climate change affects salmon throughout their life cycle and poses an additional stress. Earlier peak flows flush young salmon from rivers to estuaries before they are physically mature enough for the transition, increasing a variety of stresses including the risk of being eaten by predators. Earlier snowmelt leaves rivers and streams warmer and shallower during the summer and fall (Thomas *et al*. 2009).

Increasing air temperatures, particularly during the summer, lead to rising water temperatures, which increase stress on coldwater fish such as salmon and steelhead. Projected temperatures for the 2020s and 2040s under a higher emissions scenario suggest that the habitat quality and quantity for these fish is likely to decrease dramatically (Mote *et al*. 2008; Salathé *et al*. 2005; Keleher *et al*. 1996; McCullough *et al*. 2001).

Warmer water temperatures and lower base flows will negatively affect salmonids in several ways. Fish metabolism increases with water temperature, reducing growth if more energy is devoted to searching for food. Warmer water causes salmonid eggs

to hatch sooner. Resulting young may be smaller, and emerge at a time when their insect prey base is not available. (Thomas *et al*. 2009). In addition, diseases and parasites that infect salmon are more prevalent in warmer water.

Ocean conditions are also important to salmon populations, as they reside there for years. The oceans are also impacted by warmer temperatures. Warm coastal temperatures have been correlated with low salmon abundance; higher salmon abundance is associated with cooler ocean temperatures (Janetos *et al*. 2008; Crozier *et al*. 2008).

6.2 Climate Change and Environmental Variability

For ecosystem concerns (e.g., warming, wildfire, sea level rise, anthropogenic influences, El Niño) related to long-term climate changes, all regions under the management jurisdiction of NMFS are expected to experience environmental conditions that have not been experienced before. Warming over this century is projected to be considerably greater than over the last century (Thomas *et al*. 2009). Since 1900, the global average temperature has risen by about 1.5°F. By about 2100, it is projected to rise between 2°F and 10.5°F (**Figure 6-1**), but could increase up to 11.5°F (Thomas *et al*. 2009; California Climate Change Center 2006). In the United States, the average temperature has risen by a comparable amount and is very likely to rise more than the global average over this century, with some variation according to location. Several factors will determine future temperature increases. Increases at the lower end of this range are more likely if global heat-trapping gas emissions are substantially reduced.

If emissions continue to rise at or near current rates, temperature increases are more likely to be near the upper end of the range. Volcanic eruptions or other natural variations could temporarily counteract some of the human-induced warming, slowing the rise in global temperature, but these effects would only last a few years (Thomas *et al*. 2009).

Climate-related fire dynamics also will be affected by changes in the distribution of ecosystems across the landscape. Torn *et al*. (1998) project that there will be a doubling of catastrophic wildfires in some regions due to faster and more intense burning associated with warming, drying vegetation, and elevated wind speed. Increasing temperatures and shifting precipitation patterns also will drive declines in high elevation ecosystems such as alpine forests. As an example, under higher emissions scenarios (Figure 6-1), high-elevation forests in California are projected to decline by 60 to 90 percent before the end of the century. At the same time, grasslands are projected to expand, another factor likely to increase fire risk. Climate changes also could create subtle shifts in fire behavior, allowing more "runaway fires" – fires that are thought to have been brought under control, but then rekindle (Thomas *et al*. 2009).

Current climate trends predict a future of warmer oceans and melting glaciers and icecaps, all of which are expected to raise mean sea levels, leading to the inundation and displacement of many estuaries. A rise in sea level will most dramatically affect those estuaries that are confined by surrounding development, which prohibits their boundaries from naturally shifting in response to inundation. Projections for sea level rise by 2100 vary from 0.18 to 0.58

meters (m), to 0.5 to. 1.4 m (IPCC 2007a; Rahmstorf 2007; Raper and Braithwaite 2006). Paleoclimatic data suggest that the rate of future melting of Greenland and Antarctic ice sheets and related sea-level rise could be faster than currently projected (NMFS 2009). A projected 1 m rise in sea level could potentially inundate 65 percent of the coastal marshlands and estuaries in the United States. In addition, there could be shifts in the quality of the habitats in affected coastal regions. Prior to being inundated, coastal watersheds would become saline due to saltwater intrusion into the surface and groundwater. Regarding California's water supply, the largest effect of sea level rise would likely be in the Delta (DWR 2005c). Increased intrusion of salt water from the ocean into the Delta could lead to increased releases of water from upstream reservoirs or reduced pumping from the Delta to maintain compliance with Delta water quality standards (Anderson *et al*. 2008).

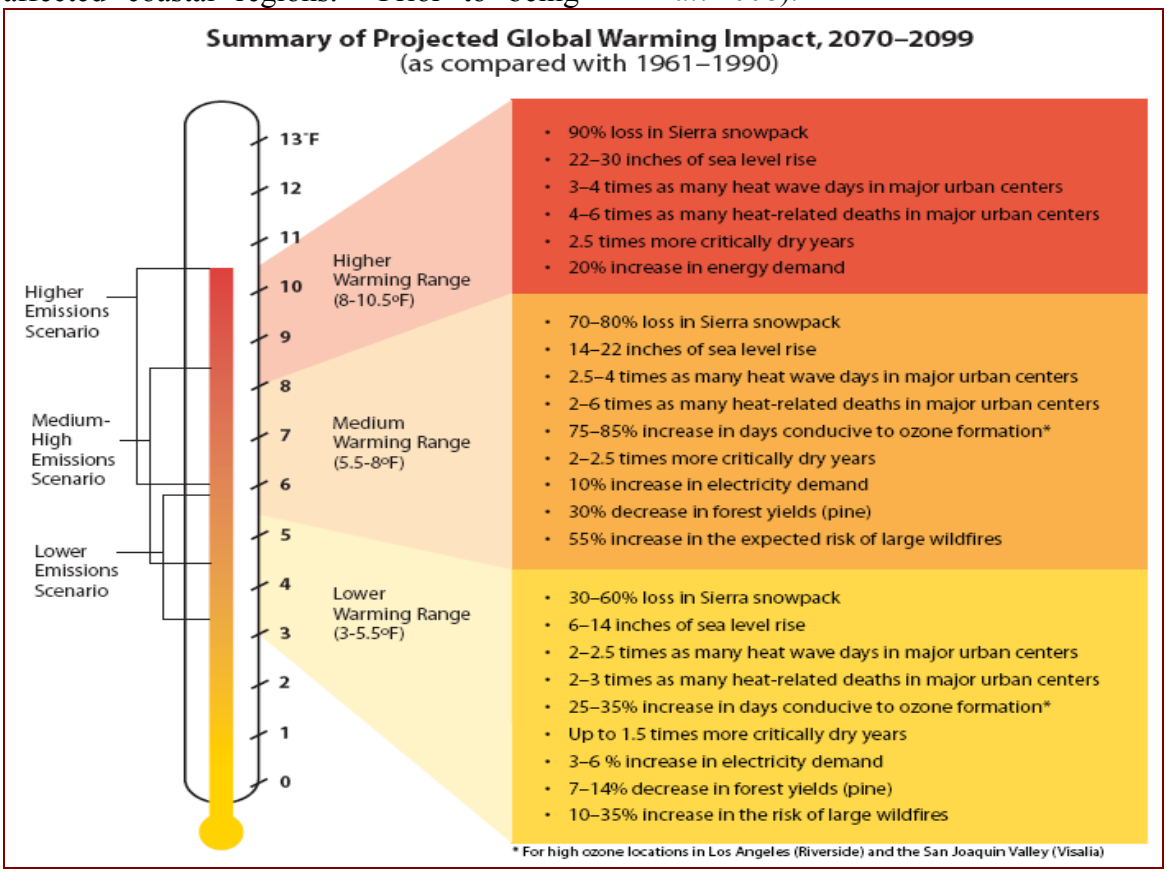


Figure 6-1. Summary of Projected Global Warming Impacts (2070 to 2099 compared to 1961 to 1990). ***(Source: California Climate Change Center 2006)***



Figure 6-2. Schematic of Coastal Upwelling Near the California Coast. Winds from the northwest during spring and summer drive surface water offshore, and it is replaced by cool water high in nutrients that is "upwelled" onto the continental shelf. *(Source: NMFS 2009 - image from NOAA Cordell Bank National Marine Sanctuary).*

Anthropogenic influences on salmon and steelhead habitat play a primary role in climate influences on extinctions (Francis and Mantua 2003). Over the past 150 years, human activities have degraded, and in some cases completely eliminated, much of the historic stream and estuarine habitats for anadromous salmonids. In many ways, human actions have forced semi-permanent changes to the salmonid landscape that parallel those typically associated with climate change (Karr 1994). For example, stream temperatures, flow regimes, sediment transports, and pool-to-riffle ratios are all subject to anthropogenic and climate changes. Karr (1994) indicates that one major difference between perturbations due to natural climate events versus one caused by human activities is the time scale of the resulting impacts. A warm phase of the El Niño-Southern Oscillation generally impacts precipitation and flow over a single year, while hydropower dam construction alters flow for decades to centuries (Francis and Mantua 2003).

Because it affects the distribution of heat in the atmosphere and the oceans, climate change will affect winds and currents that move along the nation's coasts, such as the California Current that bathes the West Coast from British Columbia to Baja California (Thomas *et al*. 2009). Wind-driven upwelling of deeper ocean water along the coast in this area is vital to moderation of temperatures and the high productivity of Pacific Coast ecosystems (**Figure 6-2**). Warmer temperatures are likely to increase ocean stratification, yet possible increases in winds may counter that in ways that mitigate or even increase the wind-driven upwelling of nutrients that fuel a productive food web (CIG 2004).

Coastal currents are subject to periodic variations caused by the El Niño-Southern Oscillation and the Pacific Decadal Oscillation, which have substantial effects on the success of salmon and other fishery resources. Climate change is expected to affect such coastal currents, and possibly the larger scale natural oscillations as well,

although these effects are not yet well understood (Thomas *et al*. 2009).

In addition to carbon dioxide's heat-trapping effect, the increase in its concentration in the atmosphere is gradually acidifying the ocean (Thomas *et al*. 2009). About one-third of the carbon dioxide emitted by human activities has been absorbed by the ocean, resulting in a decrease in the ocean's pH. Since the beginning of the industrial era, ocean pH has declined demonstrably and is projected to decline much more by 2100 if current emissions trends continue (Thomas *et al.* 2009). Because less dissolved carbon is available as carbonate ions at a lower pH (Feely *et al*. 2008; Janetos *et al*. 2008), further declines in pH are very likely to continue to affect the ability of living organisms to create and maintain shells or skeletons of calcium carbonate. Ocean acidification also is anticipated to affect important plankton species in the open ocean, mollusks and other shellfish, and corals (Feely *et al*. 2008; Janetos *et al*. 2008; Royal Society 2005; Orr *et al*. 2005). Reductions in pH also affect photosynthesis, growth, and reproduction. The upwelling of deeper ocean water, deficient in carbonate and thus potentially detrimental to the food chains supporting juvenile salmon, has recently been observed along the West Coast (Feely *et al*. 2008).

It is unclear how coastal ocean conditions will respond to long-term climate change and, in turn, affect Chinook salmon and steelhead populations during their marine life stages. Results of studies by Pearcy (1992),Francis and Hare (1994), and Francis and Mantua (2003) indicate that many climate-related biophysical linkages to salmonid populations occur very early in the salmon's marine life history - likely just months after juvenile fish enter the ocean. This hypothesis that cohort survival can be greatly impacted by climate driven conditions (e.g. upwelling and resultant prey availability) when juvenile salmon enter the ocean was also found to apply to Central Valley Chinook salmon (Lindley *et al*. 2009), further indicating that coastal and estuarine environments are key areas of biophysical interaction. While there is uncertainty regarding how coastal ocean conditions will respond to long-term climate change, it is likely that near-shore marine areas will remain important for salmon survival.

6.3 Climate Change Effects on Ocean Conditions

Most climate factors affect the entire West Coast complex of salmonids. This is particularly true in their marine phase, because the California populations are believed to range fairly broadly along the coast and intermingle, and climate impacts in the ocean occur over large spatial scales (Schwing 2009). Because ocean warming will be widespread, populations at the southern extreme of their ranges will be most susceptible to future warming. Salmon and steelhead residing in coastal areas where upwelling is the dominant process are more sensitive to climate-driven changes in the strength and timing of upwelling. Coastal sea level is generally not a major issue along the West Coast, but future sea level rise will be important to juvenile fish in the San Francisco Bay and Delta, as well as in lagoons and estuaries where the annual cycle of bar development and breaching are important to salmonid life history strategies. Perhaps the greatest uncertainty is how ocean acidification will affect salmonids and their marine ecosystem (Schwing 2009). The following is a general discussion of anticipated future changes in ocean conditions, as they may affect off-shore areas used by winter- and spring-run Chinook salmon, and steelhead during their marine life stages.

6.3.1 California Current Ecosystem

The California Current Ecosystem (CCE) is designated by NMFS as one of eight large marine ecosystems within the United States Exclusive Economic Zone. The California Current begins at the northern tip of Vancouver Island, Canada and ends somewhere between Punta Eugenia and the tip of Baja California Mexico (NMFS 2009). The northern end of the current is dominated by strong seasonal variability in winds, temperature, upwelling, plankton production and the spawning times of many fishes, whereas the southern end of the current has much less seasonal variability. For some groups of organisms, the northern end of the CCE is dominated by sub-arctic boreal fauna whereas the southern end is dominated by tropical and sub-tropical species. Faunal boundaries (i.e., regions where rapid changes in species composition are observed) are known for the waters between Cape Blanco Oregon/Cape Mendocino California, and in the vicinity of Point Conception California (**Figure 6-3**). Higher trophic level organisms often take advantage of the strong seasonal cycles of production in the north by migrating to the region during the summer to feed. Climate signals in this region are quite strong. During the past 10 years, the North Pacific has seen two El Niño events (1997/98, 2002/03), one La Niña event (1999), a four-year climate regime shift to a cold phase from 1999 until late 2002, followed by a four-year shift to warm phase from 2002 until 2006. The response of ocean conditions, plankton and fish to these events is well documented in the scientific literature. The biological responses are often so strong that the animals give early warning of events before such shifts are noticed in the physical oceanographic records (Osgood 2008). Numerous climate stressors (e.g., warming, sea level rise, freshwater flow) impact productivity and structure throughout the CCE. It is difficult to isolate the effect of individual stressors on most individual species, and most of these stressors impact many species at multiple trophic levels.

Five climate-related issues are of greatest concern in the CCE (Osgood 2008). The following provides a summary of these issues, based upon the analysis developed as part of NMFS' framework for a long-term plan to address climate impacts on living marine resources (Osgood 2008).

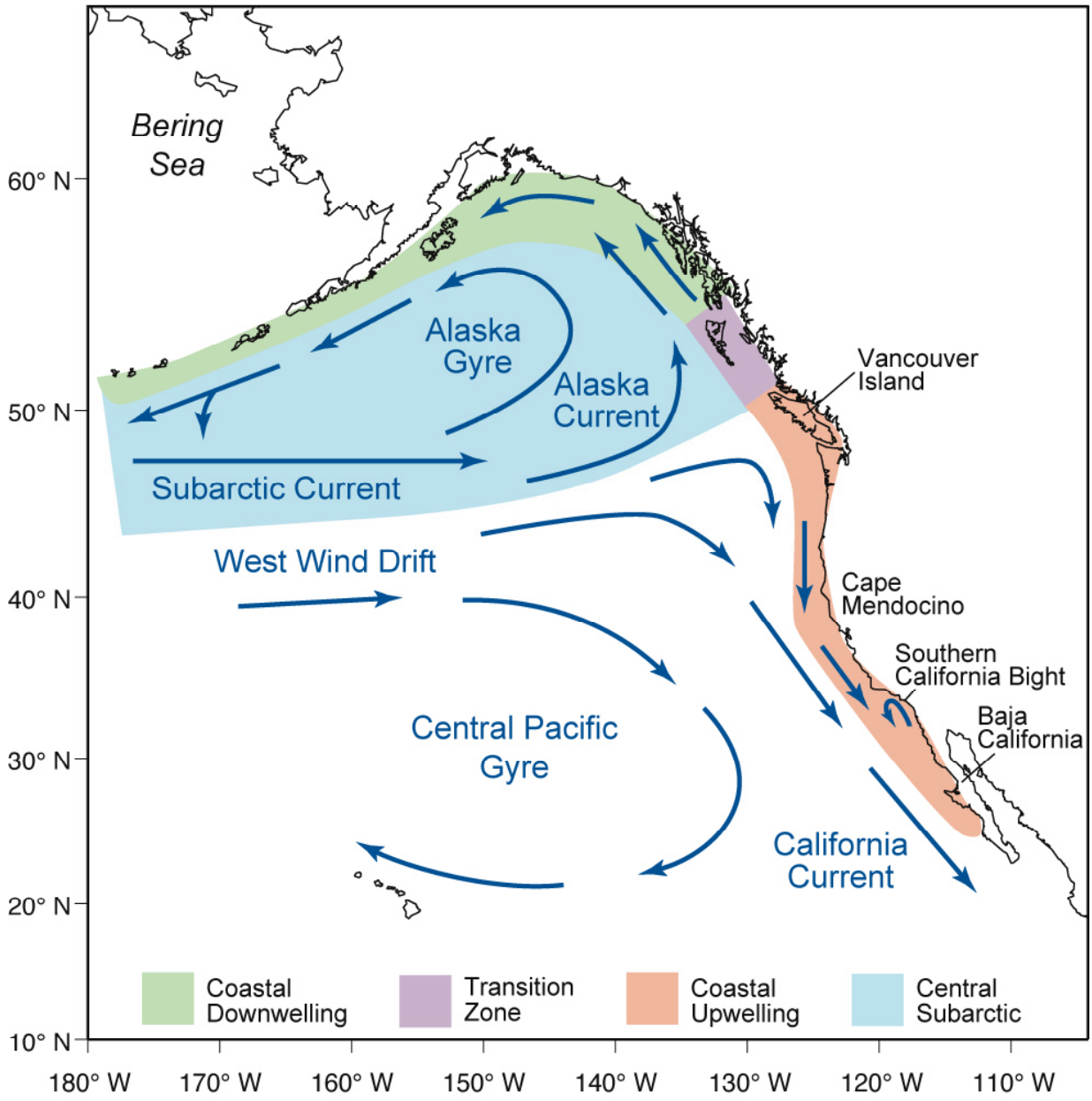


Figure 6- 3. The Principal Ocean Currents Affecting the Coastal Waters off of California. Eastward flow (West Wind Drift) bifurcates as it nears the west coast. The southward arm (the California Current) transports, cool, low salinity, nutrient-rich water along the U.S. west coast. (Source: Image from J.A. Barth, Oregon State University)

INCREASED FUTURE CLIMATE VARIABILITY

One of the likely consequences of global climate change will be a more volatile climate with greater extreme events on the intra-seasonal to inter-annual scales. For the CCE, more frequent and severe winter storms are expected to occur, with greater wind mixing, higher waves and coastal erosion, and more extreme precipitation events and years, which would impact coastal circulation and stratification. Some global climate models predict a higher frequency of El Niño events; others predict that the intensity of these events will be stronger. If true,

primary and secondary production will be greatly reduced in the CCE, with negative effects transmitted up the food chain.

The Pacific Decadal Oscillation is a pattern of Pacific climate variability that shifts phases approximately every 20 to 30 years. During a "warm" or "positive" phase, the west Pacific becomes cool and part of the eastern ocean warms; during a "cool" or "negative" phase, the opposite pattern occurs. Most models project roughly the same timing and frequency of decadal variability in the North Pacific under the impacts of global warming. However, combined with the global warming trend, the CCE is expected to experience a greater frequency of years consistent with historical periods of lower productivity (e.g., positive Pacific Decadal Oscillation values). Based on ongoing observations, a positive Pacific Decadal Oscillation and a warmer ocean result in dominance of small warm-water zooplankton (which are lipid-depleted), which may result in food chains with lower bioenergetic content. By about 2030, it is expected that the minima in decadal regimes will be above the historical mean of the 20th Century (i.e., the greenhouse gas warming trend will be as large as natural variability).

The Extent and Timing of Freshwater Input

While variability in ocean conditions has substantial impacts on salmon survival and growth, future changes in freshwater and river conditions also will have a great effect on production of anadromous fish. Warmer air temperatures will result in more precipitation earlier in the year, and less snowpack. Changes in the seasonal and inter-annual timing and intensity of rainfall and snowpack, for example, are expected to increase winter and spring runoff and decrease summer runoff. These hydrologic changes may alter the way that water supplies from the Sacramento River are managed for hydropower generation and water storage, which may affect the manner in which Chinook salmon, steelhead and other estuarine-dependent species are managed.

Climate models project the 21st Century will feature greater annual precipitation in the Pacific Northwest, extreme winter precipitation events in California, and a more rapid spring snowmelt leading to a shorter, more intense spring period of river flow and freshwater discharge (Thomas *et al*. 2009). These changes are projected to considerably alter coastal stratification and mixing, riverine plume formation and evolution, and the timing of transport of anadromous fish populations to and from the ocean. A warmer and drier future also means that extra care will be needed in planning the allocation of water for the coming decades (Thomas *et al*. 2009). The current allocation of water resources between salmon and human requirements in the western United States has been a critical factor in the success of many salmon populations, and will be more so if future water availability is altered (Osgood 2008).

Changes in the Timing and Strength of the Spring Transition, and Their Resultant Effects on Marine Populations

The primary issue for the CCE is the onset and length of the upwelling season - when upwelling begins and ends (i.e., the "spring" and "fall" transitions). The biological transition date provides an estimate of when seasonal cycles of significant plankton and euphausiid production are initiated. At present, there is some evidence that coastal upwelling has become stronger over the past several decades due to greater contrasts between warming of the land (resulting in lower atmospheric pressure over the

continent), relative to ocean warming. The greater cross-shelf pressure gradient will result in higher along-shore wind speeds and the potential for more upwelling (Bakun 1990). Regional climate models project that not only will upwelling-favorable winds will be stronger in summer, but that the peak in seasonal upwelling will occur later in the summer (Snyder *et al*. 2003).

Even though southward winds that cause coastal upwelling are likely to increase in magnitude, these winds may be less effective in driving vertical transport of nutrient-rich water because it is not known if these winds will be able to over-ride increased water column stratification (Osgood 2008; NMFS 2009). That is, the winds may not be able to mix this light buoyant water or transport it offshore resulting in the inability of the cold nutrient-rich water to be brought to the ocean surface. Thus, phytoplankton blooms may not be as intense, which may impact organisms up the food chain (Roemmich and McGowan 1995).

Given that the future climate will be warmer, the upper ocean at the watershed scale will almost certainly be, on average, more stratified (Osgood 2008). This will make it more difficult for winds and upwelling to mix the upper layers of the coastal ocean, and will make offshore Ekman pumping less effective at bringing nutrients into the photic zone. The result will be lower primary productivity throughout the salmon marine habitat (with the possible exception of the nearshore coastal upwelling zones) (Osgood 2008).

Should global warming result in shorter winters in the Pacific Northwest, areas where production is light limited (e.g., the northern California Current) may see higher productivity (Osgood 2008). During most years since 2002, phytoplankton blooms are initiated as early as February off northern California in years when storm intensity is low. These early blooms result in bursts in egg production by both copepods and euphausiids, initiating a cohort of animals that reach adulthood one to two months earlier than a cohort that is initiated with the onset of upwelling during March or April. The result would be a longer plankton production season. Alternatively, regional climate projections are for a later shift in the start time, peak times and end of the upwelling season, which could counter the idea of a longer upwelling season (Osgood 2008).

Ocean Warming and Increased Stratification, and Their Resultant Effects on Pelagic Habitat

This issue focuses on the central and southern California Current, and on the organisms that utilize the upper ocean habitat in this region. Generally warmer ocean conditions will cause a northward shift in the distribution of most species, and possibly the creation of reproductive populations in new regions. Existing faunal boundaries are likely to remain as strong boundaries, but their resiliency to shifts in ocean conditions due to global climate change is not known (Osgood 2008). Warmer water temperatures also will affect freshwater salmon and steelhead habitats by reducing habitat opportunity on both spatial and seasonal time scales. In coastal and oceanic regions, the southern boundaries of pelagic habitats used by many populations are expected to shift northward.

Warmer air temperatures may lead to increased stratification of the coastal CCE. The warmer temperatures will increase the heat flux into the ocean. Mixing and diffusion are not likely to redistribute this heat rapidly enough to prevent an increase in thermal stability and stratification of the upper ocean (Osgood 2008). The vertical gradient in ocean water temperature off of the California coast

has intensified over the past several decades (Palacios *et al*. 2004). Areas with enhanced riverine input into the coastal ocean will also see greater vertical stratification. Moreover, increased melting of glaciers in the Gulf of Alaska coupled with warmer sea surface temperatures will result in increased stratification. Because some of the source waters that supply the northern California Current originate in the Gulf of Alaska, more stratified source waters will contribute to increased stratification of coastal waters of the northern California Current (Osgood 2008).

Changes to Ocean Circulation and Their Resultant Effects on Species Distribution and Community Structure

NMFS (2008) states that this is a climate-induced ecosystem concern primarily for the northern California Current, although changes in transport are known to have subtle effects on the entire Current. A particular biological concern is related to the variability in the transport of organisms, which impacts zooplankton species composition and regional recruitment patterns for demersal fish stocks.

As previously discussed, the California Current extends from the northern tip of Vancouver Island, Canada to southern Baja California, Mexico. As the current flows from north to south, the waters warm and mix with offshore waters such that both temperature and salinity increase gradually in a southward direction (Osgood 2008). Observations of the biota of the California Current show that there are pronounced latitudinal differences in the species composition of plankton, fish, and benthic communities, ranging from cold water boreal sub-arctic species in the north to warm water subtropical species in the south. Changes in abundance and species composition can be gradual in some cases, but it is widely accepted that faunal boundaries (zones of rapid change in species composition) are present in the waters in the vicinity of Capes Blanco and Mendocino, and at Point Conception. The strongest contrasts are observed during summer (Osgood 2008).

The strong contrast in species composition between shelf and offshore waters during summer is due to the upwelling process. A combination of upwelling itself, along with the sub-arctic water which feeds the inshore arm of the northern end of the CCE, create conditions favorable for development of a huge biomass of sub-arctic zooplankton. This pattern is slightly modified as a function of the phase of the Pacific Decadal Oscillation. During a cool phase, all of the northern CCE becomes more sub-Arctic in character (both shelf-slope-oceanic regions); during a warm phase of the Pacific Decadal Oscillation, the water masses and associated copepod community become far more similar to a sub-tropical community. Copepod biodiversity increases in coastal waters, due to shoreward movement of offshore waters onto the continental shelf, due to either weakening of southward wind stress in summer or strengthening of northward wind stress in winter. Thus, when Pacific Decadal Oscillation is in a positive phase, a greater proportion of the water entering the northern end of the current is sub-tropical in character rather than sub-Arctic.

Regardless of the season, the source waters that feed into the California Current from the north and from offshore can exert some control over the phytoplankton and zooplankton species that dominate the current (**Figure 6-4**).

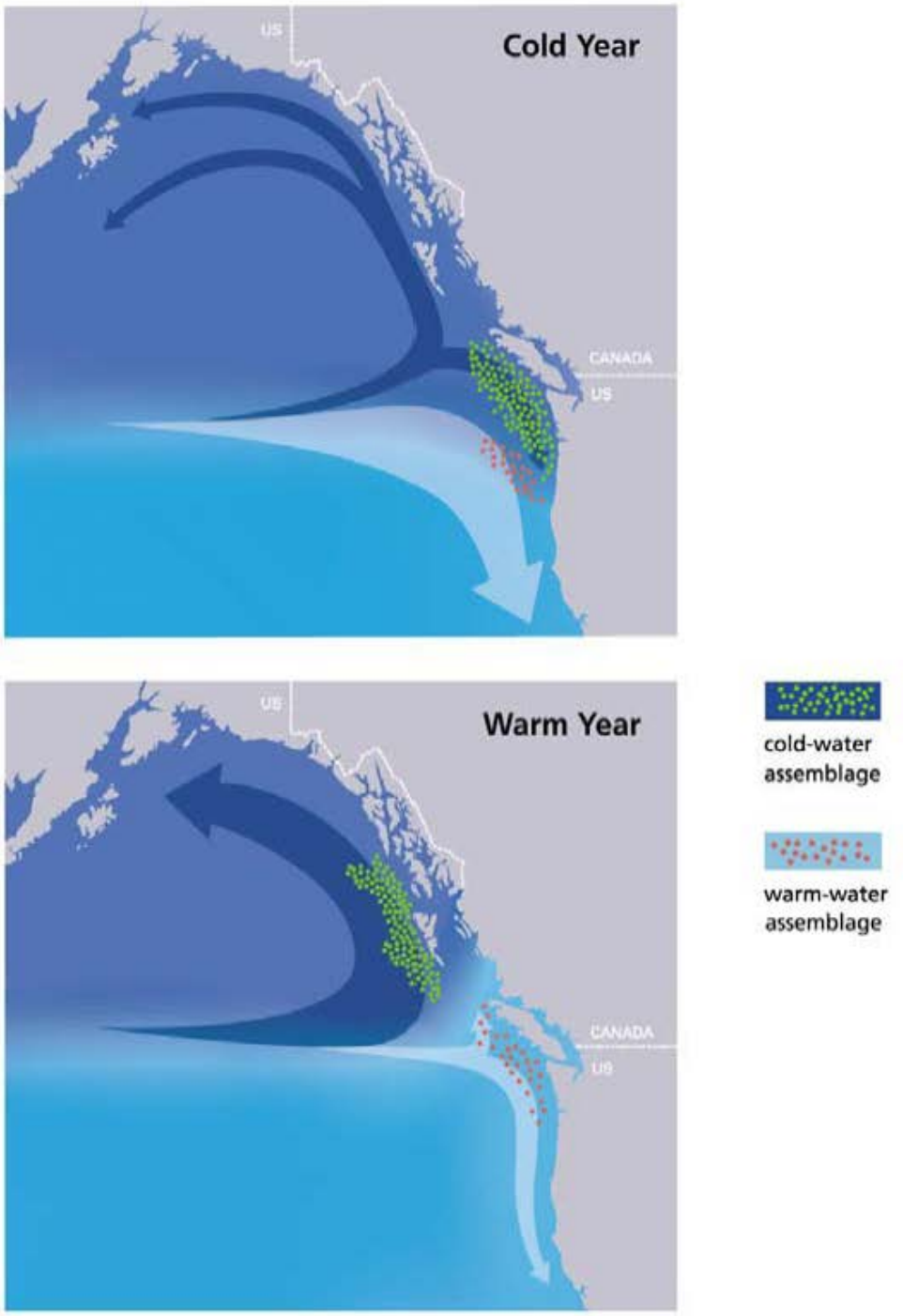


Figure 6-4. Schematic of the Flow of the North Pacific Current South into the California Current and North into the Gulf of Alaska. Cool years (such as La Niña and negative PDO years) are associated with greater flow into the California Current, which favors a southward displacement of coldwater and warmwater species. ***(Source: Osgood 2008)***

Hooff and Peterson (2006) suggest that knowledge of source waters is critical to understanding ecosystem dynamics in the shelf waters of the Northern CCE because waters from the Gulf of Alaska carry large, lipid-rich copepods to the shelf waters, whereas waters coming from an offshore source carry small, oceanic lipid-poor copepods to the shelf waters. Thus, changes reflected by Pacific Decadal Oscillation shifts may result in local food chains that have considerably different bioenergetic content. Given, for example, that: (a) salmon returns are low when the Pacific Decadal Oscillation is in a positive, warm water phase, but high when the Pacific Decadal Oscillation is in a negative, cold-water phase; and (b) salmon returns to Pacific Northwest rivers are highly correlated with copepod community structure (Peterson and Schwing 2003), variations in the bioenergetic content of the food web may represent a mechanistic link between Pacific Decadal Oscillation sign change and salmon survival (Osgood 2008). This mechanistic link may also apply to Chinook salmon originating from the Central Valley because some of the source waters that supply the Gulf of the Farallones, where Central Valley salmon first enter the ocean, originate in the Gulf of Alaska and Central Valley Chinook salmon abundance was found to be correlated with prey availability in the Gulf of the Farallones (Wells *et al*. 2012).

Northward shifts in distribution also are possible. Generally warmer conditions could result in a northward shift in the distribution of some species, and possibly the creation of reproductive populations in new regions. Alternatively, if upwelling strengthens due to global climate change, regardless of the sign of the Pacific Decadal Oscillation, cold-water species should still be favored in the coastal upwelling zones (Osgood 2008). However, the onshore-offshore gradients in temperature and species abundance should strengthen if offshore waters become warmer and upwelling becomes stronger, creating stronger upwelling fronts, and perhaps a greater level of mesoscale activity. It is unclear how faunal boundaries might be affected (Osgood 2008).

6.4 Climate Change Effects on Salmon and Steelhead in the Central Valley

In California, there have been observed changes in air temperatures, annual precipitation, runoff, and sea levels over the past century (Anderson *et al*. 2008). Regional-scale climate models for California are in broad agreement that temperatures in the future will warm significantly, total precipitation may decline, and snowfall will decline significantly (Lindley *et al*. 2007). Literature suggests that by 2100, mean summer temperatures in the Central Valley may increase by 2 to 8°C, precipitation will likely shift to more rain and less snow, with significant declines in total precipitation possible, and hydrographs will likely change, especially in the southern Sierra Nevada mountains. Thus, climate change poses an additional risk to the survival of salmonids in the Central Valley. As with their ocean phase, Chinook salmon and steelhead will be more thermally stressed by stream warming at the southern ends of their ranges (e.g., Central Valley Domain). For example, warming at the lower end of the predicted range (about 2°C) may allow spring-run Chinook salmon to persist in some streams, while making some currently utilized habitat inhospitable (Lindley *et al*. 2007). At the upper end of the range of predicted warming, very little spring-run Chinook salmon habitat is expected to remain suitable (Lindley *et al*. 2007).

The complex life history of salmonids as well as the complexity of their multiple aquatic habitats makes it difficult to isolate what environmental factors, or drivers, are responsible for variability in these populations

(Schwing 2009). Overall, the climate-species linkages for salmon are extremely complex. In a recent report to the Pacific Fishery Management Council, CDFW identified 46 possible reasons for the collapse of the 2004 and 2005 broods of Central Valley fall-run Chinook salmon. It is difficult to isolate the immediate effect of an individual stressor on a species, and most stressors impact many species at multiple trophic levels. Further, it is not likely that there is one single stressor, but a combination of several factors that drive ecosystem variability and change (Schwing 2009). Nevertheless, it is possible to focus on a relatively small number of factors that are sufficiently sensitive to climate change and impact the populations and freshwater and marine ecosystems of California anadromous salmonids.

This Recovery Plan addresses the California Central Valley steelhead DPS, and two Chinook salmon ESUs - Sacramento River winter-run Chinook salmon, and Central Valley spring-run Chinook salmon. Because of their extended use of the Sacramento and San Joaquin River systems, they are very dependent on runoff from the Sierra snowpack and the variability of precipitation affecting it (Osgood 2008), as previously discussed. The future climate of the freshwater habitats of the Central Valley Domain is expected to include:

- More frequent intense winter storms, high stream flow events, and floods
- Earlier snowmelt, with higher peak flows in winter, less spring runoff, and much lower summer flows
- Considerably warmer stream, river and ocean water temperatures during the summer
- Greater inter-annual precipitation variability, more frequent wet and drought years, and extended droughts
- Years with weaker fall storms, and delays in the onset of high stream flows
- More frequent wildfires and infestations, and increased erosion and sedimentation

The impacts of climate change on winter-run and spring-run Chinook salmon will differ due to differences in their life history. Winter-run Chinook salmon adults return and migrate upstream in winter through early spring, where they hold for several months before spawning in late spring and summer (Williams 2006). This spawning timing and subsequent fry emergence allows winter-run Chinook salmon juveniles to rear and move downstream during the cooler fall, winter, and spring months (Yoshiyama *et al*. 1998). That is, the juveniles can rear in freshwater for several months, without being exposed to stressful summer water temperatures. However, incubation, the most temperature-sensitive life stage, coincides with the time when river temperatures can exceed the lethal range for embryo incubation. Thus, winter-run Chinook salmon occur currently only in the Sacramento River, where summer water temperatures are cool enough to enable successful embryo incubation, but warm enough in winter to support juvenile rearing (Stillwater 2006 in Schwing 2009). They also spawn in deeper water than other populations (Moyle 2002). Juvenile winter-run Chinook salmon have historically exploited the floodplain habitat created by winter flooding in the Sacramento River Basin, which results in higher juvenile growth rates and presumably higher ocean survival (Sommer *et al*. 2001 in Schwing 2009).

The life history of spring-run Chinook salmon is to migrate upstream in spring, hold through the summer in deep pools, and then spawn in early fall, with juveniles emigrating after either a few months or a year in freshwater. However, they have considerable flexibility in their life history strategies. Age at spawning for spring-run Chinook salmon varies from two to four years.

Central Valley watersheds are fed predominantly by runoff from Sierra snowmelt, which has been historically highest during the late spring and early summer. The resulting high flow allows Chinook salmon to reach their summer holding areas, while the lower flow extending from the summer into early fall is cool enough for spawning. In the San Joaquin River drainage, snowmelt at high elevations produced a long runoff period that benefited spring-run Chinook salmon, making them the dominant run in the region. However, the recent trend toward an earlier seasonal runoff and lower flow in spring and summer has reduced the potential for survival in these watersheds, and will make the transit of adults returning to their spawning streams more difficult (see watershed profile information for individual rivers located in the Southern Sierra Nevada Diversity Group).

Because eggs and juveniles are less tolerant of warm water temperatures, spawning occurs during the fall, after streams cool. On their migration to the ocean, juvenile fish access temporary habitats with warmer water temperatures and abundant food in floodplain, tidal marsh, and estuarine habitats. These habitats are very important in smolt growth and survival - smolt size at ocean entry strongly affects survival during the first year at sea (Williams 2006). After reaching the ocean in the late spring and summer, smolts forage near the coast on crustaceans, euphausids, and prey fishes (MacFarlane and Norton 2002) that are associated with upwelling. Smolt survival over their first winter is dependent on a threshold of prey and the resultant smolt condition after the first summer at sea (Williams 2006).

Because of their close proximity, a relatively small wildfire could simultaneously burn the headwaters of all three remaining spring-run Chinook populations. Such a fire has a 10 percent chance of occurring in any given year in California (Lindley *et al*. 2007), but this probability will increase due to climate change. Prolonged drought due to lower precipitation shifts in snowmelt runoff, and greater climate extremes could also easily render most existing spring-run Chinook salmon habitat unusable, either through temperature increases or lack of adequate flows.

Increased water temperature, low flow, drought and other climate-related events will compound the threats to Chinook salmon due to human manipulation of their freshwater habitats. Because of these watersheds' great dependence on Sierra snowpack melt, the projected shift toward earlier runoff (Dettinger and Cayan 1995; Cayan *et al*. 2001) will exacerbate sensitivity to low flow and warm stream conditions at critical life stages. Winter-run Chinook salmon are especially vulnerable to climate warming, prolonged drought, and other catastrophic climate events, because they have only one remaining population that spawns in the hottest time of the year (also see the conceptual recovery scenario for winter-run Chinook salmon). Additionally, future ocean productivity will decline due to altered upwelling cycles, thus reducing prey availability and salmon ocean survival (NMFS 1997 in Schwing 2009).

Central Valley steelhead also exhibit a flexible life history, allowing them to compensate for the variable conditions and extremes of their habitat (McEwan 2001). Most juveniles

remain in streams for one or two years before becoming smolts and emigrating out to the Delta and ocean (Hallock 1961 in Schwing 2009). Others may remain in the rivers their entire lives. Temperature and water quality are critical factors for fry and juvenile survival (Moyle 2002). Fry move into cooler, deeper, faster-flowing channels in the late summer and fall (Hartman 1965, Everest and Chapman 1972, and Fontaine 1988 in Schwing 2009). Juvenile steelhead prefer deep pools with heavy cover, as well as higher-velocity rapids (Bisson *et al*. 1982, 1988 and Dambacher 1991 in Schwing 2009).

The distribution of steelhead today is greatly reduced from the historical distribution. Dams and water diversions limit steelhead access to less than 20 percent of their historical spawning and rearing areas in the Central Valley (Yoshiyama *et al*. 2001; Lindley *et al*. 2006). Climate warming will further restrict access to cool water streams. Most of the same climate factors that affect other California steelhead populations are critical to Chinook salmon. The diversity and variability of their life history complicates their management. Yet this same attribute reduces their vulnerability to climate change.

Additionally, low flows during juvenile rearing and outmigration are associated with poor survival through the Delta (Kjelson and Brandes 1989; Baker and Morhardt 2001; and Newman and Rice 2002) and poor returns in subsequent years (Speed 1993). Climate change also may impact Central Valley salmonids through community effects. For example, warming may increase the activity and metabolic demand of predators, reducing the survival of juvenile salmonids (Vigg and Burley 1991).

6.5 Concepts for Buffering Climate Change Effects and Application in this Recovery Plan

The general concepts of resiliency and refugia discussed below have been used in the strategy (Chapter 3) of this recovery plan to identify a distribution of habitat in the Central Valley and habitat types that are most likely to allow winter-run Chinook salmon, spring-run Chinook salmon, and steelhead to withstand the effects of climate change. This distribution of habitat is reflected in the ESU/DPS level recovery criteria relating to population spatial structure. The types of habitats that these species will need in the face of climate change have been factored into the watershed prioritizations identified in the recovery strategy.

6.5.1 Resiliency

In ecology, resiliency carries the additional meaning of how much disturbance a system can "absorb" without crossing a threshold and entering an entirely different state of equilibrium (e.g., distinctly different physical habitat structure or conditions) (Bakke 2009). In regard to recovery, habitat restoration, and conservation of at-risk aquatic species, resiliency also requires that certain key habitat characteristics or processes will change little, or not at all, in response to climate change. When it comes to stream aquatic habitat, the most important elements to remain steady are temperature and disturbance regime (Bakke 2009). Resiliency is temporally dependent and given enough time, large disturbances are virtually certain to occur on the landscape and to the climate. Resiliency can only function on a landscape scale; there must be enough individual rivers available with the appropriate habitat and connectivity so that a disturbance to one portion of the system has a minimal impact on at-risk aquatic species because

other parts of the system are able to support sensitive populations through the recovery and recolonization period (Bakke 2009).

In the long-term, there is no substitute for a landscape that offers redundancy of habitat opportunities. This recovery plan incorporates the resiliency concept by using the Central Valley diversity groups as recovery units (see Section 3.2.1) and generally calling for multiple viable populations within each of the units. Having an ESU or DPS spatial structure with each diversity group represented and population redundancy within each diversity group follows the historic population structure, which allowed the species to withstand extreme climactic events and persist for thousands of years. Because the biological recovery criteria for each of the three species covered in this plan (Section 4.3.4) are based on the species' historic spatial structure, it is assumed that an ESU/DPS that meets those criteria should be resilient to disturbances caused by climate change.

6.5.2 Refugia

Refugia are places in the landscape where organisms can go to escape extreme conditions (Bakke 2009). Typically, this refers to short-term conditions such as floods or high water temperatures. But in the context of climate change, refugia can also be places where a population may persist through decades and centuries of unfavorable climate conditions and instability. For coldwater obligate fish species, refugia will continue to be areas where groundwater emergence influences water temperature and volume. These refugia will exist on multiple scales: (1) local areas of cold water emergence within a reach otherwise insufficiently cold; (2) lower sections of rivers downstream of reservoirs with large amounts of coldwater storage; and (3) entire stream systems where groundwater hydrology is dominant or snowmelt hydrology is preserved due to high elevations. Thus, the same set of circumstances producing cold water conditions in the current landscape may, to varying degrees, produce thermal refugia against global warming.

The coldwater refugia concept has been applied in this recovery plan as a factor in the prioritization of watersheds. For example, Battle Creek, Mill Creek, and Deer Creek each were identified as core 1 watersheds for spring-run Chinook salmon, in part, because fish in those watersheds should be able to withstand warming air temperatures either by coldwater spring inputs (Battle Creek) or having access to holding and spawning habitat at relatively high elevation (Mill Creek and Deer Creek). As another example of how the refugia concept was applied in this recovery plan, the Sacramento River downstream of Shasta Dam was identified as a core 1 area for winter-run Chinook salmon, in part, because, in wetter year types, suitable water temperatures for spawning and incubation are provided during the summer via coldwater releases from the dam. Even with the projected effects of climate change, it is likely that suitable temperatures for winter-run Chinook salmon will be available downstream of Shasta Dam during wetter years. However, considering the expected increase in the frequency of dry years, which often result in mortality during egg incubation, it will be increasingly difficult to maintain the species without access to coldwater in the summer on a more consistent annual basis. As such, the McCloud River watershed, which receives coldwater from high elevation snowmelt and from springs, has been identified as a primary area for reintroduction. Reintroducing salmon and steelhead to historic high elevation habitats is a key part of the recovery strategy (see Section 3.3.2) because coldwater refugia will be needed to allow the species to withstand climate change.

7.0 Implementation

"Although recovery actions can, and should, start immediately upon listing a species as endangered or threatened under the ESA, prompt development and implementation of a recovery plan will ensure that recovery efforts target limited resources effectively and efficiently into the future."

NMFS 2010b. Interim Endangered and Threatened Species Guidance

7.1 Costs and Benefits of Salmon and Steelhead Recovery

Implementing the recovery actions in this recovery plan will be expensive, with a rough estimate ranging from $17 to $37 billion[29]. This investment in recovery of salmon and steelhead will result in economic, societal and ecosystem benefits. Monetary investments in watershed restoration projects can promote the economy in a myriad of ways. These include stimulating the economy directly through the employment of workers, contractors and consultants, and the expenditure of wages and restoration dollars for the purchase of goods and services. Habitat restoration projects have been found to stimulate job creation at a level comparable to traditional infrastructure investments such as mass transit, roads, or water projects (Oregon Watershed Enhancement Board 2010). In addition, viable salmonid populations provide ongoing direct and indirect economic benefits as a resource for fish, recreation, and tourist related activities. Dollars spent on salmon and steelhead recovery will promote local, State, Federal and tribal economies, and should be viewed as an investment with both societal (clean rivers, healthy ecosystems) and economic returns.

[29] Estimate derived by summing the costs of all recovery actions presented in Chapter 5.

The largest direct economic returns resulting from recovered salmon and steelhead are associated with sport and commercial fishing. On average 1.6 million anglers fish the Pacific region annually (Oregon, Washington and California) and 6 million fishing trips were taken annually between 2004 and 2006 (NMFS 2010a). Most of these trips were taken in California and most of the anglers lived in California. The California salmon fishery is estimated to generate $118 to $279 million in income annually, and provide roughly two to three thousand jobs (Michael 2010). With a revived sport and commercial fishery, an increase in economic gains and the creation of jobs would be realized across California, but most notably for river communities and rural coastal counties.

Many of the actions identified in this Recovery Plan are designed to improve watershed-wide processes which will benefit many native species of plants and animals (including other state and federally listed species) by restoring natural ecosystem functions. In addition, restoration of habitat in watersheds will provide substantial benefits for human communities. Some of these benefits are: improving and protecting the quality of important surface and ground water supplies; reducing damage from flooding resulting from floodplain development; and controlling invasive exotic animal and plant species which can threaten water supplies and

increase flooding risk. Restoring and maintaining healthy watersheds also enhances important human uses of aquatic habitats, including outdoor recreation, ecological education, field based research, aesthetic benefits, and the preservation of tribal and cultural heritage.

The final category of benefits accruing to recovered salmon and steelhead populations are even more difficult to quantify and are related to the ongoing costs associated with maintaining populations that are at risk of extinction. Significant funding is spent annually by entities (Federal, State, local, private) in order to comply with the regulatory obligations that accompany populations that are listed under the ESA.

Important activities, such as water management for agriculture and urban use, are now constrained to protect ESA listed populations of salmon and steelhead. Recovering the salmonid populations so the protections of the ESA are no longer necessary will also result in elimination of the regulatory requirements imposed by the ESA, and allow greater flexibility for land and water managers to optimize their activities and reduce costs related to ESA protections. Salmon recovery is best viewed as an opportunity to diversify and strengthen the economy while enhancing the quality of life for present and future generations.

7.2 Integrating Recovery Implementation into NMFS Actions

It is a challenging undertaking to facilitate a change in practice and policy that reverses the path towards extinction of a species to one of recovery. This change can only be accomplished with effective outreach and education, strong partnerships, focused recovery strategies and solution-oriented thinking that can shift agency and societal attitudes, practices and understanding.

Implementation of the recovery plan by NMFS will take many forms and is generally and specifically described in the NMFS Protected Resources Division Strategic Plan 2006 (NMFS 2006). The Recovery Planning Guidance (NMFS 2010b) also outlines how NMFS will cooperate with other agencies regarding plan implementation. These documents, in addition to the ESA, will be used by NMFS to set the framework and environment for plan implementation. The PRD Strategic Plan asserts that species conservation (in implementing recovery plans) by NMFS will be more strategic and proactive, rather than reactive. To maximize existing resources with workload issues and limited budgets, the PRD Strategic Plan champions organizational changes and shifts in workload priorities to focus efforts towards "…t*hose activities or areas that have biologically significant beneficial or adverse impacts on species and ecosystem recovery*" (NMFS 2006).

NMFS actions to promote and implement recovery planning include:

- Formalizing recovery planning goals on a program-wide basis to prioritize work load allocation and decision-making (to include developing the mechanisms to make implementation (*e.g.,* restoration) possible).
- Conducting outreach and education.
- Facilitating a consistent framework for research, monitoring, and adaptive management that can directly inform recovery objectives and goals.
- Establishing an implementation tracking system that is adaptive and pertinent to support the annual reporting for the Government Performance and Results Act, Bi-Annual Recovery Reports to

Congress and the 5-Year Status Reviews.

To achieve recovery, NMFS will need to promote the recovery plan and provide needed technical information and assistance to other entities that implement actions that may impact the species' recovery. For example, NMFS intends to work with key partners on high priorities such as facilitating fish passage assessments and ensuring protective measures consistent with recovery objectives are included in County General Plans.

While recovery plans are guidance documents not regulatory documents, the intent is that they are used to prioritize and target necessary actions for the survival and recovery of the species. The Recovery Planning Guidance (NMFS 2010b) specifically outlines NMFS' obligations:

> "...the ESA clearly envisions recovery plans as the central organizing tool for guiding each species' recovery process. They should also guide Federal agencies in fulfilling their obligations under section 7(a)(1) of the ESA… and provide context and a framework for implementing other provisions of the ESA with respect to a particular species, such as section 7(a)(2) consultations on Federal agency activities, development of Habitat Conservation Plans or Safe Harbor agreements under section 10, special rules for threatened species under section 4(d), or the creation of experimental populations in accordance with section 10(j)."

As further discussed below, this recovery plan is intended to inform decisions made pursuant to or concerning critical habitat designation under section 4, land acquisition under section 5, take prohibitions through sections 4(d) and 9, cooperation with state(s) under section 6, needed research under section 10, and fishery management actions taken and Essential Fish Habitat (EFH) consultations conducted under the provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

The approaches NMFS intends to use when implementing various sections of the ESA are discussed in detail and are summarized in **Table 7-1**. These approaches are intended to formalize the recovery plans in the daily efforts and decision-making at NMFS in the Southwest Region. Of necessity, some of these methods address the urgent issues of staffing and workload that NMFS faces. As a result, our commitment to implementing recovery plans extends to the ways in which we prioritize the many requests for consultations and permits we receive.

7.2.1 Working with Constituents and Stakeholders

NMFS commits to using recovery plans as a guiding mechanism for its daily endeavors. Successful implementation of this recovery plan will require the support, efforts and resources of many entities, from Federal and State agencies to individual members of the public. NMFS commits to working cooperatively with other individuals and agencies to implement recovery actions and to encourage other Federal agencies to implement actions where they have responsibility or authority.

7.2.2 ESA Section 4

Section 4 provides the mechanisms to list new species as threatened or endangered, designate critical habitat, develop protective regulations for threatened species, and develop recovery plans. Critical habitat designations may be revised as needed to reflect recovery strategies.

Sacramento River winter-run Chinook salmon critical habitat was designated on June 16, 1993, and includes the Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta;

all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Estuary to the Golden Gate Bridge north of the San Francisco/Oakland Bay Bridge (58 FR 33212). CV spring-run Chinook salmon and CV steelhead critical habitat was designated on September 2, 2005, and includes stream reaches such as those of the Feather and Yuba rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks, the Sacramento River, as well as portions of the northern Delta (70 FR 52488).

NMFS will reevaluate the designations in light of the data and criteria developed for this plan, and may propose the designation of additional habitat. The key recovery areas, special management considerations and recovery priorities identified in this recovery plan will inform future critical habitat designations. Certain unoccupied historic habitats that may be essential for recovery, and that are recommended for future critical habitat consideration include:

Sacramento River winter-run Chinook salmon

- Little Sacramento River
- McCloud River
- Battle Creek
- Non-natal rearing tributaries to the Sacramento River

Although these areas may provide sites and habitat components that are consistent with the physical and biological features that are essential for the conservation of Sacramento River winter-run Chinook salmon described in the final rule designating critical habitat for that ESU (58 FR 332112, 33216-17; June 16, 1993), a more detailed evaluation of habitat conditions will need to be undertaken when re-considering whether a system should be proposed for critical habitat. In the Little Sacramento and McCloud rivers and Battle Creek, these sites and habitat components include freshwater rearing, migration and spawning habitats. Although these habitats are currently blocked by dams, the many miles of relatively unimpaired cold water habitats and the fact that they historically supported winter-run Chinook salmon may make these areas highly valuable to the recovery of the species. Non-natal rearing tributaries to the Sacramento River include freshwater rearing habitat. Some non-natal rearing areas potentially have a high value because they provide critical and improved growing conditions, particularly during high winter flow events on the Sacramento River.

CV spring-run Chinook salmon and CV steelhead

- Little Sacramento River
- McCloud River
- North Fork Feather River
- North, Middle and South Yuba River
- Upper American River
- Mokelumne River
- North Fork Stanislaus River
- Tuolumne River
- Merced River
- San Joaquin River (CV spring-run Chinook salmon only)

This list represents the unoccupied historic habitat identified in the Conceptual Recovery Footprint maps presented in Chapter 3 (Figures 3-5 and 3-6). Although these areas may provide sites and habitat components consistent with the primary constituent elements (PCEs) essential for the conservation of CV spring-run Chinook salmon and CV steelhead that are included in the critical habitat designated for this ESU and DPS (50 C.F.R. § 226.211(c)), a more detailed evaluation of habitat conditions will need to

be undertaken when re-considering whether a system should be proposed for critical habitat.[30]

Section 4(d) of the ESA directs the Secretary of Commerce (who has delegated such authority to NMFS) to issue regulations as deemed necessary and advisable to conserve species listed as threatened. ESA section 9 prohibits any take of species listed as endangered. Pursuant to regulations issued under section 4(d) of the ESA (commonly referred to as 4(d) rules), NMFS may also prohibit the take of threatened species. Section 4(d) of the ESA gives NMFS the discretion to customize prohibitions and regulate activities to provide for the conservation of threatened species when applying the take prohibitions that apply to endangered species under ESA section 9. A 4(d) rule is currently in place for Central Valley spring-run Chinook salmon and CV steelhead at 50 C.F.R. § 223.203. That 4(d) rule applies the endangered species prohibitions of section 9(a)(1) to threatened Central Valley spring-run Chinook salmon and CV steelhead, subject to certain limitations. Those limitations include limits on take prohibitions found in 50 C.F.R. § 223.203 (b).

Based on our review of the special management considerations necessary to implement recovery actions for spring-run Chinook salmon and steelhead, development of additional 4(d) limits on the take prohibitions for the following activities are recommended for consideration:

- Fish passage facilities that are consistent with NMFS fish passage criteria
- Levee construction or maintenance activities that meet the following requirements, provided they are applicable to the levee activity being considered:
  - Part of a comprehensive flood management program that has been approved by NMFS and includes a detailed conservation strategy for implementing recovery actions for floodplain and riparian habitat restoration
  - Levee relocations that create frequently activated floodplain areas (Williams *et al*. 2009), and minimize the potential for the stranding of juvenile fish
  - Slurry wall construction within urban river corridors
  - In-river repair and maintenance actions within urban flood corridors that meet NMFS design and maintenance criteria for urban levees
- Spawning gravel augmentation projects below dams
- Adult and juvenile fish collection and relocation actions that are part of a NMFS-approved fish reintroduction program

The above recommendations are made because the activities could provide for the conservation of threatened species, potentially without involving the additional time and cost involved with methods of ESA compliance that are currently available for these activities.

[30] As described in the Recovery Strategy (Chapter 3), it is important to note that it is not necessary to re-establish populations in all of these watersheds to meet the recovery criteria for CV spring-run Chinook salmon or CV steelhead. In fact, successful reintroductions into just a few areas will allow the recovery criteria to be met.

7.2.3 ESA Section 5

Section 5 of the ESA provides that the Secretary of the Interior and the Secretary of Agriculture, with respect to the National Forest System, shall establish and implement a program to conserve fish, wildlife, and plants, including listed endangered and threatened species. To carry out this program, the appropriate Secretary shall use certain land acquisition and other authority, and is given additional authority related to land and water acquisition. Multiple National Forests lands are present within the Central Valley domain.

7.2.4 ESA Section 6

Section 6 of the ESA describes protocols for consultation and agreements between NMFS and the states for the purpose of conserving threatened or endangered species. The current agreement under section 6 of the ESA between NMFS and California covers abalone and green sturgeon. NMFS will explore options with CDFW for including winter-run Chinook salmon, spring-run Chinook salmon, and steelhead in the existing or a new agreement under section 6 of the ESA.

Table 7-1. Summary of approaches NMFS intends to use when implementing various sections of the ESA and MSFCMA.

Authority	Description	Implementation Actions
ESA Section 7	Section 7(a)(1) Interagency Cooperation (Use of authorities)	Use threats assessments and recovery actions to guide Federal partners to further the conservation of listed Central Valley salmon and steelhead.
ESA Section 7	Section 7(a)(2) Interagency Cooperation (Consultation)	Continue to use the viable salmonid population concept described in this Recovery Plan to help determine effects of proposed actions on the likelihood of species' survival and recovery.
	Note: Permits issued under section 10(a)(1) of the ESA also undergo section 7 consultation prior to issuance.	Use threats assessments and recovery strategy as a guide to prioritizing consultations when making workload decisions.
		Place high priority on consultations for actions that implement recovery strategy or specific actions.
		Streamline consultations for those actions with little or no effect on recovery areas or priorities.
ESA Section 9	Section 9 Enforcement	Prioritize those actions and areas deemed of greatest threat or importance for focused efforts to halt illegal take of listed species.
ESA Section 10	Section 10(a)(1)(B) Incidental Take Permits	Prioritize permit applications that address identified research and monitoring needs in the recovery plan.
		Prioritize cooperation and assistance to landowners proposing activities or programs designed to achieve recovery objectives.
Magnuson-Stevens Fishery Conservatio	Fishery Management	Implement fishery regulations to maintain salmon harvest levels at or below those necessary to allow for the recovery of listed salmon and steelhead.

Authority	Description	Implementation Actions
n and Mana geme nt Act		Implement fishery regulations to reduce bycatch of salmon in federally-managed fisheries.

7.2.5 ESA Section 7

Section 7(a)(1) provides that all Federal agencies shall "…in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species…." "Conservation" is defined in the ESA as "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to [the ESA] are no longer necessary." 16 U.S.C. § 1532(3). . Therefore, a key theme is *recovery*. To encourage Federal agencies to fulfill their section 7(a)(1) requirement to carry out conservation programs for listed Central Valley salmon and steelhead, NMFS will:

1. Encourage development of a West Coast Region California Central Valley Area Office or Regional Memorandum of Understanding (MOU) similar to a 1994 MOU [Daily Env't Rep. (BNA) No. 188, at E-1] between Agencies (which expired in 1999), establishing a framework for cooperation and participation to further the purposes of the ESA that specifically outlines a process for coordinating and implementing appropriate recovery actions identified in recovery plans.
2. Prepare, and send after recovery plan approval, a letter to all other appropriate Federal agencies outlining section 7(a)(1) obligations and meet with these agencies to discuss listed salmonid conservation and recovery priorities.
3. Encourage use of conservation bank credits when appropriate to contribute toward recovery of listed anadromous salmonids in the Central Valley.
4. In addition to minimization of incidental take or effects to habitat, encourage meaningful and focused mitigation, in alignment with recovery goals for restoration and threat abatement, for actions that incidentally take listed Central Valley salmon and steelhead or affect their habitat.
5. Encourage Federal partners to include recovery actions in project proposals.
6. Conduct outreach to Federal partners, and provide an outline of 7(a)(1) obligations.

Under section 7(a)(2), Federal agencies must consult with NMFS (and/or USFWS) when they determine an action may affect a listed species or its critical habitat. NMFS then conducts an analysis of potential effects of the action. In the process of consultation, NMFS currently expends considerable effort to assist agencies in avoiding and minimizing the potential effects of proposed actions to ensure agency actions do not

jeopardize a species or destroy or degrade habitat. Consultations have helped prevent and minimize take.

To improve the section 7(a)(2) consultation process, NMFS will utilize its authorities to:

- Continue to use the viable salmonid population concept described in this Recovery Plan to help determine effects of proposed actions on the likelihood of species' survival and recovery.
- Place high priority on consultations for actions that implement recovery strategy or specific actions.
- Develop and maintain databases to track the amount of incidental take authorized and effectiveness of conservation and mitigation measures.
- Provide recommended actions in the recovery plan as section 7(a)(1) conservation recommendations as applicable.
- While still fulfilling all relevant statutory and regulatory requirements, focus staff priorities, to the extent possible, away from section 7 compliance in watersheds not designated as a priority for recovery and direct efforts to recovery implementation
- Streamline consultations for those actions with little or no effect on recovery areas or priorities.
- Prioritize staff efforts to carefully and consistently consider short-term and long-term impacts to watershed processes when conducting jeopardy analysis for Federal actions in key listed Central Valley salmon and steelhead watersheds.
- Apply the VSP framework and recovery priorities to evaluate population and area importance in jeopardy and adverse modification analysis.
- Encourage action agencies to purchase credits from a NMFS approved conservation bank whenever appropriate.

Within this framework NMFS will utilize its authorities to:

- Encourage the Federal Emergency Management Agency (FEMA) to fund upgrades for flood-damaged facilities to meet the requirements of the ESA and facilitate recovery.
- Encourage the U.S. Environmental Protection Agency (USEPA) to prioritize action on pesticides known to be toxic to fish and/or are likely to be found in fish habitat; and to take protective actions, such as restrictions on pesticide use near water.
- Encourage the Federal Highway Administration and Caltrans to develop pile driving guidelines, approved by NMFS, for all bridge construction projects in key Dependent, Independent, and other watersheds with extant listed Central Valley salmon and/or steelhead populations.
- Encourage the development of section 7 Conservation Recommendations to help prioritize Federal funding towards recovery actions (NMFS, USFWS, NRCS, USEPA, etc) during formal consultations.
- Encourage all Federal agencies, or their designated representatives, to field review projects and actions upon project

completion to determine whether or not the projects were implemented as planned and approved. Encourage all Federal agencies, or their designated representatives to report the initial findings of such field reviews to NMFS.

- ❑ Encourage Federal agencies to coordinate and develop programmatic consultations for activities that contribute to the recovery of listed Central Valley salmon and steelhead, to streamline their permitting processes.
- ❑ Encourage all consulting agencies to provide biological assessments that comport to 50 CFR 402.14(c) for all projects in all watersheds where listed Central Valley salmon and/or steelhead are present and/or with designated critical habitat.

7.2.6 ESA Section 9

Section 9 prohibits the taking of endangered species; these prohibitions may be extended through 4(d) rules to threatened species, as discussed above. The recovery plan will assist NMFS' Enforcement personnel by targeting key watersheds essential for species recovery. Core watersheds identified in this plan should be considered the highest priority areas. NMFS biologists will work closely with NMFS Enforcement regarding the identification of threats and other activities believed to place Chinook salmon and steelhead at high risk of take and/or extirpation. Actions will include the following:

- ❑ NMFS will conduct outreach and provide enforcement with a summary of the recovery priorities and threats.
- ❑ NMFS will prioritize those actions and areas deemed of greatest threat or importance for focused efforts to halt illegal take of listed species.
- ❑ NMFS will develop a plan to outline responsibilities and priorities to ensure activities by NMFS staff, when supporting enforcement, are focused on the highest recovery priorities.
- ❑ When a take has occurred, NMFS biologists will work with NMFS enforcement, to the extent feasible, with the development of a take case.
- ❑ NMFS enforcement will work with CDFW, in conjunction with the Joint Enforcement Agreement to increase patrols and landowner outreach in critical watersheds, particularly during droughts, when listed Central Valley salmon and steelhead are potentially at greater threat of unauthorized taking.
- ❑ Regular meetings between recovery staff and Enforcement will occur. NMFS Enforcement will place a high priority on identification and curtailment of threats in key watersheds identified for recovery.

7.2.7 ESA Section 10

Section 10(a)(1)(A) provides NMFS authority to issue permits to authorize take of listed species for scientific purposes, or to enhance the propagation or survival of listed species.

Section 10(a)(1)(B) provides NMFS authority to issue permits to authorize take of listed species that is incidental to otherwise lawful activities for non-federal entities. Requests for such a permit must be accompanied by a conservation plan that, among other things, describes the effects of the incidental taking and how the entity will minimize and mitigate those effects.

To improve the section 10 authorization process, NMFS will utilize its authorities to:

<u>Section 10(a)(1)(a) Research Permits</u>

- ❑ Prioritize permit applications that address identified research and monitoring needs in the recovery plan.
- ❑ Evaluate all proposed activities against the identified threats, recovery strategy, and recovery actions identified in the plan.
- ❑ Develop and maintain databases to track the amount of take authorized and the effectiveness of conservation and mitigation measures.

Section 10(a)(1)(B) Habitat Conservation Plans (HCPs)

The USFWS/NMFS Habitat Conservation Planning Handbook (USFWS and NMFS 1996) stresses the need for consistency of mitigation measures for a species and for specific standards. Although, not a preferred option (according to the USFWS/NMFS HCP Handbook), if offsite mitigation is necessary this recovery plan can be used to target watersheds for recovery actions. In some circumstances off-site mitigation may provide greater opportunity for recovery than onsite mitigation (*i.e.*, if an HCP's covered activities occur in a non-focus watershed).

Within the HCP framework NMFS will utilize its authorities to cooperate and assist landowners in proposing activities or programs designed to contribute to recovery objectives.

Section 10(j) Experimental Populations

Section 10(j) of the ESA provides for the designation of specific populations of species as "experimental populations" under certain circumstances and procedures. The potential use of section 10(j) of the ESA could facilitate reintroductions by helping to minimize regulatory requirements on land and water users. This regulatory approach has been taken in order to help facilitate the reintroduction of spring-run Chinook salmon into the San Joaquin River downstream of Friant Dam. However, the regulatory context for future fish reintroductions in the Central Valley will be determined on a case by case basis.

7.2.8 Fisheries Management and EFH

Much of listed Central Valley salmon and steelhead habitat is located in areas identified as Essential Fish Habitat (EFH) for the Pacific Coast Salmon Fishery Management Plan (FMP) under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). NMFS anticipates the objectives and recovery strategies will serve as a guide when providing conservation recommendations for actions that may adversely affect EFH. In addition, NMFS will implement fishery regulations, through coordination with PFMC, to maintain salmon harvest levels at or below those necessary to allow for the recovery of listed salmon; and NMFS will work to implement fishery regulations to reduce bycatch of listed salmon in federally-managed fisheries.

7.2.9 Coordination with other NMFS Divisions and the PFMC

Other divisions within NOAA can contribute significantly to recovery. NMFS staff will coordinate closely with the SWFSC and the NOAA Restoration Center, to assist in the development, review and funding of restoration projects.

In addition NMFS staff will need to coordinate closely with the PFMC for establishing an ecosystem-based fishery management plan to prevent overfishing of listed Chinook salmon.

7.2.10 Technical Assistance

In conjunction with NMFS' statutory authorities and obligations we are engaged in a significant amount of outreach to various constituencies where we provide technical assistance regarding listed salmon and steelhead, their habitat needs, and various life history requirements. Due to the large proportion of private lands and the limited contributions of ESA section 7, developing partnerships through providing technical assistance will be critical for recovery. Through this role NMFS will focus efforts in key areas critical for recovery through the following actions:

- Work with individual cities and counties throughout the Central Valley so they have sufficient information to develop city planning and land use policies protective of listed Central Valley salmon and steelhead.
- Continue working with the Natural Resource Conservation Service, Resource Conservation Districts, and Reclamation Districts, to encourage improved agricultural practices as well as land use practices of rural residential landowners.
- Prioritize cooperation and assistance to landowners proposing activities or programs designed to achieve recovery objectives.
- Work with the SWRCB to restore and maintain natural flow patterns of clean, cold water across the ESUs/DPS.

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October 30, 2015

VIA U.S. MAIL

NOV 12 2015

BDCP/WaterFix Comments
P.O. Box 1919
Sacramento, CA 95812
E-Mail: BDCPComments@icfi.com

Re: Supplemental CD to Support San Luis & Delta-Mendota Water Authority/Westlands Water District's October 30, 2015 Comments on Bay Delta Conservation Plan/California WaterFix Partially Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement

Enclosed is a CD that contains the studies referenced in the comment letter that is being submitted by email and U.S. mail on October 30, 2015 by the San Luis & Delta Mendota Water Authority and Westlands Water District.

Should you have any questions please contact Rebecca Akroyd at (916) 321-4519.

CD Contents

CD includes cited references not previously provided with the Water Authority and Westlands' July 29, 2014 comments

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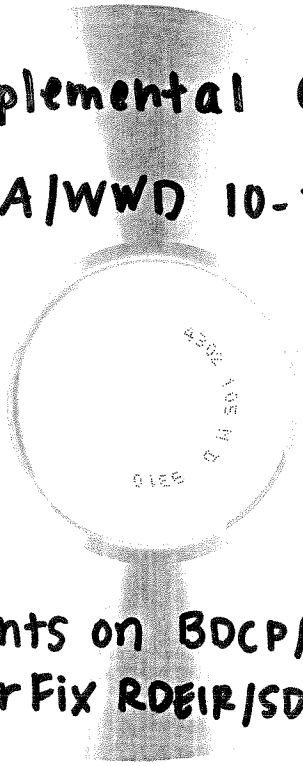
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Supplemental CD

SLDMWA/WWD 10-30-15



Comments on BDCP/cal.
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