Chapter 7
Aquatic Biological Resources

7.1 Introduction

This chapter describes the environmental setting for aquatic biological resources and the regulatory background associated with this resource area. It also evaluates environmental impacts on aquatic biological resources that could result from the Lower San Joaquin River (LSJR) alternatives, the significance of any impacts, and, if applicable, the mitigation measures that would reduce significant impacts.

The Southern Delta Water Quality (SDWQ) alternatives would not affect aquatic biological resources. As summarized in Section 7.4.2, *Methods and Approach*, the SDWQ alternatives would not result in a change in the water quality at Vernalis and, therefore, would not result in a change from baseline conditions. As discussed in Chapter 5, *Surface Hydrology and Water Quality,* and Appendix F.2, *Evaluation of Historical Flow and Salinity Measurements of the Lower San Joaquin River and Southern Delta,* it is not expected that salinity within the southern Delta would exceed historical monthly salinity levels, which generally range between 0.2 deciSiemens per meter (dS/m) (0.134 parts per thousand [ppt]) and 1.2 dS/m, (0.768 ppt), which are levels that indicator species can tolerate. Therefore, the SDWQ alternatives are not analyzed in detail in this chapter.

As described in Chapter 1, *Introduction*, the plan area generally includes those portions of the San Joaquin River (SJR) Basin that drain to, divert water from, or otherwise obtain beneficial use (e.g., surface water supplies) from the three eastside tributaries[1] of the LSJR. These include the Stanislaus River from and including New Melones Dam and Reservoir to its confluence with the LSJR; the Tuolumne River from and including New Don Pedro Dam and Reservoir to its confluence with the LSJR; the Merced River from and including New Exchequer Dam and Lake McClure to its confluence with the LSJR; and, the SJR between its confluence with the Merced River and downstream to Vernalis (i.e., LSJR). The evaluation of impacts in this chapter focuses on these water resources within the plan area that comprise the ecosystem for aquatic species. This chapter also evaluates other areas outside of the LSJR and the three eastside tributaries (i.e., the greater San Francisco Bay/Sacramento-San Joaquin Delta [Bay-Delta]), to the extent that environmental impacts from the LSJR and SDWQ alternatives may affect aquatic resources in these areas.

The extended plan area, also described in Chapter 1, *Introduction,* generally includes the area upstream of the rim dams[2]. The area of potential effects for this area is similar to that of the plan area and includes the zone of fluctuation around the numerous reservoirs that store water on the Stanislaus and Tuolumne Rivers. (The Merced River does not have substantial upstream reservoirs that would be affected.) It also includes the upper reaches of the Stanislaus, Tuolumne, and Merced Rivers. Unless otherwise noted, all discussion in this chapter refers to the plan area. Where appropriate, the extended plan area is specifically identified.

---

[1] In this document, the term *three eastside tributaries* refers to the Stanislaus, Tuolumne, and Merced Rivers.

[2] In this document, the term *rim dams* is used when referencing the three major dams and reservoirs on each of the eastside tributaries: New Melones Dam and Reservoir on the Stanislaus River; New Don Pedro Dam and Reservoir on the Tuolumne River; and New Exchequer Dam and Lake McClure on the Merced River.

This chapter evaluates the potential for impacts on aquatic resources as a result of the LSJR and SDWQ alternatives within the plan area. Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30,* evaluates the various benefits for native fishes potentially resulting from the LSJR alternatives. Chapter 19 focuses on the benefits of temperature and floodplain inundation to Central Valley fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley steelhead (*Oncorhynchus mykiss*) as a result of the LSJR alternatives (including the adaptive implementation approaches describe in the program of implementation). Chapter 19 quantitatively evaluates temperature and floodplain inundation during February–June and compares conditions between baseline and the various LSJR alternatives on the three eastside tributaries and the LSJR.

In Appendix B, *State Water Board's Environmental Checklist*, the State Water Board determined whether the plan amendments[3] would cause any adverse impact on resources in each of the listed environmental categories and provided a brief explanation for its determination. Impacts in the checklist that are identified as "Potentially Significant Impacts" are discussed in detail in the resource chapters.

This chapter addresses Appendix B, Section IV, *Biological Resources*, and the potential for the plan amendments to have a substantial adverse impact on sensitive or special status aquatic species, either directly or through habitat modification, including interference with migratory movement or reproductive sites. Potential impacts on terrestrial species are analyzed in Chapter 8, *Terrestrial Biological Resources.* Due to the complexity of aquatic resources, review in this chapter is accomplished through analyzing specific potential impacts, described as Impacts AQUA-1 through AQUA-12 (Table 7-1). Accordingly, this chapter evaluates potential impacts in greater detail than those directly specified in Appendix B so as to thoroughly analyze the project on aquatic resources.

The LSJR alternatives could affect reservoir operations in the Stanislaus, Tuolumne, and Merced Rivers, flows in each of these tributaries, and flows in the LSJR and Delta, resulting in potential impacts on aquatic habitat and aquatic biological communities, including native and nonnative fish species. The following analysis evaluates the impacts on aquatic resources that are expected to result from the LSJR alternatives based on the predicted responses of indicator species to the frequency and magnitude of flows, water temperature, and other habitat metrics relative to baseline conditions.

The potential impacts of the LSJR alternatives on aquatic resources are summarized in Table 7-1 as Impacts AQUA-1 through AQUA-12. As described in Chapter 3, *Alternatives Description*, LSJR Alternatives 2, 3, and 4 each includes four methods of adaptive implementation. The recirculated substitute environmental document (SED) provides an analysis with and without adaptive implementation because the frequency, duration, and extent to which each adaptive implementation method would be used, if at all, within a year or between years under each LSJR alternative, is unknown. The analysis, therefore, discloses the full range of impacts that could occur under an LSJR alternative, from no adaptive implementation to full adaptive implementation. As such, Table 7-1 summarizes impact determinations with and without adaptive implementation.

Impacts related to the No Project Alternative (LSJR/SDWQ Alternative 1), are presented in Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* and the supporting technical analysis is presented in Appendix D, *Evaluation of the No Project Alternative (LSJR*

[3] These plan amendments are the *project* as defined in State CEQA Guidelines, Section 15378.

Alternative 1 and SDWQ Alternative 1). Chapter 16, *Evaluation of Other Indirect and Additional Actions,* includes discussion of impacts related to actions and methods of compliance.

The indicator species, or key evaluation species, used to determine impacts of the LSJR alternatives on aquatic resources include anadromous[4] fish (fall-run Chinook salmon and steelhead), coldwater reservoir fish (e.g., rainbow trout[5]), and warmwater reservoir fish (e.g., largemouth bass). Indicator species were selected based on their sensitivity to expected changes in environmental conditions in the plan area and their utility in evaluating broader ecosystem and community-level responses to environmental change. In particular, the responses of Central Valley fall-run Chinook salmon to changes in flow, water temperature, and other flow-related variables have been well studied and provide a general indication of the overall response of the ecosystem to hydrologic change.

Table 7-1. Summary of Aquatic Resources Impact Determinations

Alternative	Summary of Impact (s)	Impact Determination with or without Adaptive Implementation
Impact AQUA-1: Changes in spawning success and habitat availability for warmwater species resulting from changes in reservoir water levels		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Significant[c]
LSJR Alternatives 2, 3, and 4	The frequency of 15-foot fluctuations in reservoir levels would not change or would be reduced relative to baseline conditions; therefore, no significant reductions in spawning success and habitat availability for warmwater species would occur.	Less than significant
Impact AQUA-2: Changes in availability of coldwater species reservoir habitat resulting from changes in reservoir storage		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Significant[c]
LSJR Alternatives 2, 3, and 4	Changes in average reservoir storage levels at the end-of-September would range from little or no change to substantial increases relative to baseline levels; therefore, no significant reductions in coldwater habitat availability would occur.	Less than significant
Impact AQUA-3: Changes in quantity/quality of physical habitat for spawning and rearing resulting from changes in flow		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Less than significant[c]
LSJR Alternative 2	Suitable spawning habitat on the three eastside	Less than significant

[4] *Anadromous* refers to fish that are born in freshwater then migrate to the ocean for feeding and growth, finally returning to freshwater to spawn.

[5] Rainbow trout and steelhead are the same species, *Oncorhynchus mykiss*, but distinguished taxonomically by their different forms. In this document *rainbow trout* refers to the form of this species that remains mostly or entirely in freshwater while *steelhead* refers to the anadromous form. It should be recognized that both forms exist in populations with access to the ocean, including populations within the plan area.

Alternative	Summary of Impact (s)	Impact Determination with or without Adaptive Implementation
	tributaries would remain unchanged or increase. Therefore, no significant adverse impacts on the amount of spawning habitat for Chinook salmon and steelhead in the Stanislaus, Tuolumne, and Merced Rivers would occur. No reductions in Chinook salmon fry and juvenile rearing habitat are expected on the Stanislaus River or LSJR compared to baseline. In the Tuolumne and Merced Rivers, weighted usable area (WUA) for Chinook salmon fry and juvenile rearing would decrease, but floodplain habitat would increase in response to higher spring flows. No substantial differences would occur in WUA for steelhead fry and juvenile rearing compared to baseline conditions. No long-term reductions in habitat availability for other native fish species would occur. Therefore, no significant adverse impacts on the amount of habitat for Chinook salmon, steelhead, and other native fishes in the Stanislaus, Tuolumne and Merced Rivers and the LSJR would occur.	
LSJR Alternative 3	Reductions in WUA for Chinook salmon spawning would occur in the three eastside tributaries, but higher flows and lower temperatures are expected to improve attraction and migration and the longitudinal extent of suitable spawning habitat. SJR Alternative 3 would substantially improve rearing habitat conditions for Chinook salmon and steelhead in the three eastside streams and LSJR. Considering the overall beneficial effects of higher flows on rearing habitat availability, no significant adverse impacts on Chinook salmon and steelhead populations would occur. Higher spring flows under LSJR Alternative 3 would also benefit other native fish species.	Less than significant
LSJR Alternative 4	Under LSJR Alternative 4, predicted changes in WUA values for Chinook salmon and steelhead spawning in the Stanislaus, Tuolumne, and Merced Rivers would be similar in magnitude to those predicted under LSJR Alternative 3. LSJR Alternative 4 would further improve rearing habitat conditions for Chinook salmon and steelhead in the three eastside tributaries and LSJR. Higher spring flows under LSJR Alternative 4 would also further improve habitat conditions for other native fish species. Therefore, no significant adverse impacts would occur.	Less than significant

Alternative	Summary of Impact (s)	Impact Determination with or without Adaptive Implementation
Impact AQUA-4: Changes in exposure of fish to suboptimal water temperatures resulting from changes in reservoir storage and releases		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Significant[c]
LSJR Alternative 2	No substantial changes would occur in exposure of Chinook salmon and steelhead adult migration, spawning and incubation, juvenile rearing, and smolt life stages to suboptimal water temperatures in the Stanislaus, Tuolumne, Merced, and LSJR. Therefore, no significant adverse impacts on Chinook salmon and steelhead populations would occur.	Less than significant
LSJR Alternative 3	Decreases in exposure of Chinook salmon and steelhead life stages to suboptimal water temperatures would occur for spawning/incubation in the Tuolumne River (March); spring rearing in the Tuolumne, Merced, and LSJR (April–May); and summer rearing (steelhead only) in the Stanislaus, Tuolumne, and Merced Rivers (July). Therefore, no significant adverse impacts would occur. LSJR Alternative 3 would have beneficial temperature effects on Chinook salmon and steelhead in the Stanislaus, Tuolumne, and Merced Rivers (including Chinook salmon reared at Merced River Hatchery), and the LSJR.	Less than significant
LSJR Alternative 4	Decreases in exposure of Chinook salmon and steelhead life stages to suboptimal water temperatures would occur for spawning/incubation in the Stanislaus, Tuolumne, and Merced Rivers (February–March); spring rearing in the Stanislaus, Tuolumne, Merced, and LSJR (March–May); spring outmigration in the Stanislaus, Tuolumne, and Merced Rivers (April–June); and summer rearing (steelhead only) in the Tuolumne River (July). Therefore, no significant adverse impacts would occur. Overall, LSJR Alternative 4 would have beneficial temperature effects on Chinook salmon and steelhead in the Stanislaus, Tuolumne, and Merced Rivers (including Chinook salmon reared at Merced River Hatchery), and the LSJR.	Less than significant

Alternative	Summary of Impact (s)	Impact Determination with or without Adaptive Implementation
Impact AQUA-5: Changes in exposure to pollutants resulting from changes in flow		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Significant[c]
LSJR Alternative 2	Changes in the frequency and magnitude of flows would not be sufficient to result in long-term adverse changes in dilution effects and exposure of fish to potentially harmful contaminants.	Less than significant
LSJR Alternative 3	Similar or higher 10th and 50th (median) percentile flows in most months would result in similar or reduced long-term exposure of fish to potentially harmful pollutants. Decreases in exposure of Chinook salmon and steelhead life stages to suboptimal water temperatures would contribute to reductions in the potential for adverse effects associated with contaminant exposure.	Less than significant
LSJR Alternative 4	Dilution would potentially increase as a result of the increase in flows, and temperatures would either be maintained or reduced; thus, an increase in exposure to pollutants would not occur.	Less than significant
Impact AQUA-6: Changes in exposure to suspended sediment and turbidity resulting from changes in flow		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Less than significant[c]
LSJR Alternatives 2, 3, and 4	Changes in the frequency, duration, and magnitude of increased suspended sediment and turbidity levels would be minor and within the range of historical levels experienced by native fishes and other aquatic species on the three eastside tributaries and the LSJR.	Less than significant
Impact AQUA-7: Changes in redd dewatering resulting from flow fluctuations		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Less than significant[c]
LSJR Alternatives 2, 3, and 4	There would be no substantial changes on the three eastside tributaries or the LSJR in the frequency and magnitude of flow reductions associated with potential impacts on Chinook salmon and steelhead redd dewatering.	Less than significant
Impact AQUA-8: Changes in spawning and rearing habitat quality resulting from changes in peak flows		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Less than significant[c]
LSJR Alternatives 2, 3, and 4	Modeled results indicate that changes in peak flows are not expected to affect the frequency and magnitude of gravel mobilization events in the Stanislaus, Tuolumne, and Merced Rivers. Therefore, no long-term changes in geomorphic conditions	Less than significant

Alternative	Summary of Impact (s)	Impact Determination with or without Adaptive Implementation
	significantly affecting spawning and rearing habitat quality would occur.	
Impact AQUA-9: Changes in food availability resulting from changes in flow and floodplain inundation		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Less than significant[c]
LSJR Alternative 2	No substantial changes are likely to occur in frequency and magnitude of floodplain inundation and associated food web conditions in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR. Therefore, no significant impacts on food availability would occur.	Less than significant
LSJR Alternatives 3 and 4	Higher spring flows and associated increases in riparian and floodplain inundation in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR would potentially increase food abundance and growth opportunities for fish on floodplains as well as contribute to downstream food web support. This represents a beneficial effect on aquatic biological resources in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR.	Less than significant
Impact AQUA-10: Changes in predation risk resulting from changes in flow and water temperature		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Significant[c]
LSJR Alternative 2	No substantial changes are predicted to occur in habitat availability and water temperatures potentially affecting Chinook salmon and steelhead populations or conditions supporting predator populations.	Less than significant
LSJR Alternatives 3 and 4	Higher flows and cooler water temperatures in the three eastside tributaries would reduce predation impacts by improving growth opportunities and reducing temperature-related stress in juvenile Chinook salmon and steelhead and limiting the distribution and abundance of largemouth bass and other nonnative species that prey on juvenile salmonids.	Less than significant
Impact AQUA-11: Changes in disease risk resulting from changes in water temperature		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note. [a]	Significant[c]
LSJR Alternatives 2, 3, and 4	The frequency of spring water temperatures associated with potential increases in disease risk would stay the same or decrease.	Less than significant

Alternative	Summary of Impact (s)	Impact Determination with or without Adaptive Implementation
Impact AQUA-12: Changes in southern Delta and estuarine habitat resulting from changes in SJR inflows and export effects		
No Project Alternative (LSJR/SDWQ Alternative 1)	See note.[a]	Less than significant[c]
LSJR Alternatives 2, 3, and 4	No substantial changes in southern Delta and estuarine habitat would occur. The combination of monthly changes in pumping rates, SJR flow, and Delta outflow would not have substantial long-term effects on flow patterns in the southern Delta. Furthermore, there would be little effect on Delta outflows and the position of X2;[b] Delta operations would continue to be governed by current restrictions on export pumping rates, inflow/export ratios, and Old Middle River flows to protect listed fish species from direct and indirect impacts of southern Delta operations.	Less than significant

[a] The No Project Alternative (LSJR/SDWQ Alternative 1) would result in the continued implementation of flow objectives and salinity objectives established in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* the No Project Alternative impact discussion, and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

[b] X2 is the location of the 2 parts per thousand (ppt) salinity contour (isohaline), 1 meter off the bottom of the estuary measured in kilometers upstream from the Golden Gate Bridge. The abundance of several estuarine species has been correlated with X2. In the 2006 Bay-Delta Plan, a salinity value—or electrical conductivity (EC) value—of 2.64 millimhos/centimeter (mmhos/cm) is used to represent the X2 location. Note, in this SED, EC is generally expressed in deciSiemens per meter (dS/m). The conversion is 1 mmhos/cm = 1 dS/cm.

[c] Adaptive implementation does not apply to the No Project Alternative.

7.2 Environmental Setting

This section describes the life history, habitat requirements, and factors that affect the abundance of aquatic biological resources, including special-status, recreational, and indicator species in the plan area, and reviews historical and current fish communities and environmental stressors in the LSJR, three eastside tributaries, and the southern Delta. Additional background information and technical support for Section 7.2, *Environmental Setting*, and Section 7.4, *Impact Analysis*, are presented in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*. In particular, Appendix C, Chapter 3, *Scientific Basis for Developing Alternative San Joaquin River Flow Objectives*, provides additional information on the life history of the indicator species (Chinook salmon and steelhead), detailed descriptions of existing fish monitoring and research programs, and reviews of published and unpublished technical information supporting current scientific understanding of the roles of flow, water temperature, and other mechanisms affecting Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR.

7.2.1 Fish Species

The LSJR, the three eastside tributaries, and the southern Delta support a diverse assemblage of native and nonnative fishes. Historically, the SJR and the three eastside tributaries in the plan area supported a distinctive native fish fauna adapted to widely fluctuating riverine conditions ranging from large winter and spring floods to low summer flows. Prior to large-scale hydrologic and physical alteration of the basin and species introductions, these environmental conditions resulted in a rich and diverse native fish fauna characterized by four major fish assemblages. The rainbow trout assemblage occurred in high gradient, upper elevation portions of the SJR basin, and commonly included riffle sculpin (*Cottus gulosus*), Sacramento sucker (*Catostomus occidentalis*), and speckled dace (*Rhinichthys osculus*). The California roach assemblage occurred in small, warm tributaries at middle elevations, and may have seasonally included Sacramento sucker, Sacramento pikeminnow, Chinook salmon, and steelhead. The Pikeminnow-hardhead-sucker assemblage historically occurred in larger mainstem portions of the SJR and its tributaries and included speckled dace, California roach, riffle and prickly sculpin, threespine stickleback, and rainbow trout. Anadromous species, including Chinook salmon, steelhead (anadromous or sea-run rainbow trout), and Pacific lamprey, spawned and reared in this zone. The deep-bodied fish assemblage generally occurred in the low gradient, valley-bottom portions of the SJR, and included Sacramento perch (*Archoplites interruptus*), thicktail chub, tule perch, hitch, and blackfish. Chinook salmon, steelhead, and sturgeon occurred in this zone on their way upstream to spawn or on their way downstream toward the ocean (Moyle 2002).

The fish assemblages that currently occur in SJR and the three eastside tributaries are the result of substantial changes to the physical environment and a long history of species introductions. A number of the native species are now uncommon, rare, or extinct, and have been designated as special-status species (Table 7-2). Some of these special-status species (e.g., rainbow trout, fall-run Chinook salmon, and steelhead) are the indicator species mentioned in Section 7.1, *Introduction*. Other species, both native and nonnative, support important recreational fisheries in the plan area (Table 7-3).

Table 7-2. Special-Status Fish Species that Occur in the Plan Area

Species Name	Status[a] Fed/State	Recreationally Important? Yes/No	Location	Habitat	Critical Habitat Designated?
Central Valley fall-/late fall–run Chinook salmon[b] *Oncorhynchus tshawytscha*	SC/CSC–	Yes	Pacific Ocean, San Francisco Bay-Sacramento-San Joaquin Delta (Bay-Delta), SJR and the three eastside tributaries, Sacramento River and major tributaries.	Prefer well-oxygenated, cool, riverine habitat with water temperatures ~~8~~5.0°C–~~12.5~~19.0°C (~~46~~41.~~5~~0°F–~~54.5~~66.2°F). Habitat types are riffles, runs, and pools.	No

Species Name	Status[a] Fed/State	Recreationally Important? Yes/No	Location	Habitat	Critical Habitat Designated?
Central Valley spring-run Chinook salmon *Oncorhynchus tshawytscha*	T/CT	No	Pacific Ocean, Bay-Delta, Sacramento River and major tributaries.[c]	Prefer well-oxygenated, cool, riverine habitat with water temperatures 8.0°C–12.5°C (46.5°F–54.5°F). Coldwater pools are needed for holding adults.	Yes, but not in the plan area.
Central Valley steelhead[b] *Oncorhynchus mykiss*	T/–	Yes	Pacific Ocean, Bay-Delta, SJR and three eastside tributaries, Sacramento River and major tributaries.	Prefer well-oxygenated, cool, riverine habitat with water temperatures 7.8°°C–18°C (46°F–64.4°F). (Moyle 2002). Habitat types are riffles, runs, and pools.	Yes, the LSJR from the Merced River confluence to Vernalis, including the three eastside tributaries, and the southern Delta.
Green sturgeon (southern DPS) *Acipenser medirostris*	T/CSC	No	Pacific Ocean, Bay-Delta, Sacramento River.	Occur in both freshwater and saltwater habitat. Spawn in deep pools or in turbulent areas in the mainstem of large rivers (Moyle 2002), with well-oxygenated water with temperatures 8°C–14°C (46.5°F–57.2°F). Salinity tolerance to 35 ppt for adults.	Yes, the Bay-Delta.
Delta smelt *Hypomesus transpacificus*	T/CE	No	Primarily in the Bay-Delta, but has been found as far upstream as the mouth of the American River, on the Sacramento River, and at Mossdale on the SJR; range extends downstream to San Pablo Bay.	Endemic to the Bay-Delta and generally spend entire lifecycle in the open surface waters of the Bay-Delta and Suisun Bay. Prefer areas where fresh and brackish water mix in the salinity range of 2–7 ppt. Salinity tolerance to 19 ppt, sometimes higher (Bennett 2005).	Yes, the legal Delta and Suisun Bay and Marsh.

	Status[a]	Recreationally Important?			
Species Name	Fed/State	Yes/No	Location	Habitat	Critical Habitat Designated?
Longfin smelt *Spirinchus thaleichthys*	–/CT	No	Primarily in the Bay-Delta, but also in Humboldt Bay, Eel River estuary, and Klamath River estuary.	Primary habitat is the open water of estuaries; can be found in both the seawater and freshwater areas, typically in the middle or deeper parts of the water column. Salinity tolerance to 35 ppt. Spawning takes place in salt or brackish estuary waters with freshwater inputs (Merz et al. 2013).	No
Sacramento splittail *Pogonichthys macrolepidotus*	–/CSC	~~No~~Yes	Throughout the year in low-salinity waters and freshwater areas of the Bay-Delta, Yolo Bypass, Suisun Marsh, Napa River, ~~and~~ Petaluma River, Sacramento River and tributaries (lower Feather and American Rivers), SJR, and accessible tributaries (Moyle 2002).	Utilize floodplain habitat for feeding and spawning. Spawn among submerged and flooded vegetation in sloughs and the lower reaches of rivers. Estuarine species found 10–18 ppt, can tolerate up to 29 ppt (Cech et al. 1990).	No
Kern brook lamprey *Lampetra hubbsi*	–/CSC	No	Lower Merced River, Kaweah River, Kings River, and SJR.	Silty and backwaters and stream margins of Sierra foothill rivers.	No
River lamprey *Lampetra ayresi*	–/CSC	No	Bay-Delta and SJR from Friant Dam to Merced River and the LSJR.	Has not been thoroughly studied in California but appears to be more abundant in the Lower Sacramento River and LSJR than in other streams in California.	No

Species Name	Status[a] Fed/State	Recreationally Important? Yes/No	Location	Habitat	Critical Habitat Designated?
California roach (Sacramento-San Joaquin roach and Red Hills roach) *Lavinia symmetricus ssp.*	–/CSC	No	Sacramento–San Joaquin Watersheds; Red Hills roach known to occur only in several small streams in Tuolumne River basin.	California roach generally occur in small, warm streams, and individuals frequent a wide variety of habitats, often isolated by downstream barriers. Tolerant of relatively high water temperatures 30°C–35°C (86°F–95°F) with low oxygen levels.	No
Pacific lamprey *Entosphenus tridentatus*	SC/–	No	Pacific Ocean, Bay-Delta, SJR and three eastside tributaries, Sacramento River.	Prefer well-oxygenated, cool, riverine habitat with water temperatures 12°C–18°C (53.5°F–64.5°F). Spawning habitats are similar to that of salmonids. They are anadromous.	No
Hardhead *Mylopharodon conocephalus*	–/CSC	No	SJR and the three eastside tributaries, Sacramento River and major tributaries.	Prefer low to mid-elevation environments with clear, deep pools and runs with sand-gravel-boulder substrates. Optimal water temperatures range from 24°C–28°C (75°F–82°F); however, most streams where these fish occur have temperatures over 20°C (68°F) (Moyle 2002).	No

Species Name	Status[a] Fed/State	Recreationally Important? Yes/No	Location	Habitat	Critical Habitat Designated?

DPS = Distinct population segment
°F = Degrees Fahrenheit
°C = Degrees Celsius
ppt = Parts per thousand

[a] Status:

Federal

E = Listed as endangered under the federal Endangered Species Act (ESA).
T = Listed as threatened under ESA.
SC = Listed as a species of concern.
– = No federal status.

State

CE = Listed as endangered under the California Endangered Species Act (CESA).
CT = Listed as threatened under CESA.
CSC = California species of special concern.
– = No state status.

[b] Central Valley fall-run Chinook salmon and Central Valley steelhead are considered indicator species of coldwater communities.

[C] A conservation stock of spring-run Chinook is being developed at the San Joaquin River Conservation and Research Facility at Friant Dam and has been released experimentally since 2014 to the LSJR.

Table 7-3. Recreationally Important Fish Species in the Plan Area

Species Name	Status Fed/State	Recreationally Important? Yes/No	Location	Habitat	Critical Habitat Designated?
Rainbow trout *Oncorhynchus mykiss*[a, b]	–/–	Yes	SJR and the three eastside tributaries, Sacramento River and major tributaries. Also stocked in reservoirs in the plan area.	Prefer well-oxygenated, cool, riverine habitat with water temperatures 7.8°C–18°C (46°F–64.4°F). Habitat types are riffles, runs, and pools.	No

Species Name	Status Fed/State	Recreationally Important? Yes/No	Location	Habitat	Critical Habitat Designated?
Largemouth bass[b] *Micropterus salmoides*	–/–	Yes	Bay-Delta, SJR, Sacramento River, and tributaries. Also stocked in reservoirs in the plan area.	Found in warm, quiet water with low turbidity and aquatic plants, such as lakes, reservoirs, sloughs, and river backwaters. Constructs its nests for eggs in shallow water. Optimal temperatures range from 25°C–30°C (77°F–86°F) but can persist in temperatures that approach 36°C–37°C (97°F–99°F) (Moyle 2002).	Not applicable – nonnative introduced species
Striped bass *Morone saxatilis*	–/–	Yes	Bay-Delta, SJR and three eastside tributaries, Sacramento River and major tributaries.	Found in lakes, ponds, streams, wetlands, and brackish and marine waters. Anadromous, they spawn in fresh water in the spring (April–May) when water temperatures are about 15.5°C (60°F).	Not applicable - nonnative introduced species
White sturgeon *Acipenser transmontanus*	–/–	Yes	Pacific Ocean, Bay-Delta~~.~~	Inhabits riverine, estuarine, and marine (35 ppt) habitats at various life stages (Moyle 2002). Greatest portion of the population occurs in the brackish portion of the estuary.	No
American shad *Alosa sapidissima*	–/–	Yes	Bay-Delta, Sacramento River and major tributaries, and SJR. Also stocked in reservoirs in the plan area.	Prefer well-oxygenated, cool, riverine habitat. Peak spawning in Millerton Reservoir occurs in mid-~~May~~ June to mid-~~June~~July, with water temperatures of 11°C–17°C (51.8°F–62.6°F).	Not applicable – nonnative introduced species

Species Name	Status Fed/State	Recreationally Important? Yes/No	Location	Habitat	Critical Habitat Designated?
Kokanee *Oncorhynchus nerka*	–/–	Yes	Reservoirs in the plan area.	Landlocked populations occur in well-oxygenated reservoirs on three eastside tributaries. Preferred water temperatures are 1°C–15°C (50°F–59°F).	Not applicable – nonnative introduced species

°F = degrees Fahrenheit
°C = degrees Celsius
[a] In this document, *rainbow trout* refers to non-anadromous forms of the species *O. mykiss* above impassable dams. However, it should be recognized that both anadromous (steelhead) and non-anadromous forms occur below these dams. The anadromous form is recognized by the National Marine Fisheries Service as a distinct population segment of *O. mykiss*, which is listed as threatened under the ESA (see Table 7-2).
[b] Largemouth bass are considered an indicator species of warmwater reservoir fish communities that include fishes such as sunfish and catfish. Rainbow trout are considered an indicator species of coldwater reservoir fish communities.

Chinook Salmon

Central Valley Fall-Run

The Central Valley fall-run Chinook salmon evolutionarily significant unit (ESU) is listed as a federal species of concern. Currently, fall-run Chinook salmon are the most abundant of the Central Valley races, contributing historically to large commercial and recreational fisheries in the ocean and popular sport fisheries in the freshwater streams. Fall-run Chinook are raised at five major Central Valley hatcheries that release more than 32 million smolts each year (CDFW 2016a). The federal status of fall-run Chinook salmon is due in part to concerns regarding hatchery influence.

Central Valley fall-run Chinook salmon historically spawned in all major Central Valley tributaries, as well as the mainstem of the Sacramento River and SJR (Moyle 2002). Because much of fall-run Chinook salmon historical spawning and rearing habitat included the reaches downstream of major dams, the fall runs in the Central Valley were not as severely affected by early water projects as were spring-run Chinook salmon and steelhead, which ascended to higher elevations to spawn (Reynolds et al. 1993; Yoshiyama et al. 1996; McEwan 2001). Changes in seasonal hydrologic patterns resulting from operation of upstream reservoirs for water supplies, flood control, and hydroelectric power generation have altered instream flows and habitat conditions for fall-run Chinook salmon and other species downstream of the dams (Williams 2006).

Trends in adult fall-run Chinook salmon escapement on the SJR and the three eastside tributaries have been relatively low since the 1950s, ranging from several hundred adults to approximately 100,000 adults. Results of escapement estimates have shown a relationship between adult escapement in one year and spring flows on the SJR 2.5 years earlier when the juveniles in the cohort were rearing and migrating downstream through the Sacramento-San Joaquin Delta (Delta). Adult escapement appears to be cyclical and may be related to hydrology during juvenile rearing and migration periods, among other factors (CDFG 2005; SJRTC 2008). Population trends for fall-run

Chinook salmon are discussed in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*.

SJR fall-run Chinook salmon migrate into natal streams from late October to early December, with peak migration typically occurring in November (Table 3.13 of Appendix C). SJR fall-run Chinook salmon typically begin spawning between November and January when temperatures in the rivers are lower than 55°F. The majority of redds (a gravel depression in the riverbed the adults make with their tails for spawning) are observed in the month of November (McBain and Trush 2002). Egg incubation typically occurs between November and March, lasting 40–60 days, but can vary depending on water temperatures and timing of spawning. Optimal water temperatures for egg incubation range from 41 degrees Fahrenheit (°F) to 55°F (Moyle 2002; USEPA 2003). Eggs that incubate at temperatures higher than 60°F and lower than 38°F have suffered high mortality rates (Boles et al. 1988).

Newly hatched salmon (alevins) remain in the gravel for about 4–6 weeks, depending on surrounding water temperatures, until the yolk sac has been absorbed (Moyle 2002; NMFS 2009a). Generally, alevins suffer low mortality when consistently incubated at water temperatures between 50°F and 55°F. However, if incubated at constant temperatures between 55°F and 57.5°F, mortality has been shown to increase in excess of 50 percent (Boles et al. 1988).

Most fall-run Chinook salmon fry (the life stage after alevins) emerge from the gravel between February and March (McBain and Trush 2002) and are immediately dispersed into downstream feeding areas. However, many juveniles may rear in the river for some length of time before migrating downstream (Moyle 2002). Rearing and outmigration of fall-run Chinook salmon typically occurs between February and June; however, rotary screw trap and trawl data from the LSJR and its tributaries indicate that peaks in fry outmigration occur in February and March, and peaks in smolt (> 75 mm) outmigration occur in April and May.

Preferred rearing temperatures for Chinook have been reported to occur within the range of 54°F–58.5°F (12.2°C–14.7°C) (Hicks 2002) with optimum temperatures for growth occurring at temperatures of 50°F–60°F (10°C–15.6°C) (McCullough et al. 2001). Chinook salmon exhibit positive growth at temperatures ranging from 46.4°F–77°F (8°C–25°C), with optimum growth rates occurring at about 66.2°F (19°C) when fed maximal rations (Myrick and Cech 2001).

Juvenile Central Valley fall-run Chinook salmon undergo a change known as *smoltification* when they reach 3–4 inches (75–100 millimeters [mm]) during outmigration. Smoltification involves physiological and morphological changes that prepare juveniles for ocean entry (CDFG 2010). Elevated stream temperatures during rearing or downstream smolt migration can inhibit smolt development in anadromous salmonids. Water temperatures that have been reported in the literature to impair smoltification range from approximately 53.6°F–59°F (12°C–15°C) (McCullough et al. 2001). Evidence of impaired smoltification in Central Valley fall-run Chinook salmon has been observed at water temperatures above approximately 60.8°F (16°C), with significant impairment occurring at water temperatures above approximately 68°F (20°C) (Marine and Cech 2004).

Central Valley Spring-Run

The Central Valley spring-run ESU is a special-status species currently listed as threatened under the Endangered Species Act (ESA) and the California Endangered Species Act (CESA).

Spring-run Chinook salmon once occupied all major river systems in California and were widely distributed in Central Valley rivers (Myers et al. 1998). Spring-run Chinook salmon were widely distributed in streams of the Sacramento River and SJR Basins, spawning and rearing over extensive areas in the upper and middle reaches (elevations ranging from 1,400 to 5,200 feet (ft) [450 to 1,600 meters (m)]) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud, and Pit Rivers (Myers et al. 1998). Run sizes in the nineteenth century were probably in the range of 1 million fish per year +/-500,000 (Yoshiyama et al. 1998; Moyle et al. 2008). From 1900 to 1948, hydroelectric development and irrigation projects truncated large portions of the headwaters of most Central Valley Rivers by dam construction and greatly reduced access of spring-run Chinook salmon to spawning habitat (Yoshiyama et al. 1996). The SJR population was essentially extirpated by the late 1940s. Populations in the Upper Sacramento, Feather, and Yuba Rivers were eliminated with the construction of major dams during the 1950s and 1960s. Naturally spawning populations of spring-run Chinook salmon are currently restricted to accessible reaches of the Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Mill Creek, Feather River, and Yuba River (CDFG 1998). Naturally-spawning populations of Central Valley spring-run Chinook salmon with consistent spawning returns use the Bay-Delta as a migration corridor and are currently restricted to Butte Creek, Deer Creek, and Mill Creek (Moyle 2002; Good et al. 2005).

Spring-run Chinook salmon populations were extirpated from the SJR Basin after construction of Friant Dam, which was completed in 1948 (Moyle 2002). However, in 2006 parties agreed to a stipulated settlement that required the reintroduction of spring-run Chinook salmon to this section of the SJR and required minimum flows to sustain the reintroduced population. In 2009, through the San Joaquin River Restoration Program (SJRRP),[6] the first restoration flows were released from Friant Dam. In 2010, the SJR reconnected to the LSJR at the Merced River confluence. The major goal of the SJRRP is to establish a naturally self-sustaining population (see Chapter 17, *Cumulative Impacts, Growth-Inducing Effects, and Irreversible Commitment of Resources*, for a discussion of the program) (USBR 2011).

An experimental population of spring-run Chinook salmon has been designated under Section 10(j) of the ESA in the San Joaquin River from Friant Dam downstream to its confluence with the Merced River (78 FR 79622), and spring-run Chinook salmon are currently being reintroduced to the San Joaquin River. A conservation stock of spring-run Chinook is being developed at the San Joaquin River Conservation and Research Facility at Friant Dam and individuals have been released annually since 2014 to the lower San Joaquin River (USFWS 2017). In 2016, the San Joaquin River Restoration Program released 57,320 Feather River Hatchery and 47,560 San Joaquin River Conservation and Research Facility spring-run Chinook salmon juveniles to the San Joaquin River just upstream of the confluence with the Merced River. The first year in which the fish released in 2014 may have returned was 2016. No fish have been detected returning to the San Joaquin River to spawn from the initial 2014 release (NMFS 2017).

Currently, no spring-run Chinook salmon populations are found in the tributaries of the SJR (NMFS 2014), although there are occasional observations of small numbers of Chinook salmon in the tributaries that display spring-run characteristics. It is not well understood if these fish are in fact spring-run Chinook salmon, and if they are, from which Sacramento River tributary they have strayed from. ~~Spring-run Chinook salmon populations were extirpated from the SJR Basin after construction of Friant Dam, which was completed in 1948 (Moyle 2002). However, in 2006 parties~~

[6] Implementation of the settlement and the Friant Dam release flows required by the San Joaquin River Restoration Program are expected to increase the existing SJR flows at Stevinson in the near future.

~~agreed to a stipulated settlement that required the reintroduction of spring-run Chinook salmon to this section of the SJR and required minimum flows to sustain the reintroduced population. In 2009, through the San Joaquin River Restoration Program (SJRRP),[7] the first restoration flows were released from Friant Dam. In 2010, the SJR reconnected to the LSJR at the Merced River confluence. The major goal of the SJRRP is to establish a naturally self-sustaining population (see Chapter 17, *Cumulative Impacts, Growth-Inducing Effects, and Irreversible Commitment of Resources*, for a discussion of the program) (USBR 2011).~~

The Central Valley spring-run Chinook salmon ESU has displayed broad fluctuations in adult abundance between 1960 and 2009. Although recent population trends are negative, annual abundance estimates display a high level of variation. The overall number of spring-run Chinook salmon remains well below estimates of historical abundance. Central Valley spring-run Chinook salmon have some of the highest population growth rates in the Central Valley, but other than in Butte Creek and the hatchery-influenced Feather River, population sizes are very small relative to fall-run Chinook salmon populations (Good et al. 2005).

In general, physical parameters (e.g., temperature and salinity thresholds) for spring-run Chinook salmon are similar to that of fall-run Chinook salmon, although the timing of the freshwater lifecycle is different. Spring-run Chinook salmon enter freshwater in the winter and spring and spawn in the late summer. This life history requires that they migrate far enough upstream to find habitat that remains cool enough (less than 70°F) for the adults to survive (Williams 2006). Embryos are less tolerant of warm water than adults, and as with fall-run Chinook salmon, spawning begins when water cools below 57°F to 59°F. The spring-run Chinook salmon lifecycle is well adapted to streams with snowmelt runoff and access to high elevation holding and spawning habitat (Williams 2006).

Rainbow Trout and Central Valley Steelhead

Rainbow trout and steelhead are the same species, *O. mykiss*, but distinguished by their behavior. All forms of the species spend the first part of their lives in freshwater, but steelhead are anadromous, migrating to the ocean (35 ppt) after 1–3 years. Rainbow trout are the most abundant and wide-spread native salmonids in western North America and recreationally important species. Hatchery and naturally produced populations of rainbow trout occur in reservoirs, lakes, and streams above impassable dams throughout California, and are sustained by both stocking and natural reproduction. However, mixing of rainbow trout in hatcheries and indiscriminate stocking have blurred distinctions among populations (Moyle 2002). For the purposes of this document, rainbow trout is used to distinguish *O. mykiss* populations above impassable dams, while steelhead is used to distinguish populations below these dams. However, it should be recognized that both forms can occur in *O. mykiss* populations with access to the ocean.

The Central Valley steelhead, a distinct population segment (DPS) of West Coast steelhead, is a special-status species that is listed as threatened under ESA (Moyle 2002), but not under CESA. The general habitat requirements of Central Valley steelhead also apply to rainbow trout as defined here. Historically, Central Valley steelhead were widely distributed throughout the Sacramento River and SJR. Historical Central Valley steelhead run sizes are difficult to estimate given the paucity of data, but may have approached one to two million adults annually (McEwan 2001). Adult steelhead typically migrate upstream and spawn during the winter months when river flows are

~~[7] Implementation of the settlement and the Friant Dam release flows required by the San Joaquin River Restoration Program are expected to increase the existing SJR flows at Stevinson in the near future.~~

high and water clarity is low. Unlike Chinook salmon, adult steelhead may not die after spawning and can return to coastal waters. In addition, steelhead frequently inhabit streams and rivers that are difficult to access and survey. Thus, information on the trends in steelhead abundance in the Central Valley has primarily been limited to observations at fish ladders and weirs (McEwan 2001).

Until recently, Central Valley steelhead were thought to be extirpated from the SJR Basin. However, recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras Rivers and other streams previously thought to be devoid of steelhead (McEwan 2001; Zimmerman et al. 2008). 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 steelhead are widespread throughout accessible streams and rivers in the Central Valley (Good et al. 2005). Non-hatchery stocks of rainbow trout that have anadromous components within them are found in the Upper Sacramento River and its tributaries: Mill, Deer, and Butte Creeks; and the Feather, Yuba, American, Mokelumne, and Calaveras Rivers (McEwan 2001).

~~The most recent status review~~A recent evaluation of the Central Valley steelhead DPS (NMFS 2009a) found that the status of the population appears to have worsened since the 2005 status review (Good et al. 2005), when it was considered to be in danger of extinction. Analysis of data from the Chipps Island monitoring program indicates that natural steelhead production has continued to decline, and hatchery-origin fish represent an increasing fraction of the juvenile production in the Central Valley. In recent years, the proportion of hatchery-produced juvenile steelhead in the catch has exceeded 90 percent, and in 2010 it was 95 percent of the catch. This recent trend appears to be related to poor ocean conditions and dry hydrology in the Central Valley (NMFS 2009b). Population trends for Central Valley steelhead are discussed in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*.

Central Valley steelhead in the plan area can begin upstream migration as early as July and continue through April, with upstream migration peaking between October and February. Central Valley steelhead spawn downstream of impassable dams on the three eastside tributaries and the LSJR, similar to SJR Basin fall-run Chinook salmon (NMFS 2009c). Spawning typically occurs from December through ~~June~~ April and peaks between January and March (NMFS 2009a; McBain and Trush 2002; Table 3.14 of Appendix C) where cool (30°F–52°F), well-oxygenated water is available year-round (McEwan and Jackson 1996). Once spawning is complete, adult Central Valley steelhead may return to the ocean in preparation for a subsequent year, while others may die after spawning.

Depending on water temperature, Central Valley steelhead eggs may incubate in redds from 4 weeks to 4 months before hatching as alevins (McEwan 2001; NMFS 2009c). When water temperatures are warmer, less incubation time is needed and, conversely, when water temperatures are cooler, more incubation time is needed. Central Valley steelhead eggs that typically incubate at 50°F–59°F hatch in about 4 weeks, and alevins emerge from the gravel 4–8 weeks after hatching (Shapovalov and Taft 1954; Reynolds et al. 1993). Juvenile Central Valley steelhead rear for 1–3 years (1 percent spend 3 years) in cool, clear, fast flowing, permanent freshwater streams and rivers where riffles predominate over pools (CDFG 2010). Some juveniles may utilize tidal marsh areas, nontidal freshwater marshes, and other shallow water areas in the Bay-Delta as rearing areas for short periods prior to their final emigration to sea (NMFS 2009a).

Juveniles are dependent on suitable rearing habitat for an extended amount of time prior to outmigration, especially during the summer when suitable conditions are most restricted due to a host of stressors such as temperature, water quality and quantity, and ability to access floodplains. Diversity and richness of habitat and food sources, particularly in shallow water habitats, allows juveniles to grow larger before ocean entry, thereby increasing their chances of survival in the marine environment. A longer rearing period for juvenile Central Valley steelhead allows for them to be considerably larger and have a greater swimming ability than Chinook salmon juveniles during outmigration (ICF International 2012).

Central Valley steelhead juveniles generally begin outmigration anywhere between late December and July, with peaks occurring between March and April (McBain and Trush 2002; Table 3.14 of Appendix C; USBR 2008). As with Chinook salmon, juveniles undergo smoltification during outmigration. Central Valley steelhead smoltification has been reported to occur successfully at 44–52°F (Myrick and Cech 2001; USBR 2008).

Green Sturgeon

The North American green sturgeon (southern DPS) is a special-status species listed under ESA as threatened and identified as a California species of special concern (Table 7-2).

North American green sturgeon range along the Pacific coast from Mexico to Alaska (Colway and Stevenson 2007; Moyle 2002). Spawning populations of green sturgeon are currently found in three river systems: the Sacramento and Klamath Rivers in California and the Rogue River in southern Oregon (NMFS 2009a). More recently, spawning occurred in June in the Feather River during 2011 (Seesholtz et al 2014). The southern DPS of green sturgeon includes all green sturgeon populations south of the Eel River, with the ~~only known~~majority of the spawning population being in the Sacramento River (NMFS 2009a) and limited spawning in the Feather River (Seesholtz et al. 2014). Within the Central Valley, green sturgeon have been observed in San Francisco Bay, San Pablo Bay, Suisun Bay, the Delta, Sacramento River, Feather River, Yuba River, Sutter Bypass, and Yolo Bypass (74 FR 52300; Israel and Klimley 2008; Moyle 2002; Gleason et al. 2008; Dubois et al. 2009, 2010, 2011, 2012; NMFS 2005; NMFS 2010). Currently, spawning is limited to the Feather River (Seesholtz et al. 2014) and the Sacramento Rivers below Shasta and, Keswick Dams, which block passage of green sturgeon to historic spawning areas above the dams (NMFS 2005). It is suspected that green sturgeon once spawned in the SJR but have since been extirpated (Moyle 2002; Israel and Klimley 2008). Moyle (2002) suggested that reproduction may have taken place in the SJR because ~~adults~~ young green sturgeon have been captured at Santa Clara Shoal and Brannan Island. Egg and larval green sturgeon are confined to freshwater portions of the Sacramento River, while juvenile and sub-adult green sturgeon occur in riverine, subtidal, and intertidal habitats in the Lower Sacramento River and Bay-Delta (Israel and Klimley 2008).

Musick et al. (2000) suggest that the abundance of North American green sturgeon populations has declined as much as 88 percent. Based on the incidental capture of green sturgeon during surveys for white sturgeon, CDFG (2002) estimated that green sturgeon abundance in the Bay-Delta estuary ranged from 175 (1993) to more than 8,400 (2001) adults between 1954 and 2001. However, these estimates are uncertain and subject to the inherent biases of the sampling methods (NMFS 2009a). A decline in abundance is indicated by reductions in the average number of juvenile green sturgeon salvaged at the state and federal pumping facilities in recent years compared with annual salvage estimates before the mid-1980s (NMFS 2009a). A decline in abundance of green and white sturgeon since the 1960s is also evident from a reduction in the number of green and white sturgeon salvaged per acre-foot (AF) of water exported (April 5, 2005, 70 FR 17386). A recent genetic analysis indicated that spawning populations above Red Bluff Diversion Dam ranged from 32 to 124 spawning pairs between 2003 and 2006 (Israel and May 2010).

Green sturgeon pass through the San Francisco Bay to the ocean (35 ppt), where they primarily move northward, spending much of their lives in the ocean or in Oregon and Washington estuaries (Kelley et al. 2007). Adult green sturgeon are marine dependent and spends less time in estuarine and freshwater environments. Typically, these fish spend 3–13 years in the ocean before returning to freshwater to spawn (Moyle 2002). The LSJR and Bay-Delta serve as a migratory corridor, feeding area, and juvenile rearing habitat (ICF International 2012). Adult green sturgeon begin their upstream spawning migration into the San Francisco Bay in March, reach Knights Landing during April, and spawn between March and July (Heublein et al. 2006). Spawning typically occurs at temperatures between 46°F and 66°F (8°C–19°C) (Moyle 2002). ~~Maximum~~ Average spawning temperature ~~occurs at~~ was ~~58~~56.3°F (~~14.4~~13.5°C) in the Sacramento River (~~Kohlhorst 1976~~Poytress et al 2015). Preferred spawning habitats for green sturgeon are thought to contain large cobble in deep and cool pools with turbulent water (Adams et al. 2002; Moyle 2002).

Larval green sturgeon exhibit nocturnal activity patterns (Cech et al. 2000) and begin nocturnal downstream migrational movements approximately 10 days after hatching (Kynard et al. 2005). Young green sturgeon appear to rear for the first 1 to 2 months in the Upper Sacramento River between Keswick Dam and Hamilton City (CDFG 2002). Juveniles spend 1–4 years in freshwater and estuarine habitats before they enter the ocean (Nakamoto et al. 1995). Younger fish have a lower salinity tolerance than adults, something that develops at a certain age (Allen et al. 2009).

Delta Smelt

Delta smelt is listed as threatened under ESA and endangered under CESA, and the U.S. Fish and Wildlife Service (USFWS) has designated critical habitat for delta smelt that incorporates the Bay-Delta. Delta smelt is considered one of the species affected by the Pelagic Organism Decline (Sommer et al. 2007).

Delta smelt are small fish (55–70 mm), that rarely live more than 1–2 years, have low fecundity, and are not recreationally or commercially fished. Delta smelt ~~is~~ are endemic to ~~only~~ the Bay-Delta, and individuals generally spend their entire lifecycles in the open surface waters of the Bay-Delta and Suisun Bay. The geographic distribution of delta smelt includes low salinity and freshwater zones of the Bay-Delta system, including the Sacramento River downstream of Isleton, the Cache Slough subregion (Cache Slough-Liberty Island and the Sacramento Deep Water Ship Channel), the SJR downstream of Mossdale, and Suisun Bay and Suisun Marsh (Moyle 2002) and also the lower Napa River. Delta smelt are a euryhaline fish (occurring over a wide range of salinities) that are rarely found in water more than 10–12 ppt salinity; therefore, its distribution is thought to be related largely to freshwater flows into the Bay-Delta (Bennett 2005; Moyle 2002).

Delta smelt typically migrate December–March in response to ~~“first flush”~~precipitation events that increase flow and turbidity in the Delta (Sommer et al. 2011). However, there is evidence of year-round residence of delta smelt in the northwestern Delta (Cache Slough region) (Nobriga et al. 2008; Lehman et al. 2010), possibly because turbidity and prey abundance are sufficient to support them (Sommer et al. 2004; Lehman et al. 2010). Spawning does not begin until late February, with peaks from March–May (Bennett 2005). Embryonic development is reported to last 11–13 days at 57°F–61°F (Moyle 2002). Baskerville-Bridges et al. (2004) reported hatching of delta smelt eggs after 8–10 days at 59°–62.5°F. Although spawning may occur at up to 71.5°F, hatching success of the larvae is very low at that high of temperatures (Bennett 2005). Spawning occurs primarily in sloughs and shallow edge areas in the Sacramento and Mokelumne Rivers and the SJR, the western and southern Delta, Suisun Bay, Suisun Marsh, and occasionally, in wet years, the Napa River (Wang 2007). Delta smelt have been found on the Sacramento River as far upstream as the confluence with American River and as far downstream as Mossdale on the SJR (Moyle 2002; Hobbs et al. 2007).

Upon hatching, larvae are semi-buoyant, staying near the bottom (Bennett et al. 2002), and are transported downstream to the low salinity habitat. However, recent evidence of year-round residence of delta smelt in the areas around Cache Slough indicates that downstream transport is not necessary for successful rearing. Within a few weeks, larvae develop an air bladder and become pelagic (living or occurring in the open sea) (Moyle and Bennett et al. 2002). Young-of-the-year delta smelt (i.e., production from spawning in the current year) rear from late spring through fall and early winter. Once in the rearing stage, growth is rapid, and juvenile fish are commonly 40–50 mm total length (TL) by early August (Radtke 1966). They reach adult size by early fall. Delta smelt growth during the fall months slows considerably (only 3–9 mm total), presumably because most of the energy ingested is being directed towards gonadal development (Radtke 1966; Mager 2004). Delta smelt are visual feeders (Baskerville-Bridges et al. 2004), swimming near the water surface and feeding on zooplankton in the wild (USFWS 2008). Feeding is size-based, with first-feeding larvae (5–8 mm standard length [SL]) consuming sub-adult cyclopoid and calanoid copepods (Nobriga 2002) and older larvae (10–15 mm SL) consuming adult copepods (Nobriga 1998).

Delta smelt ~~seem to~~ prefer water with high turbidity, based on a negative correlation between water quality and the frequencies of delta smelt occurrence in survey trawls during summer, fall, and early winter. For example, the likelihood of delta smelt occurrence in trawls at a given sampling station decreases with increasing Secchi depth[8] (Feyrer et al. 2007; Nobriga et al. 2008). This is consistent with behavioral observations of captive delta smelt. Few daylight trawls catch delta smelt at Secchi depths over 0.5 m and capture probabilities are highest at 0.40 m depth or less. Delta smelt's preference for turbid water may be related to increased foraging efficiency (Baskerville-Bridges et al 2004) and reduced risk of predation (~~NMFS~~ USFWS ~~2009a~~2008).

Temperature and salinity also affect delta smelt distribution. Swanson et al. (2000) indicate delta smelt tolerate temperatures between 46.5°F and 77°F; however, warmer water temperatures of more than 77°F restrict their distribution more than colder water temperatures. Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures are usually less than 77°F in summer (Nobriga et al. 2008). Suisun Bay and Suisun Marsh may be beneficial habitat for delta smelt due to salinity, which ranges from 0.5–10 ppt, though recent evidence suggests their presence may be more due to the food web. Typically, delta smelt follow X2,[9] low salinity habitat <2ppt that has decreased considerably in recent years (Feyrer et al. 2011).

[8] Secchi depth is a measurement of water clarity. A small white Secchi disk is lowered into the water column until it is no longer visible. Increased Secchi depth is an indicator of clear or less turbid water.

[9] X2 is the location of the 2 parts per thousand salinity contour (isohaline), 1 meter off the bottom of the estuary measured in kilometers upstream from the Golden Gate Bridge. The abundance of several estuarine species has been correlated with X2. In the 2006 Bay-Delta Plan, a salinity value—or electrical conductivity (EC) value—of 2.64 millimhos/centimeter (mmhos/cm) is used to represent the X2 location. Note, in this SED, EC is generally expressed in deciSiemens per meter (dS/m). The conversion is 1 mmhos/cm = 1 dS/cm.

Longfin Smelt

Longfin smelt is a special-status species that is ~~not~~ a candidate for ~~listed~~ listing under ESA, ~~but~~ and is listed as threatened under CESA (Baxter et al. 2009; California Fish and Game Commission 2009). Longfin smelt is considered one of the species affected by the Pelagic Organism Decline (Sommer et al. 2007).

Populations of longfin smelt in California historically have been known to occur from the Bay-Delta, Humboldt Bay, the Eel River estuary, and the Klamath River estuary (Emmett et al. 1991). Longfin smelt occur throughout the Bay-Delta, including the Cache Slough region and Yolo Bypass. Adults occur seasonally as far downstream as the South Bay, but they are concentrated in Suisun, San Pablo, and North San Francisco Bays (Baxter 1999a). Longfin smelt generally have a 2-year lifecycle. During this second year, they primarily inhabit the San Francisco Bay, but are thought to be pelagic (~~ocean-going~~living or occurring in open water). Thus, they have a salinity tolerance up to 35 ppt, though this is lower in younger life stages.

Spawning typically takes place as early as November and may extend into June, peaking between February and April. Spawning occurs in fresh or slightly brackish water over aquatic vegetation or sandy-gravel substrates when temperatures drop roughly below 64.5°F (Baxter et al. 2009). Based on their distribution patterns during the spawning season, the main spawning area appears to be downstream of Rio Vista on the Sacramento River (ICF International 2012). Spawning probably also occurs in the eastern portion of Suisun Bay and, in some years, the larger sloughs of Suisun Marsh. (Hobbs. et al. 2010). Historically, spawning probably also occurred in the SJR. Recent catches of longfin smelt in the SJR have been extremely low, potentially as a result of low flows in the river, which contribute to habitat degradation, unsuitable water temperature, and poor water quality (Moyle 2002).

Longfin smelt eggs typically hatch in February and disperse downstream (Wang 2007). The principal nursery habitat for larvae is the Suisun and San Pablo Bays (Meng and Matern 2001). However, the distribution of eggs may be shifted upstream in years of low outflow (Moyle 2002). Mortality for longfin smelt is highest February–May when larvae complete fin development (Wang et al. 2007), begin feeding, and are more exposed to predators. A positive relationship is observed between longfin smelt abundance and Delta outflow during the designated critical outflow period for longfin smelt between December and May (Stevens and Miller 1983; Kimmerer 2002), also suggesting a relationship to estuarine salinity. Longfin smelt have salinity tolerance up to ocean salinities, but are generally found between 0–20 ppt. Like delta smelt, longfin smelt larvae, in particular, are mostly found at <10 ppt, focusing near X2 (Hobbs et al. 2010; Kimmerer 2002).

Sacramento Splittail

Sacramento splittail is a special-status species that is not listed as threatened or endangered under ESA or CESA but is a California species of special concern. Sacramento splittail support a seasonal recreational fishery.

Sacramento splittail was listed as a federally threatened species but was delisted September 22, 2003. It is a large minnow endemic to the Bay-Delta and is primarily found in~~confined to~~ the lower reaches of the Sacramento River and SJR, the Delta, Suisun and Napa Marshes, and tributaries of northern San Pablo Bay (Wang 1986; Moyle et al. 1995). During relatively wet years, splittail may be found farther upstream, including as far south as Salt Slough, upstream of the Merced River confluence in the SJR (Baxter 1999b and 2000, as cited in Moyle

2002). Although the Sacramento splittail generally abides in freshwater, the adults and sub-adults have a moderate to high tolerance for saline waters (up to 10–18 ppt) and are therefore considered an estuarine species. The salt tolerance of Sacramento splittail larvae is unknown (Meng and Moyle 1995; Moyle et al. 2004).

The decline in abundance of Sacramento splittail is attributable to the loss or alteration of lowland habitats (Young and Cech Jr. 1996). Specifically, the decline in abundance has been attributed to the reduction of the Delta outflow as a result of dam construction and upstream diversions and the changes in hydrodynamics in the Delta as a result of Delta exports (CDFG 1992a; Moyle 2002). High salinities are thought to restrict the downstream range of Sacramento splittail, and without adequate Delta outflow, juveniles are not able to rear in appropriate nursery areas (Young and Cech Jr. 1996).

Sacramento splittail have a high reproductive capacity. Individuals live 5–7 years and generally begin spawning at 1–2 years. Spawning, which seems to be triggered by increasing water temperatures and hours of sunlight, occurs over beds of submerged vegetation in slow-moving stretches of water, such as flooded terrestrial areas and dead-end sloughs (Sommer et al. 1997). Large-scale spawning and juvenile recruitment occurs only in years with significant protracted (greater than or equal to 30 days) floodplain inundation (~~McBain and Trush 2002~~Moyle et al. 2007), particularly in the Sutter and Yolo Bypasses (Meng and Moyle 1995; Sommer et al. 1997). Spawning also occurs in perennial marshes and along vegetated edges of the Sacramento River and SJR (Moyle et al. 2004). Adults spawn from late February through early July, most frequently during March and April (Wang 1986), and occasionally as early as January (Feyrer 2004).

Hatched larvae remain in shallow, weedy areas until they move to deeper offshore habitat later in the summer (Wang 1986). Young Sacramento splittail may occur in shallow and open waters of the Bay-Delta and San Pablo Bay, but they are particularly abundant in the northern and western Delta.

The diet of Sacramento splittail larvae up to 15 mm in length is dominated by zooplankton, primarily cladocerans, with some copepods, rotifers, and chironomids present in small amounts; chironomids become important after splittail reach 15 mm in length (Kurth and Nobriga 2001; Moyle 2002). In the 1980s, the diet of splittail age 1 and above included the native mysid shrimp, *Neomysis*, amphipods, and harpacticoid copepods, with detritus accounting for more than half the diet (Feyrer et al. 2003). After the invasion of the overbite clam *Potamocorbula amurensis* in the 1980s and the crash of *Neomysis*, clams, especially *Potamocorbula*, became an important component of the diet (Feyrer et al. 2003).

Kern Brook Lamprey

Kern brook lamprey is not listed as threatened or endangered under ESA or CESA but is a California species of special concern.

This species was first discovered in the Friant-Kern Canal, but it has since been found in the lower reaches of the Merced River, Kaweah River, Kings River, and SJR downstream to Kerckhoff Dam (Wang 1986). Based on the life history of other non-parasitic brook lampreys, Kern brook lampreys are thought to live for 4–5 years as ammocoetes (larvae) before metamorphosing into adults. Principal habitats of Kern brook lamprey are silty backwaters of large rivers in the foothill regions (mean elevation = 440 ft; range = 100–1,100 ft). In summer, ammocoetes are usually found in shallow pools along the edges of runs with slight current, depths of 12–45 inches, and water temperatures rarely exceeding 25°C (77°F). Ammocoetes appear to prefer sand/mud substrate where they remain buried with the head protruding above the substrate and feed by filtering diatoms and other microorganisms from the water. Adults likely require coarser gravel-rubble substrate for spawning (Moyle et al. 1995).

River Lamprey

River lamprey is not listed as threatened or endangered under ESA or CESA but is a species of special concern in California.

The biology of the river lamprey has not been well studied in California. As a result, much of this discussion is derived from information known for river lamprey from British Columbia. Thus, timing and life history events may be dissimilar due to differences in abiotic factors that are unique to California river systems (e.g., temperature, hydrology). River lamprey appear to be more abundant in the Lower Sacramento River, LSJR, and Stanislaus and Tuolumne Rivers than in other streams in California (Moyle 2002) such as Mill Creek (Wang 1986).

River lamprey begin their migration into freshwater in the fall towards suitable spawning areas upstream. However, river lamprey can spend their entire lives in freshwater as adults (such as the land-locked population of Sonoma Creek) (Wang 1986). Spawning occurs February–May in gravelly riffles. The eggs hatch into ammocoetes that remain in fresh water for approximately 3–5 years in silty or sandy low-velocity backwaters or stream edges where they bury into the substrate and filter-feed on algae, detritus, and micro-organisms (Moyle et al. 1995; USBR 2011).

During summer, ammocoetes change into juveniles and then adults at approximately 12 centimeter (cm) TL. This process takes 9–10 months, during which individuals may shrink in length by up to 20 percent (Moyle 2002). Adults spend approximately 3–4 months in the ocean, where they grow rapidly to 25–31 cm TL. If the ammocoete stage is 3–5 years, the total life span of river lamprey is estimated to be 6–7 years (Moyle et al. 1995; Moyle 2002).

River lamprey adults are parasitic during both freshwater and saltwater phases (Wang 1986). Adults feed on a variety of host fish species that are small to intermediate size (4–12 inches TL) (Moyle et al. 1995).

California Roach

California roach are sub-divided into several subspecies, two of which occur in the Sacramento–San Joaquin River Basin: the Sacramento-San Joaquin roach and the Red Hills roach (Moyle 2002). The Sacramento–San Joaquin roach is widely distributed throughout Sacramento and SJR drainages, while the Red Hills roach is known to occur in Horton Creek and other small streams near Sonora, California, in the Tuolumne River drainage. This species is recognized as a California species of special concern.

California roach frequent a variety of habitats, are generally found in small, warm streams, and are most abundant in mid-elevation streams in the Sierra Nevada foothills. Roach are tolerant of relatively high temperatures (86°F–95°F) and low oxygen levels (1–2 parts per million [ppm]). They also thrive in cold, clear, well-aerated streams, in heavily modified habitats, and in the main channels of rivers (Brown and Moyle 1993), such as the Tuolumne River (Moyle 2002).

Roach are omnivorous and are largely benthic feeders. However, in the Tuolumne River (below Preston Falls), they feed in fairly fast current on drift organisms, such as terrestrial insects. In larger streams, such as the North Fork Stanislaus River, aquatic insects may dominate their diets year-round (Moyle 2002).

Roach usually mature after reaching 45–60 mm TL at 2–3 years of age. Spawning is from March through early July, depending on water temperature, usually occurring when temperatures exceed 16°C (60.8°F) (Moyle 2002).

Pacific Lamprey

Pacific lamprey is not listed as threated or endangered under ESA or CESA but is a federal species of concern.

In the Central Valley, Pacific lamprey occur in the Lower Sacramento River and SJR and many of their tributaries, including the three eastside tributaries (Brown and Moyle 1993). Similar to the river lamprey, the majority of Pacific lamprey spend the predatory phase of their lives in the ocean (35 ppt) (USBR 2011). Pacific lamprey begin their migration into freshwater towards upstream spawning areas primarily between early March and late June. Spawning habitat requirements are thought to be similar to those of salmonids (Moyle 2002).

Pacific lamprey construct nests in gravelly substrates at a depth of 30–150 cm with moderately swift currents and water temperatures of typically 12°C–18°C (53.5°F–64.5°F). The eggs hatch into ammocoetes after 19 days at 59°F and then drift downstream to suitable areas in sand or mud. Ammocoetes remain in fresh water for approximately 5–7 years, where they bury into silt and mud and feed on algae, organic material, and microorganisms in various locations. Ammocoetes change into juveniles when they reach 14–16 cm TL. Downstream migration begins when the change is complete and generally coincides with high flow events in winter and spring (Moyle 2002; USBR 2011).

Hardhead

Hardhead is a special-status species that is not listed as threated or endangered under ESA or CESA but is a California species of special concern.

Hardhead is widely distributed in low- to mid-elevation streams in the Sacramento River and SJR Basins, scattered in tributary streams, and absent from valley reaches of the LSJR (Brown and Moyle 1993). Hardhead is also abundant in a few mid-elevation reservoirs used largely for hydroelectric power generation, such as Redinger and Kerkhoff Reservoirs (Moyle 2002).

Optimal temperatures for hardhead are determined to be 75°F–83°F, and most streams where hardhead are present have summer temperatures in excess of 68°F. At higher temperatures, hardhead is relatively intolerant of low oxygen levels, a factor that may limit its distribution to well-oxygenated streams and reservoir surface waters (Moyle 2002). Hardhead prefers clear, deep (more than 80 cm) pools and runs with sand-gravel-boulder substrates and slow velocities (20–40 cm per second). These fish are primarily riverine or freshwater; hardhead are always found in association with Sacramento pikeminnow (*Ptychocheilus grandis*) and usually with Sacramento sucker (*Catostomus occidentalis*) (Moyle 2002). Hardhead tend to be absent from streams where introduced species, especially centrarchids, predominate (Brown and Moyle 1993).

Hardhead mature in their third year and spawn mainly in April and May (Grant and Maslin 1999). Juvenile recruitment patterns suggest that spawning may extend into August in some foothill streams. Hardhead from larger rivers or reservoirs may migrate 30–75 kilometers (km) or more upstream in April and May, usually into tributary streams (Moyle et al. 1995). In small streams, hardhead may move only a short distance from their home pools for spawning, either upstream or downstream (Grant and Maslin 1999).

Hardhead are omnivores that consume drifting insects and algae in the water column and forage for benthic invertebrates and aquatic plant material on the bottom of the river floor (Alley and Li 1977).

Largemouth Bass

Largemouth bass is not a special-status species. A nonnative, it was first introduced into California in 1874, it spread to suitable habitat throughout the state and has become an important warmwater game fish in the state (Dill and Cordone 1997; Moyle 2002).

Largemouth bass are found in warm, quiet water with low turbidity and aquatic plants, such as farm ponds, lakes, reservoirs, sloughs, and river backwaters. Adult bass remain close to shore and usually are abundant in water 1–3 m deep near submerged rocks or branches. Young-of-the-year largemouth bass also usually stay close to shore in schools but occasionally swim about in the open (Moyle 2002).

Many California reservoirs and farm ponds provide excellent largemouth bass fishing with sizable populations of large, fast-growing fish. In reservoirs, the manipulation of water levels for water supply or hydropower production influences bass populations by affecting food availability and spawning success (Moyle 2002). However, largemouth bass are largely more tolerant to environmental stressors, such as the change in water levels in reservoirs, than native special-status fishes (Schindler et al. 1997; Moyle 2002).

Largemouth bass tolerate extreme water quality conditions, such as temperatures of 96.8°F–98.6°F with dissolved oxygen (DO) concentrations as low as 1 milligram per liter. Water temperatures optimum for growth range from 77°F–86°F (Moyle 2002). Very little growth occurs at temperatures below 59°F or above 96.8°F (Stuber et al. 1982).

Optimal riverine habitat for largemouth bass consists of large, slow-moving rivers or pools with fine-grained (sand or mud) substrates, some aquatic vegetation, and relatively clear water. Optimal velocities are generally less than 0.2 feet/second (ft/s), and velocities more than 0.34 ft/s are avoided. Velocities of over 0.66 ft/s are believed to be unsuitable (Stuber et al. 1982).

Largemouth bass spawn for the first time during their second or third spring, when they are approximately 180–210 mm. Spawning begins in March or April when water temperatures reach 59°F–60.8°F and may continue through June when water temperatures up to 75.2°F (Moyle 2002; ICF International 2012). Males build nests in a wide variety of substrates, including sand, mud, cobble, and vegetation, and gravel. Gravel seems to be preferred, while silty substrates are unsuitable (Stuber et al. 1982). Rising waters in reservoirs may cause active nests to be located as deep as 4–5 m. The eggs adhere to the nest substrate and hatch in 2–5 days (Moyle 2002). They are brackish water tolerant but tend to stay in freshwater and can persist in waters with low DO content (Moyle 2002).

For the first month or two after hatching, the fry feed mainly on rotifers and small crustaceans, but by the time they are 50–60 mm, they feed largely on aquatic insects and fish fry, including those of their own species. Once largemouth bass exceed 100–125 mm, they feed principally on fishes; however, prey preferences can vary from year to year (Moyle 2002).

Striped Bass

Striped bass, an introduced species, is not a special-status species but supports a popular and economically important recreational fishery. It is considered one of the species affected by the Pelagic Organism Decline (Sommer et al. 2007).

Striped bass are native to the Atlantic Coast of North America and was introduced to California in 1879 (Dill and Cordone 1997; Moyle 2002). Since being introduced, striped bass have become widespread in the Bay-Delta as both juveniles and adults. The species can also be found in the larger river systems downstream of impassible dams and the LSJR (Baxter et al. 2008). There is a landlocked, self-sustaining population in Millerton Reservoir (Moyle 2002). Striped bass are anadromous, spending the majority of their lives in saltwater (35 ppt) and returning to freshwater to spawn. When not migrating, the population located in the Bay-Delta is concentrated in San Pablo Bay, San Francisco Bay, and the ocean, but only within approximately 40 miles of the Golden Gate Bridge (Moyle 2002). Striped bass spawn in the Bay-Delta and lower reaches of the Sacramento River and SJR, including their tributaries. Spawning usually begins in April or May when water temperatures reach 60°F and continues sporadically over 3–5 weeks. It peaks in May and June, depending on the interaction of three factors: temperature, flow, and salinity (Farley 1966). Optimum temperatures appear to be roughly between 59°F and 68°F. Successful spawning in the LSJR above Vernalis occurs mainly during years of high flow when the large volume of runoff dilutes salty irrigation wastewater that normally comprises much of the river flow. In years of lower flow, spawning occurs in the Bay-Delta itself. The interaction of these factors produces spawning habitat in the LSJR and the southern Delta from sloughs near Venice Island down to Antioch (Farley 1966; Moyle 2002).

Eggs hatch in approximately 2 days at 64.5°F–66°F, and the larvae stage lasts an additional 4–5 weeks. Embryos and larvae drift into the Bay-Delta[10] and disperse as they grow. Larvae and juveniles feed primarily on invertebrates but switch their diet mainly to fish when transitioning to sub-adulthood. Modeling studies indicate striped bass predation on salmonids has the potential to be high (Nobriga and Feyrer 2007; Lobonschefsky et al. 2012).

White Sturgeon

While not a special-status species, white sturgeon is a native and recreationally important species in the Bay-Delta that inhabits riverine, estuarine, and marine habitats.

Historically, white sturgeon ranged from Ensenada, Mexico, to the Gulf of Alaska. Currently, spawning populations are found in the Sacramento–San Joaquin, Columbia, Snake, and Fraser River systems (Moyle 2002). In California, white sturgeon are most abundant in the Bay-Delta and Sacramento River (Moyle 2002), but they have also been observed in the SJR system~~, particularly in wet years~~ (CDFG 2002; Beamesderfer et al. 2004; Jackson et al. 2016). Known spawning areas include the Sacramento River between the Red Bluff Diversion Dam and Jelly's Ferry Bridge (river mile [RM] 267) in areas characterized by swift currents and deep pools with gravel (CDFG 2002), and recent egg sampling surveys have detected spawning in the mainstem SJR as far upstream as Grayson (RM 142) (Jackson and Van Eenennaam 2013; Jackson et al. 2016).

White sturgeon spend most of their lives in the brackish portions of the upper estuary, although small number of individuals move extensively in the ocean (35 ppt); they are thought to be anadromous (Moyle 2002; Welch et al. 2006). Individuals can live over 100 years and can grow to over 19.7 ft (6 m), but sturgeon greater than 27 years old and over 6.6 ft (2 m) are rare (Moyle 2002). Male white sturgeon reach sexual maturity at 10–12 years of age, and females reach sexual maturity at 12–16 years (Moyle 2002). White sturgeon can spawn multiple times throughout their

[10] Larval striped bass are associated with X2.

lives. Males are believed to spawn every 1–2 years, whereas females spawn every 2–4 years (Moyle 2002). Spawning typically occurs between February and June, when temperatures are 46°F–66°F (8°C–19°C) (Moyle 2002). Maximum spawning occurs at 58°F (14.4°C) in the Sacramento River (Kohlhorst 1976). It is thought that adults broadcast spawn in the water column in areas with swift current.

Fertilized eggs sink and attach to the gravel bottom, where they hatch after 4 days at 61°F (16°C) (Beer 1981), though hatching may take up to 2 weeks at lower water temperatures. Temperatures suitable for incubation and hatching range from 46°F to 68°F (ICF International 2012). Newly hatched larvae generally remain in the gravel for 7–10 days before emergence into the water column (Moyle 2002). Larvae are yolk sac dependent for approximately 7–10 days until the yolk sac is absorbed, at which time they begin actively feeding on amphipods and other small benthic macroinvertebrates (Wang 1986). Juvenile white sturgeon feed primarily on algae, aquatic insects, small clams, fish eggs, and crustaceans, but their diet becomes more varied with age (Wang 1986; Moyle 2002). Since the invasion by the overbite clam in the western Delta and Suisun Bay during the late 1980s, the clam has become a major component of the diet of juvenile and adult white sturgeon.

Spawning success varies from year to year, but is most likely related to temperature and Delta outflow. Spring flows in wet years may be the single most significant factor for white sturgeon year class strength (Beamesderfer et al. 2005). Although the mechanism is unknown, it is hypothesized that higher flows may help disperse young sturgeon downstream, provide increased freshwater rearing habitat, increase spawning activity cued by higher upstream flows, increase nutrients in nursery areas, or increase downstream migration rate and survival through reduced exposure time to predators (USFWS 1995).

American Shad

American shad is not a special-status species. American shad was introduced into the Sacramento River in the late 1800s and supported a commercial fishery by 1879 (Reynolds et al. 1993). Once established, American shad quickly spread into other rivers along the West Coast, including the LSJR (Dill and Cordone 1997). American shad population abundance in the Central Valley has declined from historical levels. The decline is attributed to increased water diversions and changing ocean conditions. The limited population data available also appears to indicate that American shad recruitment is lower during drier years (when Delta outflow is low) (Moyle 2002). Drought conditions are often accompanied by increases of temperature, causing juveniles rearing in the Bay-Delta and LSJR to become stressed.

The geographic distribution of American shad includes the Delta and Sacramento River, American River, Feather River, Yuba River, and SJR. Mature American shad start appearing in the LSJR in late April, with increased recruitment occurring in wetter years. Peak spawning occurs from mid-~~May~~ June to mid-~~June~~ July in Millerton Reservoir at water temperatures of 51.8°F–62.6°F; however, some spawning can occur as late as early September. American shad spawn mostly in main channels of rivers over a wide variety of substrates, although sand and gravel are most commonly used. Depth of the water is usually less than 3 m but can range from 1–10m. Following their first spawning event, American shad will return annually to spawn until they are up to 7 years of age (Moyle 2002).

Depending on water temperatures, larvae hatch from eggs in 3–12 days. Larval American shad are planktonic for about 4 weeks and cannot survive in saltwater (Zydlewski and McCormick 1997). The first several months are usually spent in fresh water, but small shad can live in salinities of up to

20 ppt. American shad seem to prefer temperatures of 62.6°F–77°F during the rearing stage (Stier and Crance 1985; Moyle 2002).

While in the Bay-Delta, young American shad feed on zooplankton, especially mysid shrimp, copepods, and amphipods. Although they feed primarily in the water column, they are opportunistic and will also take abundant bottom organisms and surface insects. Entry into saltwater takes place in September, October, and November, but may start as early as June, especially in wet years when outflows are high. Peak salvage of juvenile shad at the southern Delta pumping plants generally occurs during this time (Moyle 2002).

Kokanee

Kokanee is not a special-status species. It was brought from Idaho to California in 1941 (Moyle 2002). Kokanee is the nonanadromous form of sockeye salmon; individuals mature in lakes and reservoirs rather than in the ocean. Kokanee prefer well-oxygenated, open waters of lakes and reservoirs, roughly 1–3 m from the water's surface where temperatures range between 50°F and 59°F. Most kokanee populations mature in 4 years; however, populations can mature in as little as 2 years or take as many as 7 years (Moyle 2002). Like other salmonid species, once kokanee mature, they typically return to the stream in which they were hatched as fry (Moyle 2002).

Spawning behavior of kokanee is similar to that of other salmonids (e.g., mate selection, redd construction, death after spawning). Typically, kokanee spawn between August and February; however, they have been observed to spawn as late as April in California. Most spawning takes place in the gravel riffles of small streams a short distance from a lake or reservoir where temperatures are roughly 43°F–55.5°F. Fry typically emerge from the redds in April and June and immediately move to downstream rearing habitat (Moyle 2002).

7.2.2 Reservoirs, Tributaries, and LSJR

This section describes the water bodies comprising the environmental setting for aquatic resources that may be affected by the LSJR alternatives. These water bodies are the major storage reservoirs on the Stanislaus, Tuolumne, and Merced Rivers; the downstream reaches of the Stanislaus, Tuolumne, and Merced Rivers below the rim dams; and the LSJR and southern Delta. For each water body, the indicator species and the baseline environmental stressors affecting aquatic resources are discussed. Table 7-4 summarizes the indicator species found in these geographic locations and their life stages.

Efforts to protect aquatic resources in the SJR Basin, outside the plan area, are currently underway. As discussed in Appendix K, *Revised Water Quality Control Plan*, SJRRP is currently undertaking the restoration of flow to the Upper SJR from Friant Dam to the confluence with the Merced River to restore a self-sustaining Chinook salmon fishery in the river, while reducing or avoiding adverse water supply impacts from restoration flows. Major planning and permitting activities are currently underway, as well as studies and monitoring activities to evaluate the current and future needs of fish in the river. The State Water Resources Control Board (State Water Board) will continue to coordinate adaptive implementation and future changes to the 2006 *Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary* (2006 Bay-Delta Plan) with the SJRRP to assure the protection of fish and wildlife in the SJR Basin. Following full implementation of the SJRRP, the State Water Board will also evaluate whether additional changes should be made to flow, water right, or other requirements to protect fish and wildlife in the SJR.

Stanislaus River

New Melones Reservoir

New Melones Reservoir supports sport fisheries for coldwater and warmwater species, including rainbow trout, brown trout, kokanee, largemouth bass, smallmouth bass, crappie (*Pomoxis* spp.), bluegill (*Lepomis macrochirus*) catfish, minnows, suckers, and carp. Rainbow and brown trout are generally restricted to colder, deeper water during summer, while most of the other species inhabit warmer surface and shallow inshore waters (USBR 2009).

Stanislaus River below New Melones Reservoir

Historically, spring-run Chinook salmon, fall-run Chinook salmon, Central Valley steelhead, and possibly late fall-run Chinook salmon occurred in the Stanislaus River (Yoshiyama et al. 1996, 1998). Salmon and steelhead were abundant in the Merced and Tuolumne Rivers and presumably the Stanislaus River before the Gold Rush began in 1849. Populations declined thereafter in response to dam construction, expansion of commercial fishing, and habitat degradation associated with early hydraulic mining, dredging, and water diversions. Spring-run Chinook salmon are thought to have been extirpated from the Stanislaus River after the construction of Melones Dam in 1926, which blocked access to their historical spawning habitat in the upper watershed (Yoshiyama et al. 1996, 1998). Goodwin Dam, completed in 1913, was passable but became a complete barrier to migration by 1940 and is now the upstream limit of migration for anadromous fish (Stanislaus River Fish Group 2003). These barriers likely had a similar effect on steelhead because of steelhead's dependence on higher elevation streams for holding, spawning, and early rearing.

Today, the only anadromous salmonids in the Lower Stanislaus River supports are fall-run Chinook salmon and steelhead, both of which are currently restricted to the lowermost 58 RMs below Goodwin Dam. Small numbers of adult salmon are observed in the summer, but these may be spring-run strays from the Sacramento River Basin based on the recovery of tagged adults originating from the Feather River Hatchery (Stanislaus River Fish Group 2003). Other anadromous fish species that occur in the Lower Stanislaus River include striped bass, American shad, Pacific lamprey, and river lamprey (Stanislaus River Fish Group et al. 2003). Striped bass and American shad were introduced into the Sacramento and SJR Basin in the late 1880s (Stanislaus River Fish Group et al. 2003).

Table 7-4. Geographic and Seasonal Occurrence of Indicator Fish Species and Life Stages

Life Stage	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Central Valley fall-run Chinook salmon													
Adult migration	Bay-Delta, SJR and three eastside tributaries												
Spawning/incubation	Three eastside tributaries												
Juvenile rearing/emigration	Bay-Delta, SJR and three eastside tributaries												
Central Valley steelhead													
Adult migration	Bay-Delta, SJR and three eastside tributaries												
Spawning/incubation	Three eastside tributaries												
Juvenile rearing	Three eastside tributaries												
Juvenile emigration (age 1+)	Bay-Delta, SJR and three eastside tributaries												
Rainbow trout													
Adult migration (lake to stream)	New Melones, New Don Pedro, Lake McClure and Lake McSwain												
Spawning/incubation	Three eastside tributaries												
Juvenile rearing	Three eastside tributaries												
Largemouth bass													
Spawning/incubation	Bay-Delta, SJR and three eastside tributaries, and reservoirs												
Juvenile rearing to adult	Bay-Delta, SJR and three eastside tributaries, and reservoirs												

Primary occurrence periods considered in impact assessment.

Non-primary occurrence period.

Sources: Style of table a~~A~~dapted from Rosenfield and Baxter 2007; Wang and Brown 1993; USFWS 1996; McEwan 2001; Moyle 2002; Hallock 1989; McBain and Trush 2002; NMFS 2009a; USBR 2008; and USBR 2011.

Note: Federal ESA list accessed January 12, 2012; CDFW special status list accessed January 12, 2012.

Indicator Species

Fall-Run Chinook Salmon

The fall-run Chinook salmon population of the Stanislaus River is maintained by natural production and hatchery strays originating from the Merced River, Mokelumne River, and Sacramento River Basin hatcheries. The California Department of Fish and Wildlife (CDFW [formerly California Department of Fish and Game (CDFG)]) began estimating the number of fall-run Chinook salmon that returned to spawn each year (i.e., spawning escapement) in the Stanislaus River in 1947 (Stanislaus River Fish Group 2003). Since 1947, annual escapement to the Stanislaus River has fluctuated substantially with the highest returns generally occurring during wet periods or after years of relatively high spring flows and the lowest returns generally occurring during dry periods or after years of relatively low flows (Figure 7-1).

Annual escapement of fall-run Chinook salmon was minimally estimated at 4,000–35,000 spawners (average about 11,100) from 1946–1959 before the construction of Tulloch Dam in 1959. In the following 12-year period (1960–1971), the average run size was about 6,000 fish. Fall-run abundances during the 1970s and 1980s ranged up to 13,600 (average about 4,300) spawners annually (CDFG unpublished data). The numbers of spawners returning to the Stanislaus River have been especially low during most of the 1990s—<500 fish annually in 1990–1993, 600–800 fish in 1994–1995, and <200 fish in 1996—but there was a modest increase to 1,500 spawners in 1997 and 2,200 spawners in 1998 (CDFG unpublished data) (Figure 7-1). Estimation of the proportion of hatchery- and natural-origin fall-run Chinook salmon returning to the Central Valley in recent years indicates that returns to the Stanislaus River are dominated by hatchery-origin fish. In 2011, an estimated 83 percent of the run were hatchery-produced fish originating primarily from Mokelumne River Hatchery, Coleman National Fish Hatchery, and Merced River Hatchery (Palmer-Zwahlen and Kormos 2013). Juvenile salmon may occur throughout the Stanislaus River below Goodwin Dam during the primary rearing and emigration period (February–May). Monitoring of downstream movements of juvenile Chinook salmon at Oakdale and Caswell from 1996–2005 revealed a consistent migration pattern characterized by downstream dispersal of newly emerged fry from late January through early March, followed by the emigration of smaller numbers of parr and smolts through mid-June. Peak movements of juveniles generally coincided with rapid increases or peaks in flow (i.e., flow pulses), especially during the fry emigration period (Pyper and Justice 2006).

Steelhead

Steelhead were thought to have been extirpated from their entire historical range in the San Joaquin Valley, but current populations consisting of anadromous and non-anadromous forms survive in the Stanislaus, Tuolumne, and Merced Rivers (NMFS 2009a). Information regarding steelhead numbers on the Stanislaus River is scarce and has typically been gathered incidental to existing monitoring activities for fall-run Chinook salmon. For example, in 2006–2007, 12 steelhead were observed passing through the counting weir (NMFS 2009c). Steelhead smolts have been captured in rotary screw traps at Oakdale and Caswell State Park since 1995 (S. P. Cramer and Associates Inc. 2000, 2001), but the numbers are very low, ranging from 10–30 annually. Most of the steelhead smolts are captured from January to mid-April at a size of 175–300 mm fork length. The distribution and habitat preferences of spawning adults in the Stanislaus River are unknown, but it is presumed that the majority of spawning occurs between Goodwin Dam and Orange Blossom Bridge.

Most of the environmental factors that potentially limit survival and production of fall-run Chinook salmon in the Stanislaus River likely apply to steelhead to some degree. However, because juvenile steelhead rear in the river for 1 or more years before migrating to the ocean, steelhead also require suitable flows and temperatures during the summer months.

Environmental Stressors

Baseline stressors that affect aquatic resources in the Stanislaus River include impassable dams and alteration of the natural flow regime, loss of natural riverine function and morphology, agricultural and urban land uses, gravel mining, predation, and water quality (e.g., contaminants and suspended sediment) (NMFS 2009c).

Flow Regulation

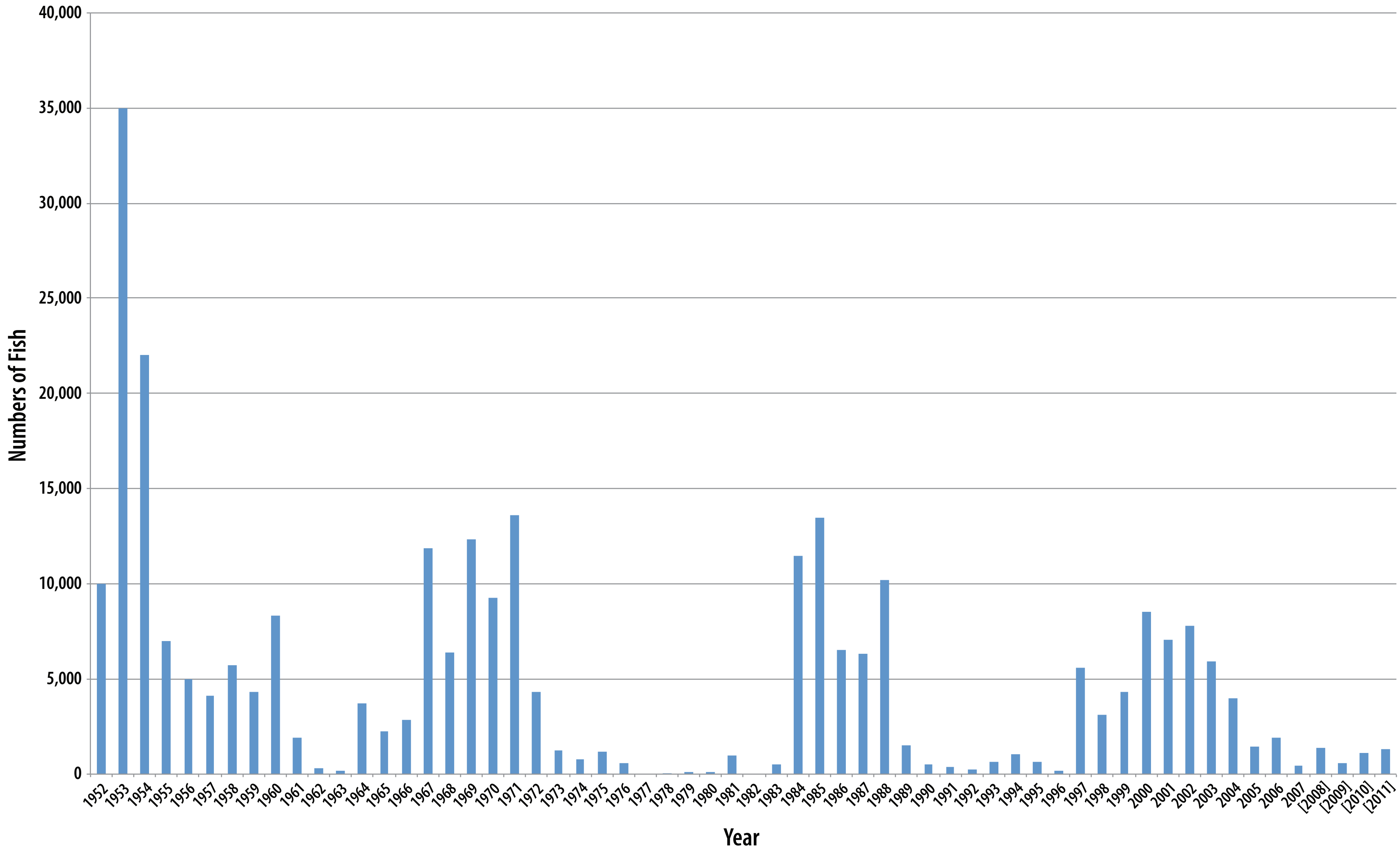
Flow releases for fishery purposes in the Lower Stanislaus River are designated in a 1987 agreement, the New Melones Interim Plan of Operations (IPO) between the U.S. Bureau of Reclamation (USBR) and CDFG. The IPO specifies interim annual flow allocations for fisheries 98,300–302,100 AF, depending on carryover storage at New Melones Reservoir and inflow. Additional flow regulation efforts exist for the Stanislaus River, including D-1422,[11] which imposes flow requirements to provide water quality control and maintain monthly total dissolved solids (TDS) concentration. The Anadromous Fish Restoration Program (AFRP) recommended a instream flow schedule that increased flows during the spring outmigration period (February–May)~~ and was expected to double salmon production for the SJR Basin~~. The National Marine Fisheries Service (NMFS) biological opinion (BO) Stanislaus River reasonable and prudent alternative, including Action 3.1.3 (NMFS BO) provides a minimum flow schedule measured at Goodwin Dam; and the U.S. Army Corps of Engineers (USACE) provides flood control release limits. (For a discussion of the flows, see Chapter 2, *Water Resources*; Chapter 5, *Surface Hydrology and Water Quality*; and Chapter 3 of Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*).

The historical relationship between spring flows during the Chinook salmon rearing and emigration period and subsequent adult abundance has been the basis for a number of analyses and experimental investigations aimed at understanding the factors influencing the population dynamics of Chinook salmon populations in the Stanislaus, Tuolumne, and Merced Rivers (see Appendix C, Chapter 3, *Scientific Basis for Developing Alternative San Joaquin River Flow Objectives*). These investigations suggest that flow in the SJR and the three eastside tributaries has a major influence on juvenile salmon survival between March and June as individuals complete the freshwater rearing, smoltification, and migration stages of their lifecycles.

Habitat Alteration

Since New Melones Dam was constructed in 1979, the quantity and quality of spawning and rearing habitat has also been adversely affected by reductions in the frequency of bed-mobilizing and channel forming flows. The effects include encroachment of riparian vegetation, increased channel

[11] State Water Board's Water Right Decision 1422 (D-1422) approved the permits for USBR's New Melones Reservoir on the Stanislaus River and conditioned the permits on meeting total dissolved solids of 500 parts per million (ppm) (833 mmhos/cm electrical conductivity [EC]) on the SJR at Vernalis.



Source: CDFG, GrandTab

Note: 2008-2011 data are preliminary

Graphics...00427.11 (3-26-2018)

Figure 7-1
Estimates of Annual Escapement of Fall-run Chinook Salmon in the Stanislaus River from 1952 to 2011

incision and bed armoring, and reductions in recruitment of spawning gravel to the active channel (Kondolf et al. 2001).

Impaired geomorphic processes associated with gravel mining and controlled flow releases as a result of dam operations are considered a major stressor on aquatic resources in the Stanislaus River. Historical gravel mining (dredged river channels and mine pits) and the cessation of gravel recruitment from upstream sources have reduced the availability of spawning gravel in the Stanislaus River below Goodwin Dam. Currently, fall-run Chinook salmon are known to spawn in a 23-mile stretch of the Stanislaus River downstream of Goodwin Dam, but most spawning occurs in the first 10 miles below New Melones Dam (USBR 2011). Since 1997, gravel replenishment projects have increased the amount of spawning habitat, but redd superimposition continues to be a problem and may limit the number of adult salmon that can successfully spawn in the Stanislaus River (Stanislaus River Fish Group 2003). Gravel replenishment projects have offset some habitat loss, but the rate of replenishment is neither sufficient to offset ongoing loss rates nor to offset losses from past years of operations (NMFS 2009c).

Flood attenuation, channel incision, and agricultural and urban encroachment have also reduced the frequency of overbank flows and the availability of floodplain habitat for salmon rearing and other ecosystem functions on the Stanislaus River (NMFS 2009c). Losses and degradation of riparian and floodplain habitat and reductions in natural hydrologic variability that connect rivers to their floodplains has been identified as a major stressor on native Central Valley fish populations through direct impacts on spawning and rearing habitat availability and indirect impacts on aquatic productivity and food web support provided by seasonal floodplain inundation (see Appendix C, *Technical Report on the Scientific Basis for Alternatives San Joaquin River Flow and Southern Delta Salinity Objectives*). Although specific food web studies have not been conducted on the Stanislaus River, current research indicates that regulated flows downstream of dams and losses of overbank flooding have likely contributed to historical declines and current limitations on native fish populations through reductions in primary and secondary production (phytoplankton and invertebrate production) associated with seasonal floodplain inundation (Sommer et al. 2004; Ahearn et al. 2006).

Water Quality

Land uses adjacent to the Stanislaus River and within its watershed influence the water quality of the river and the types and quantities of pollutants found in the water. Poor water quality associated with agricultural runoff (i.e., pesticides) and increasing urbanization has been identified as a potential stressor on steelhead and other aquatic resources in the Lower Stanislaus River. Common pollutants include nutrients from agricultural and livestock operations; pesticides, herbicides, and fungicides applied to crops and orchards; sediment and soil from runoff of agricultural operations; oil or grease from junkyards along the river; and trace metals, heavy metals, and sediment from historical and current mining or gravel extraction operations (NMFS 2009a). Water quality impairments for the Stanislaus River below New Melones Reservoir include diazinon, group A pesticides,[12] and mercury. Additionally, chlorpyrifos and water temperature may also be added to

[12] Group A pesticides include one or more of the following compounds: Aldrin, Dieldrin, Endrin, Chlordane, Lindane, Heptachlor, Heptachlorepoxide, and Endosulfan and Toxaphene.

the impaired water bodies 303(d) list[13] (see Section 7.3.2, *State [Regulatory Background]*) as water quality impairments in the future.

Introduced Species and Predation

The establishment and expansion of nonnative species in the Stanislaus River, and the SJR Basin in general, has contributed to increases in potential predation-related mortality of native species such as fall-run Chinook salmon and steelhead. Striped bass, smallmouth bass, and largemouth bass are only a few of the introduced species that prey on salmonids, but they may be responsible for much of the increased predation pressure on special-status fish species compared to historical conditions (USBR 2008). Alteration of the stream channel by the creation of ditch-like channels from historical gravel mining has also improved habitat conditions and predation opportunities for striped bass, largemouth bass, and other predatory fishes that might contribute to low survival of juvenile salmon as they migrate downstream through the lower reaches of the Stanislaus River (Grossman et al. 2013). However, exact estimates in this system need further study, and approximately 9 percent of winter-run Chinook salmon in the Central Valley are thought to be predated depending on time of migration (Loboschefsky et al. 2012; Grossman et al. 2013).

Disease

Diseased fish are present and have been caught in the Stanislaus River. Naturally produced Chinook salmon juveniles caught in rotary screw traps were diagnosed with the causative agent of bacterial kidney disease (BKD), *Renibacterium salmoninarum* (Foott and Fogerty 2011). Additionally, columnaris disease, caused by the bacterium *Flexibacter columnaris*, was observed in juvenile Chinook salmon in 2007 (Foott et al 2007). This disease can rapidly increase in the population as water temperatures reach a mean daily temperature of 68°F–69.8°F (Nichols and Foott 2002).

Tuolumne River

New Don Pedro Reservoir

New Don Pedro Reservoir provides a warmwater and coldwater sport fishery. A variety of game fish are stocked in the reservoir. Warmwater game fish in the reservoir are a Florida strain of largemouth bass, smallmouth and spotted bass, channel catfish, crappie, sunfish, blue gill, and carp. Coldwater game fish in the reservoir are kokanee; Chinook salmon; and brown, brook, and rainbow trout (Don Pedro Lake 2012).

Tuolumne River below New Don Pedro Reservoir

Historically, the Tuolumne River had 99 miles of anadromous fish habitat, and currently there is approximately 5247 miles of accessible habitat (USFWS 2008). La Grange Dam is the upstream extent of accessible anadromous fish habitat. Historically, the Tuolumne River supported abundant populations of Central Valley steelhead and fall-run and spring- run Chinook salmon (Yoshiyama et al. 1996) and now supports smaller populations of steelhead and fall-run Chinook salmon (NMFS 2009c). Spring-run Chinook salmon were extirpated from the Tuolumne River Watershed when dam construction eliminated access to upstream habitats (Stillwater Sciences n.d.). Central Valley steelhead were thought to have been extirpated from the Tuolumne River, but fisheries monitoring

[13] Clean Water Act section 303(d) requires states, territories, and authorized tribes to develop a ranked list of water quality limited segments of rivers that do not meet water quality standards.

for the New Don Pedro Federal Energy Regulatory Commission (FERC) relicensing project have documented the presence of *O. mykiss* in the Lower Tuolumne River (TID and MID 2012).

The mainstem Tuolumne supports both nonnative and native fish species. Nonnative fish species important for sport fisheries include American shad, catfish species, largemouth, smallmouth and striped bass, and sunfish species. Native fish species include Pacific and river lamprey, hardhead, Sacramento pikeminnow, Sacramento blackfish, and Sacramento sucker (TID and MID 2012).

Indicator Species

Fall-Run Chinook Salmon

The fall-run Chinook salmon population is maintained by natural production and hatchery strays from the Merced River and other basin hatcheries. Since 1960, annual escapement to the Tuolumne River has fluctuated substantially, with the highest returns generally occurring during wet periods or after years of relatively high spring flows and the lowest returns generally occurring during dry periods or after years of relatively low flows (Figure 7-2). Tuolumne River Chinook salmon estimates have ranged from a high of 45,900 fish in 1959 to a low of 77 in 1991. The population estimate for 2011 was 893 fish (CDFG unpublished data). Estimation of the proportion of hatchery- and natural-origin fall-run Chinook salmon returning to the Central Valley in recent years indicates that returns to the Tuolumne River are dominated by hatchery-origin fish. In 2011, an estimated 73 percent of the run consisted of hatchery-produced fish that originated primarily from the Merced River Hatchery, Mokelumne River Hatchery, and Feather River Hatchery (Palmer-Zwahlen and Kormos 2013).

Spawning in the Tuolumne River has been observed mainly upstream of Hickman Bridge. Spawning is most heavily concentrated in the reach between RM 51.5 (upstream of Old La Grange Bridge) and Basso Bridge. Adult Chinook salmon in the Tuolumne River generally spawn September–December, but some later-arriving fish have been observed. Recent observations of fry emergence in late May suggest that adults spawn as late as February. Also, in 2000, adults were observed in the river during summer (Stillwater Sciences n.d.). Fry emergence extends primarily from January–March (McBain & Trush 2000). Juvenile Chinook salmon leave the river as fry, juveniles, smolts (subyearlings), or yearlings. Large numbers of fry leave the river particularly during wet years. Smolts emigrate February–June. A few salmon spend summer in the river and emigrate during the fall and early winter as yearlings (Stillwater Sciences n.d.).

Steelhead

The historical distribution of steelhead in the SJR Basin, including the Tuolumne River, is poorly known, but steelhead were recorded by CDFG in counts conducted at Dennett Dam (RM 16.2) in 1940 and 1942 (CDFG unpublished data). O. mykiss population estimate snorkeling surveys started in July 2008, pursuant to an April 2008 FERC order, and ended September, 2011. The estimated population results are shown in Table 7-5 (TID and MID 2012).

Table 7-5. Estimated Population of *O. Mykiss* from Turlock Irrigation District and Modesto Irrigation District (2012) Snorkel Surveys

Date	Number of Juveniles	Number of Adults
July 2008	2,472	643
March 2009	63	170
July 2009	3,475	963
March 2010	0	109
August 2010	2,405	2,139
September 2011	47,432	9,541

An acoustic tag and tracking survey was done pursuant to a May 2010 FERC Order. *O. mykiss* were tagged with acoustic tags and tracked to determine spawning locations, migration patterns, and potential habitat use of restored river reaches. Tracking began in 2010 and continued into 2011. No other fish were tagged in 2011. All tagged fish remained in the river. Two tagged fish moved up- and downstream as far as 6.8 miles, and all other fish remained near their release locations (TID and MID 2012).

Environmental Stressors

Anthropogenic factors have affected salmonid habitat on the Tuolumne River. Water supply development, flood control, gold dredging, aggregate mining, and hatchery operations have all affected salmonid populations (Stillwater 2002).

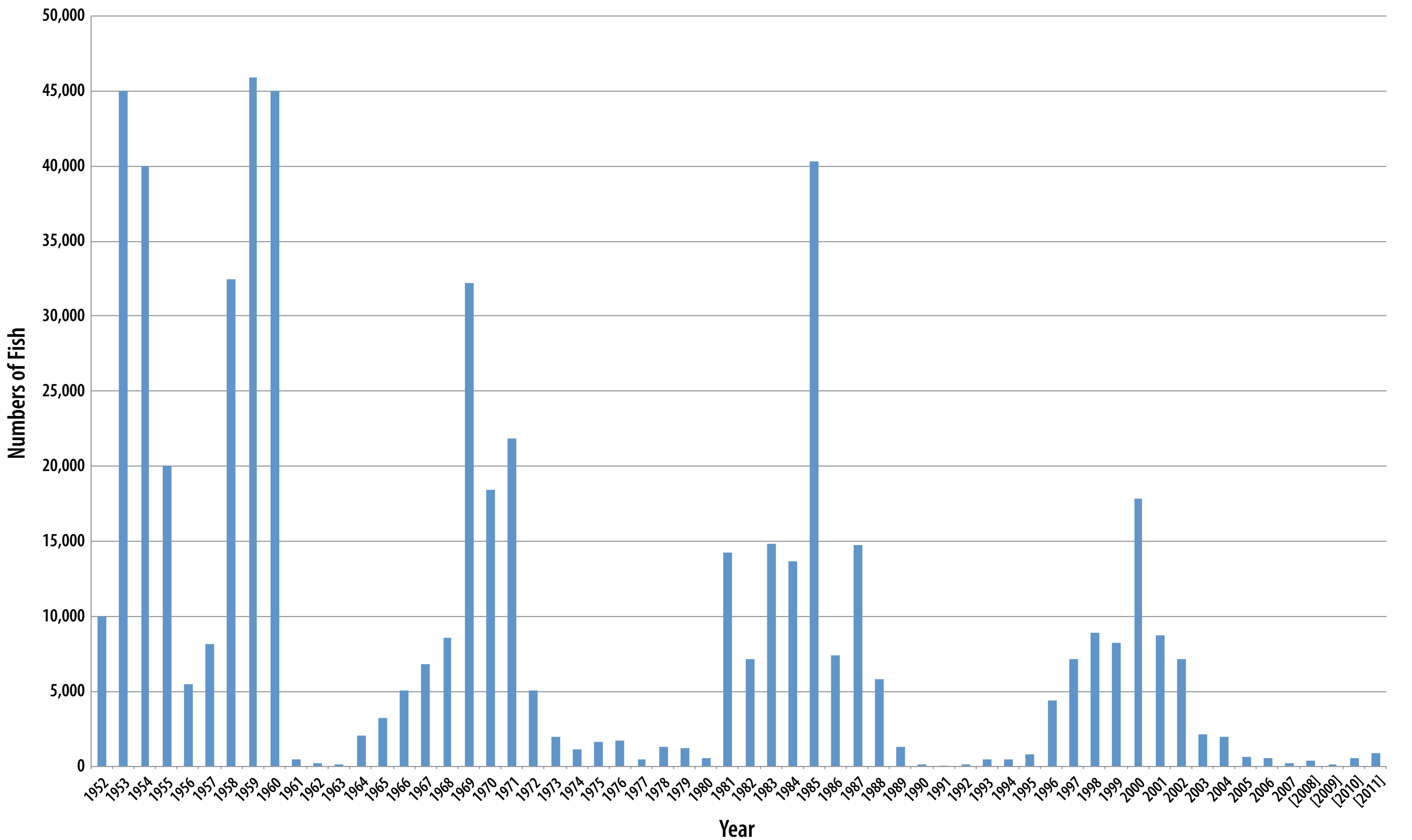
Flow Regulation

Available fish habitat on the Tuolumne River is primarily controlled by established flows. Flow requirements for the Lower Tuolumne River are specified in the *New Don Pedro Proceeding Settlement Agreement* and the *FERC License Amendment for the New Don Pedro Project*. These flows are provided to protect fall-run Chinook salmon spawning below La Grange Dam. (For a discussion of the flows, see Chapter 2, *Water Resources*; Chapter 5, *Surface Hydrology and Water Quality*; and Appendix C, Chapter 3, *Scientific Basis for Developing Alternative San Joaquin River Flow Objectives*).

The historical relationship between spring flows during the juvenile emigration period and subsequent adult abundance has been the basis for a number of analyses and experimental investigations aimed at understanding the factors influencing salmon survival and population dynamics under historical and recent water management operations in the SJR and Delta (see Appendix C, Chapter 3, *Scientific Basis for Developing Alternate San Joaquin River Flow Objectives*). These investigations suggest that flow in the SJR and the three eastside tributaries has a major influence on juvenile salmon survival between March and June as individuals complete the freshwater rearing, smoltification, and migration stage of their lifecycles.

Habitat Alteration

Habitats in the Tuolumne River downstream from LaGrange Dam have been influenced and altered by former gold mining activities and gravel mining (USBR 2011). As a result, there is limited spawning habitat in upstream areas, and this results in redd superimposition and egg mortality (Stillwater Sciences n.d.; Moyle 2002). During the early twentieth century, the Tuolumne River channel and floodplain were dredged for gold. The gold dredges excavated channel and



Graphics...00427.11 (3-26-2018)

Figure 7-2
Estimates of Annual Escapement of Fall-run Chinook Salmon in the Tuolumne River from 1952 to 2011

floodplain deposits to the depth of bedrock (approximately 25 ft [7.6 m]) and often realigned the river channel. Due to gravel mining activities, the channel has become constrained by dredge tailings, which restricts channel meander and reduces delivery of gravel to the river. Riparian vegetation is also scarce due to dredge tailings. By the end of the gold mining era, the floodplain adjacent to 12.5 miles (20 km) of the river (RM 50.5–38) had been converted to tailings deposits. Tailings remain in the reach from RM 45.4–40.3 (Stillwater Sciences n.d.). Additionally, pits were made in the channel that provide habitat for largemouth bass and other predatory fish species.

Land clearing for gold dredging, aggregate mining, and agricultural and urban development has resulted in the loss of 85 percent of the Tuolumne River's historical riparian forest. Vegetation that once extended from bluff to bluff prior to the Gold Rush is now confined to a narrow band along the active channel margins in many areas, or is nonexistent. Nearly all of the areas in the gravel-bedded zone that historically supported riparian forests have been mined, grazed, or farmed (Stillwater Sciences n.d.).

Under the FERC settlement agreement, habitat restoration has begun on the Lower Tuolumne River. A total of 14 channel restoration projects have been identified in the *Habitat Restoration Plan for the Lower Tuolumne River Corridor* (McBain and Trush 1999). From reach RM 0–52, which is below La Grange Dam, general restoration components include restoring floodplain habitat, planting riparian vegetation along the banks, and adding spawning gravel to reaches of the river that are conducive to spawning (USFWS 1999). Between 1994 and 2003, 19,250 cubic yards of gravel were added to enhance spawning and rearing habitats in the Tuolumne River (Table 7-6).

Table 7-6. Tuolumne River Gravel Augmentation Projects

Tuolumne River Projects	Gravel Volume Added (yard^3)	Year Construction Completed
La Grange Gravel Addition Project, early	6,750	1994
La Grange Gravel Addition Project, Phases I and II	12,500	1999–2003

Source: Mesick and Marston 2007.

Reductions of the magnitude, frequency, and duration of flood flows and confinement of the natural floodway of the Tuolumne River has disrupted the natural processes creating high-quality salmon spawning and rearing habitat, including shallow, slow-water river margins and floodplain habitat supporting rearing juveniles and other native fishes (McBain and Trush 2000). Losses and degradation of floodplain habitat and reductions in natural hydrologic variability that connect rivers to their floodplains has been identified as a major stressor on native Central Valley fish populations through direct impacts on spawning and rearing habitat availability and indirect impacts on aquatic productivity and food web support provided by seasonal floodplain inundation (see Appendix C, *Technical Report on the Scientific Basis for Alternatives San Joaquin River Flow and Southern Delta Salinity Objectives*). Although specific food web studies have not been conducted in the Tuolumne River, current research indicates that regulated flows downstream of dams and losses of overbank flooding have likely contributed to historical declines and current limitations on native fish populations through reductions in primary and secondary production (phytoplankton and invertebrate production) associated with seasonal floodplain inundation (Sommer et al. 2004; Ahearn et al. 2006).

Water Quality

As discussed for the Stanislaus River, land uses adjacent to and within the watershed influence the water quality of the river and the types and quantities of pollutants found in the water. Poor water quality associated with agricultural runoff and increasing urbanization has been identified as a potential stressor on steelhead and other aquatic resources in the Lower Tuolumne River. Common pollutants include nutrients from agricultural and livestock operations; pesticides, herbicides, and fungicides applied to crops and orchards; sediment and soil from runoff of agricultural operations; oil or grease from junkyards along the river; and trace metals, heavy metals, and sediment from historical and current mining or gravel extraction operations (NMFS 2009a).

Introduced Species and Predation

Studies of predator abundance, habitat use, and predation rates on juvenile Chinook salmon in the Tuolumne River indicate that predation by largemouth bass, smallmouth bass, and other nonnative fishes may be a limiting factor for Chinook salmon outmigrant survival and may be a source of mortality under low flow conditions (EA 1992; TID and MID 1992; FishBio 2013). In general, reduced spring flows, elevated water temperatures, and the presence of low-velocity habitats (including former in-channel aggregate mining pits) in the lower reaches of the Tuolumne River favor fish communities dominated by nonnative, warmwater species such as largemouth bass and other potential predators on native salmonids (EA 1992; McBain and Trush 2000; Brown and Ford 2002). For example, Brown and Ford (2002) found that the spawning success of nonnative species, as measured by the proportion of nonnative juveniles (consisting predominantly of bass and sunfish species) in winter and spring samples, was inversely related to spring discharge the previous year (Brown and Ford 2002). The response of nonnative warmwater fish species to high spring flows also included a downstream shift in distribution consistent with the hypothesized effect of higher flows and lower water temperatures on spawning success (Stillwater Sciences et al. 2006).

Hatchery Operations

As discussed above, large numbers of unmarked hatchery salmon are released into the Merced River each year and may stray into the Tuolumne River. In recent years, up to 200,000 hatchery-origin salmon from the Merced River Hatchery have been released annually in the Tuolumne River. As a result, a significant number of hatchery-origin Merced River salmon return to the Tuolumne River each year. Fish produced by the hatcheries have the potential to negatively affect natural fall-run Chinook salmon by displacing wild salmonid juveniles through competition and predation, competing with natural adults for limited resources, and hybridizing Central Valley Chinook salmon with fish from outside the SJR Basin (CDFG 2011a).

Disease

Fish species on the Tuolumne River are susceptible to similar diseases as those discussed for fish in the Stanislaus River. The causative agent of BKD was detected in naturally produced juveniles caught in rotary screw traps from Tuolumne River (Nichols and Foott 2002).

Merced River

Lake McClure and Lake McSwain

Lake McClure, which is impounded by New Exchequer Dam, and Lake McSwain, which is impounded by McSwain Dam, both support warmwater and coldwater sport fish species. Lake McClure contains a variety of sport fish species, such as largemouth bass, spotted bass, bluegill, green sunfish, kokanee, rainbow trout, and Chinook salmon. Common carp and catfish are also in the reservoir (Merced ID 2011). CDFW annually stocks rainbow trout, kokanee, and Chinook salmon. Spawning habitat for warmwater fish species is available in low gradient areas in Lake McClure. Spawning gravels in six tributaries surrounding the reservoir could provide spawning habitat for both warmwater and coldwater species. Lake McSwain has the same fish species, but also contains brook and brown trout (Merced ID 2011).

Merced River below Crocker-Huffman Dam

As with the Stanislaus and the Tuolumne Rivers, the Merced River historically supported abundant populations of coldwater fish species, such as Central Valley steelhead and spring- and fall-run Chinook salmon. Chinook salmon may have occurred up to an elevation of 2,000 ft near El Portal. By 1925, Crocker-Huffman, Merced Falls, and New Exchequer Dams had blocked anadromous fish passage (Stillwater Sciences 2002). Crocker-Huffman and Merced Falls dams have fish ladders, but they were shut down when the Merced River Hatchery was constructed at the base of Crocker-Huffman Dam. These barriers likely had a similar effect on steelhead because of their dependence on higher elevation streams for holding, spawning, and early rearing (Stillwater Sciences 2002).

Today, the river supports only fall-run Chinook salmon and a small population of wild and hatchery steelhead. Currently, the Merced River is accessible to anadromous fishes for the first 51 RMs, with access terminating at Crocker-Huffman Dam (USBR 2011). There are also limited numbers of hatchery-reared, late-fall-run Chinook that have strayed from their natal streams. The Merced River Hatchery, which has been operated by CDFW since 1971, produces fall-run Chinook salmon that are released into the Merced River and used for studies throughout the SJR Basin (Stillwater Sciences 2002).

There is a variety of introduced fish species in the mainstem Merced River, including catfish, several species of bass, sunfish, American shad, threadfin shad, and carp. Native fish species include Sacramento sucker, prickly sculpin, Sacramento blackfish, Sacramento pikeminnow, Pacific and Kern Brook lamprey, hardhead, and Sacramento splittail (Stillwater Sciences 2002).

Indicator Species

Fall-Run Chinook Salmon

Since the 1940s, CDFW has conducted escapement surveys to document the number and timing of adult Chinook salmon returning to the Merced River to spawn. Since 1998, CDFW, with funding from the Central Valley Project Improvement Act–Comprehensive Monitoring and Assessment Program, also operated a rotary screw trap near the mouth of the river to document juvenile salmon outmigration and abundance (Stillwater Sciences 2002).

Annual escapement for fall-run fish has fluctuated from a high of 29,749 in 1984 to 82 adults in 1990. Before 1966, the population was less than 500 fish until minimum instream flows were established under the Davis-Grunsky Act in October of 1966 and the Merced River Hatchery opened in 1970 (Mesick 2010a). Escapement from 2007 to 2009 declined to an average of about 500 fish, presumably because of poor ocean conditions (Lindley et al. 2009). The population estimate in 2011 was 1,942 fish. Figure 7-3 shows the annual escapement of fall-run Chinook salmon from 1952 to 2011 (CDFG unpublished data). Estimation of the proportion of hatchery- and natural-origin fall-run Chinook salmon returning to the Central Valley in recent years indicates that returns to the Merced River are dominated by hatchery-origin fish. In 2011, an estimated 88–89 percent of the returns to the Merced River and Merced River Hatchery were hatchery-produced fish originating primarily from Merced River Hatchery, Mokelumne River Hatchery, and Coleman National Fish Hatchery (Palmer-Zwahlen and Kormos 2013).

Merced River fall-run Chinook salmon migrate upstream October–December and spawn through January (Stillwater Sciences 2002). Most spawning habitat is within the 24-mile reach of the Merced River between the Crocker-Huffman Dam and the town of Cressy, with rearing habitat extending downstream to the SJR confluence (USBR 2011). The majority of spawning occurs upstream of State Route 59 bridge (RM 42) (Yoshiyama et al. 2000).

Juvenile Chinook salmon rear in the river mainly between February and May, but some fish stay year-round (Yoshiyama et al. 2000). Outmigration of juveniles 0+ age (fry) occurs from January through the beginning of June. Outmigration of 1+ age fish (smolts) occurs November–February.

Steelhead

Steelhead have been captured in the rotary screw traps (Stillwater Sciences 2002), but no population estimates have been done on the Merced River. The distribution and habitat preferences of spawning adults in the Merced River is unknown, but it is presumed that the majority of spawning occurs between Crocker-Huffman Dam and the town of Cressey. Timing of adult and juvenile migration is unknown.

Most of the environmental factors that potentially limit survival and production of fall-run Chinook salmon in the Merced River likely apply to steelhead to some degree. However, because juveniles rear in the river for 1 or more years before migrating to the ocean, steelhead also require suitable flows and temperatures during the critical summer months.

Environmental Stressors

Anthropogenic factors have affected salmonid habitat on the Merced River. Water supply development, flood control, gold dredging, aggregate mining, bank stabilization, and hatchery operations have all affected salmonid populations (Stillwater 2002).

Flow Regulation

Available fish habitat on the Merced River is primarily controlled by established flows. FERC License No. 2179 for the New Exchequer project and the Davis-Grunsky Contract No. D-GG417 mandate streamflows for fishery purposes in the Lower Merced River. (For a discussion of the flows, see Chapter 2, *Water Resources*; Chapter 5, *Surface Hydrology and Water Quality*; and Appendix C, T*echnical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*). Several dams and reservoirs control flows on the mainstem Merced River, two of which are Lake McClure (impounded by New Exchequer Dam) and Lake McSwain (impounded by McSwain Dam). Lake McClure is regulated by USACE to maintain space in Lake McClure for incoming flood flows and limit the amount of water that can be released to the lower river (Stillwater 2002). Also, USACE influences flows by establishing flood control release limits for the Merced River not to exceed 6,000 cubic feet per second (cfs) downstream of Dry Creek.

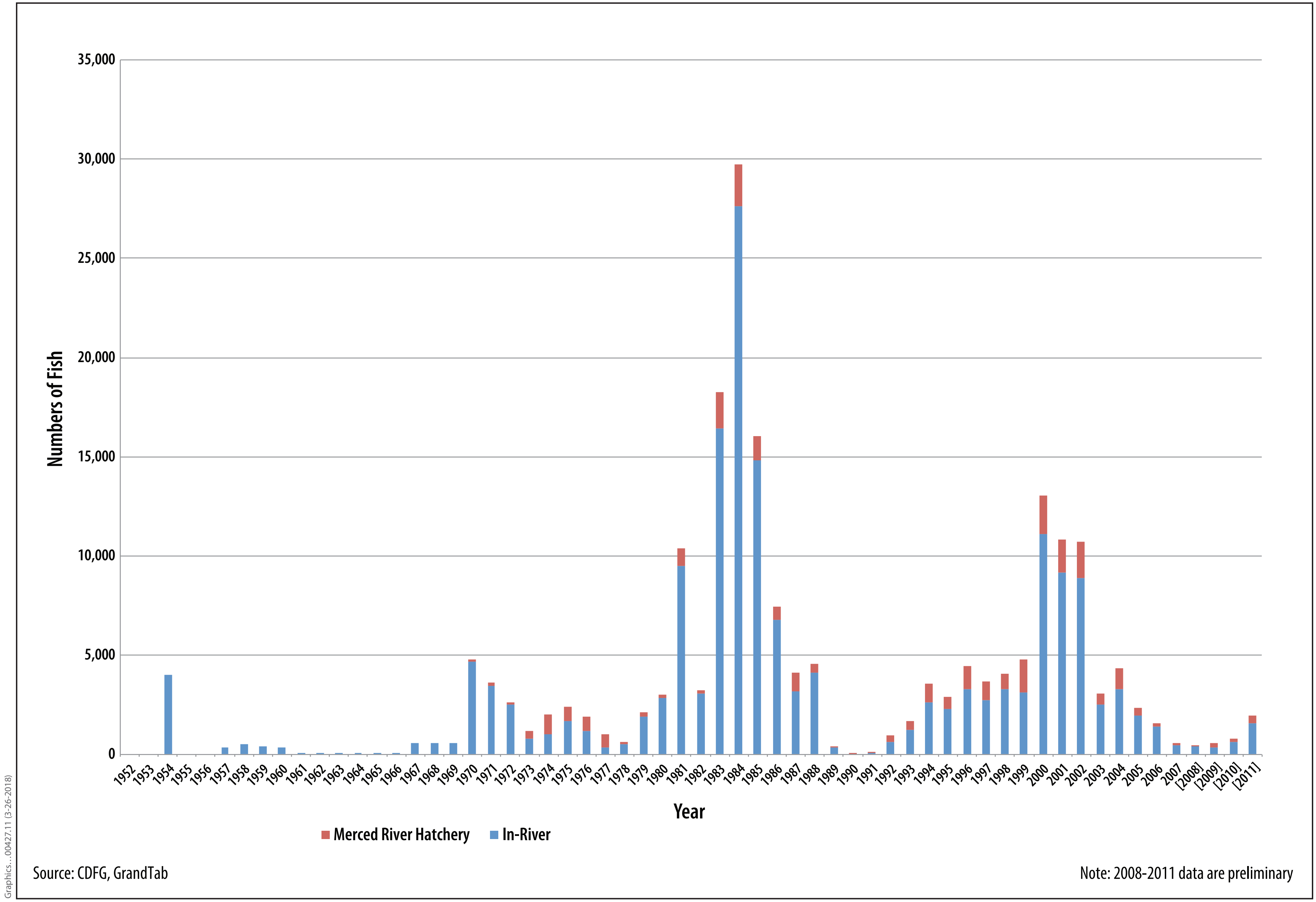


Figure 7-3
Estimates of Annual Escapement of Fall-run Chinook Salmon in the Merced River from 1952 to 2011

The historical relationship between spring flows during the juvenile emigration period and subsequent adult abundance has been the basis for a number of analyses and experimental investigations aimed at understanding the factors influencing salmon survival and population dynamics under historical and recent water management operations in the SJR and Delta (see Appendix C, Chapter 3, *Scientific Basis for Developing Alternate San Joaquin River Flow Objectives*). These investigations suggest that flow in the SJR and the three eastside tributaries has a major influence on juvenile salmon survival between March and June as individuals complete the freshwater rearing, smoltification, and migration stages of their lifecycles (Moyle 2002; Merced ID 2011).

Habitat Alteration

Gold and aggregate mining have reduced spawning and rearing habitat for Chinook salmon and steelhead. Both gold and aggregate mining have removed gravel from the river, which is used as spawning substrate for adults (Stillwater Sciences 2002). From 1907–1952, the Lower Merced River channel and floodplain were dredged for gold. After extracting the gold, the tailings were placed in rows on the floodplain. The tailings prevent riparian vegetation from establishing and confine the river channel to a narrow corridor. Because of the dredging and the lack of sediment supply from upstream, the dredged reach is characterized by long, deep pools. Both Chinook salmon and steelhead need shallow, riffle habitat with gravel for successful spawning (Stillwater 2002). Aggregate mining, which began in the 1940s and continues today, excavates floodplain habitat important for rearing Chinook salmon and spawning Sacramento splittail.

Inundation of floodplains is also important for establishing and maintaining a healthy riparian vegetation community (Stillwater Sciences 2002). Aggregate mining also creates pits that provide habitat for largemouth bass, which prey on native fish, including outmigrating juvenile Chinook salmon. In-channel mining has been discontinued, but floodplain and terrace mining continues today (Stillwater 2002). Bank stabilization has been used throughout the Merced River to prevent bank erosion.

The riprap, concrete rubble, and gabions that have been used limit channel migration and native riparian vegetation establishment (Stillwater Sciences 2002). Channel migration is important to allow different instream habitat types to form (pools, riffles, runs), which support different life stages of salmon and other fish species. Riparian vegetation along the river banks provides food and cover and controls water temperatures for juvenile salmonids. Rock stabilization along the banks prevents riparian vegetation from establishing and is typically associated with nonnative, invasive plant species such as giant reed (*Arundo donax*) (Stillwater Sciences 2002).

Flood regulation, levee construction, and floodplain alteration have reduced the extent and frequency of floodplain inundation on the Merced River (Stillwater Sciences 2002). Losses and degradation of riparian and floodplain habitat and reductions in natural hydrologic variability that connect rivers to their floodplains has been identified as a major stressor on native Central Valley fish populations through direct impacts on spawning and rearing habitat availability and indirect impacts on aquatic productivity and food web support provided by seasonal floodplain inundation (see Appendix C, *Technical Report on the Scientific Basis for Alternatives San Joaquin River Flow and Southern Delta Salinity Objectives*). Although specific food web studies have not been conducted in the Merced River, current research indicates that regulated flows downstream of dams and losses of overbank flooding have likely contributed to historical declines and current limitations on native fish populations through reductions in primary and secondary production (phytoplankton and invertebrate production) associated with seasonal floodplain inundation (Sommer et al. 2004; Ahearn et al. 2006).

Water Quality

As discussed for the Stanislaus and Tuolumne Rivers, pollutants from agriculture and increasing urbanization have been identified as potential stressors on steelhead and other aquatic resources in the Merced River. Unsuitable water temperatures for Chinook salmon and Central Valley steelhead have been identified in the Merced River. Elevated water temperatures have been recorded in the lower reach, some portions of the spawning reach, and at the Merced River Hatchery in October and November. In late April and May, water temperatures exceed limits for emigrating smolts. Elevated spring water temperatures are more prevalent on the Merced River than in the Stanislaus or Tuolumne Rivers due to the Merced River's southerly location and higher air temperatures (Stillwater Sciences 2002).

Introduced Species and Predation

Predation is a possible source limiting survival of juvenile Chinook salmon in the Merced River. As discussed previously, some hot-spots exists, such as in-river mining pits provide habitat for largemouth bass and other nonnative predatory fish species (Grossman et al. 2013).

Hatchery Operations

The Merced River has one hatchery, the Merced River Hatchery, located below the Crocker-Huffman Dam. It is the only hatchery in the SJR Basin (Stillwater Sciences 2002). In recent years, the percentage of hatchery-reared fall-run Chinook salmon returning to the LSJR and the three eastside tributaries has been high (Greene 2009) even though hatchery fish are typically less productive and have higher straying rates than wild fish. A study by Mesick (2009) found that up to 58 percent of Merced River Hatchery fall-run Chinook salmon strayed to the Sacramento River Basin when flows in the SJR were less than 3,500 cfs for 10 days in late October, but stray rates were less than 6 percent when flows were at least 3,500 cfs (CSPA and CWIN 2010; Mesick 2010b). This report indicated that providing 1,200 cfs flows from the three eastside tributaries to the LSJR for 10 days in late October increases escapement by an average of 10 percent (CSPA and CWIN 2010).

The average estimated returns of hatchery Chinook salmon to the Merced River from 1998–2007 was 72.8 percent. Because of the high numbers of hatchery fish returning to the Merced River and the low numbers of salmon returning every year, this creates a high risk of extinction for the Merced River fall-run population (Mesick 2010a). Hatchery production has been shown to negatively affect the genetic diversity and fitness of wild salmonid populations. Impacts can be genetic, ecological, or behavioral. Fish produced in the Merced River Hatchery can displace wild salmonid juveniles through competition and predation, competition with wild adults for limited resources, and introgression with other runs of Chinook salmon outside of the SJR Basin (Moyle 2002). However, a large portion of the existing genetic diversity for Central Valley Chinook salmon are contained in hatchery origin stocks, so hatchery stocks may be important contributors to overall stock recovery, including natural and hatchery origin fish.

Disease

Between 2000 and 2002, BKD was been detected in both natural and hatchery fall-run Chinook salmon juveniles in the Merced River (Nichols and Foott 2002). Occurrence of the parasite that causes BKD in samples of fish kidneys generally increased from 2 percent of the juvenile samples in 2000 to 90–100 percent of the 2001 samples. It then decreased to only 51 percent of the 2002 samples. Heavy infections were observed in 22 percent of the samples in 2002 (Nichols and Foott 2002). Proliferative Kidney Disease (PKD), caused by the myxosporean *Tetracapsuloides bryosalmonae*, has been diagnosed in Merced River Hatchery juvenile Chinook salmon for several decades, and is a currently considered a significant mortality factor for hatchery smolts during their early seaward entry phase (Foott et al. 2007).

LSJR

The LSJR between the Merced River and the Delta historically supported a distinctive native fish fauna adapted to widely fluctuating riverine conditions ranging from large winter and spring floods to low summer flows. Prior to large-scale hydrologic and physical alteration of the SJR, the fish community in this reach was dominated by fishes adapted to warmwater habitats of the valley floor, including deep, slow river channels, oxbow and floodplain lakes, swamps, and sloughs. These fishes included Sacramento perch, thicktail chub, tule perch, hitch, Sacramento blackfish (*Orthodon microlepidotus*), Sacramento splittail, Sacramento pikeminnow, and suckers. Anadromous species, including spring-run Chinook salmon, fall-run Chinook salmon, and sturgeon occurred seasonally in these reaches during their upstream and downstream migrations. Key habitats that contributed substantially to the productivity of native fishes on the valley floor were the floodplains, riparian forests, and wetlands that were inundated by winter and spring floods (Moyle 2002).

Currently, the SJR from the Merced River to the Delta provides migration habitat for fall-run Chinook salmon and steelhead as they migrate upstream to spawning tributaries and downstream toward the Delta. The seasonal timing of adults and juveniles in this reach generally corresponds to that described for each of the tributaries. Other native species that occur in this reach include Sacramento sucker, Sacramento pikeminnow, Sacramento splittail, tule perch, prickly sculpin (*Cottus asper*), Sacramento blackfish, and hardhead (Brown and May 2006).

Many of the species that were present historically in the LSJR have been replaced by nonnative fish species that are better adapted to the disturbed habitat conditions (Moyle 2002). Most notably, the deep-bodied fish assemblage of the valley floor and lower portions of the three eastside tributaries has been largely replaced by largemouth bass, sunfish species, and other nonnative warmwater species that likely prey on or compete with the native species (Moyle 2002). Nonnative fishes reported to occur in the LSJR include red shiner (*Cyprinella lutrensis*), inland silverside (*Menidia beryllina*), threadfin shad, western mosquito fish (*Gambusia affinis*), fathead minnow (*Pimephales promelas*), largemouth bass, bigscale logperch (*Percina macrolepida*), bluegill, white crappie (*Promoxis annularis*), striped bass, redear sunfish (*Lepomis microlophus*), common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), black bullhead (*Ameiurus melas*), channel catfish, and green sunfish (Brown and May 2006).

Environmental Stressors

Baseline stressors that affect aquatic resources in the LSJR include alteration of the natural flow regime, loss of natural riverine function and morphology due to habitat modification and flood control activities, predation, water quality (e.g., temperature and pollutants), and disease.

Flow Regulation

The natural hydrologic regime and geomorphic processes of the LSJR have been substantially altered by upstream dams, diversions, and agricultural drainage. Analyses of the historical relationship between spring flows during the juvenile Chinook salmon emigration period and subsequent adult abundance indicate that flow in the three eastside tributaries and LSJR has a substantial influence on juvenile salmon survival between March and June as they complete their freshwater rearing, smoltification, and migration stages. Flow in the three eastside tributaries and LSJR may affect survival through a number of mechanisms, including effects on water temperature, predation, habitat availability (e.g., access to floodplain habitat), water quality (e.g., contaminants), and entrainment in diversions (see Appendix C, Chapter 3, *Scientific Basis for Developing Alternate San Joaquin River Flow Objectives*).

Habitat Alteration

Clearing of land for agriculture and flood control activities have resulted in loss or disconnection of the river from historical wetland, riparian, and floodplain areas (Brown 2000). The loss of habitat connectivity between the river and riparian areas in the LSJR has greatly affected salmonids (McBain and Trush 2002). Riparian forests that historically surrounded river and estuarine channels had an important role in minimizing stressors related to habitat availability, water temperature, and water quality. However, riparian forests have generally been converted to agricultural uses, reducing the amount of floodplains and other habitat and increasing surface water temperatures.

Flood control levees closely border much of the river but are set back in places, creating some off-channel aquatic habitat areas when inundated. However, the levees and dikes have acted to isolate historical riparian land and floodplains from the channel. The bank protection along channel margins, coupled with a reduced flow regime, has stabilized the channel, reducing bank erosion, lateral migration, and greatly reducing the processes that create complex side channels and high flow scour channels (McBain and Trush 2002). This has led to a reduction of various types of habitat (e.g., refuge, rearing, and spawning) for steelhead, Chinook salmon, and other native fish species.

Flood regulation, channel confinement, and disconnection of historical wetland, riparian, and floodplain habitat have greatly decreased the frequency and extent of floodplain inundation and the quantity and quality of existing habitat for juvenile salmonids and other native fishes in the LSJR (McBain and Trush 2002). Losses and degradation of riparian and floodplain habitat and reductions in natural hydrologic variability that connect rivers to their floodplains has been identified as major stressors on native Central Valley fish populations. These factors directly impact spawning and rearing habitat availability and indirectly impact aquatic productivity and food web support provided by seasonal floodplain inundation (see Appendix C, *Technical Report on the Scientific Basis for Alternatives San Joaquin River Flow and Southern Delta Salinity Objectives*). Recent modeling of the potential ecological benefits associated with floodplain restoration in the LSJR and southern Delta indicates that the frequency and duration of floodplain inundation events sufficient to meet the habitat requirements of Chinook salmon, Sacramento splittail, and their food resources (phytoplankton and zooplankton), are limited under current and potential future hydrological conditions (Matella and Merenlender 2014). However, the frequency and duration of floodplain inundation events can be increased through floodplain restoration and the restoration of a more natural flow regime to achieve the desired levels of hydrologic connectivity (Matella and Merenlender 2014).

Water Quality

Water temperatures in the LSJR reflect those of the three eastside tributaries and are generally within a range considered to be suitable (< 68°F) for rearing and outmigrating Chinook salmon smolts during April and May (SJRGA 2011). ~~However, i~~In certain water year types, elevated water temperature can be a major stressor on fish, especially salmonids, during months when juveniles are rearing and outmigrating. All of the tributaries generally experience an increase in water temperatures in the late spring and summer, which then contributes to increases in water temperature in the LSJR. Summer water temperatures in many Central Valley streams regularly exceed 77°F (Moyle 2002). These sustained periods of increased water temperature are known to affect behavioral and biological functions of all fishes in the LSJR, notably salmonids and Central Valley steelhead.

The LSJR is generally considered to have poor water quality in part due to agricultural drainage, which is a major source of salts and pollutants (e.g., boron, selenium, pesticides). Discharges from the existing wastewater treatment plants (WWTP) also reduce water quality in the LSJR (State Water Board 2006). However, water quality is known to improve during periods of high flow due to dilution effects.

Introduced Species and Predation

Nonnative fish species prey on Central Valley steelhead and fall-run Chinook salmon in the LSJR. The most prevalent nonnative predators in the LSJR are: striped bass (Moyle 2002); smallmouth bass; and largemouth bass. Although bass are only one of the introduced species that prey on salmonids, they probably represent the most change in predation experienced compared to historical conditions (USBR 2008), in part due to their salt tolerance to polluted agricultural runoff especially during spawning (Moyle 2002).

Disease

Diseases have been identified in LSJR fish populations. Samples from Chinook salmon juveniles caught with a Kodiak trawl at Mossdale were positive for the causative agent of BKD (Nichols and Foott 2002). Additionally, BKD was detected in both natural and hatchery juveniles from the LSJR in both 2000 and 2001 *Ceratomyxa shasta*, a myxosporean parasite, is also a pathogen present in the Central Valley, and they are of particular concern on the LSJR (Nichols and Foott 2002).

7.2.3 Extended Plan Area

The native fish communities of the extended plan area have changed substantially beginning with gold rush immigration and subsequent landscape modification (Moyle et al. 1996). Native fishes include rainbow trout *(Oncorhynchus mykiss)*, Sacramento hitch *(Lavinia exilicauda exilicauda)*, and hardhead minnow *(Mylopharodon conocephalus)* (Moyle et al.1996). Many nonnative fish were introduced to the rivers, as well as upper watershed lakes, that had previously been fishless (Moyle et al. 1996). These species include brown trout *(Salmo trutta)* and eastern brook trout *(Salvelinus fontinalis)* (Moyle et al. 1996). The rim dams blocked upstream migration of anadromous species. The recreational fishery in the rivers and reservoirs in the extended plan area includes rainbow trout, eastern brook trout, and brown trout, including some hatchery-stocked species (Moyle et a Central California roach 1996; National Wild and Scenic River Systems 2016). There are no federal or state endangered or threatened fish species associated with the reservoirs in the extended plan area (i.e., above the rim dams) (CDFW 2016b). There are four fish species of special concern (CSC) associated with these reservoirs: hardhead minnow; Central California roach *(Lavinia symmetricus symmetricus)*; Sacramento hitch; and riffle sculpin *(Cottus gulosus)* (CDFW 2016b).

7.2.4 Southern Delta

The southern Delta is part of the larger Bay-Delta system and provides habitat for resident and migratory fish species. Essential habitats for salmonids and other fish species consist of suitable water quality and water quantity conditions. For salmonids, these conditions must support juvenile and adult physiological transitions between fresh water and saltwater (NMFS 2009b). Changes to estuarine habitat that degrade any of these conditions can have a negative effect on aquatic resources. Therefore, similar stressors influence the abundance and presence of fish in the southern Delta and Bay-Delta as described above for the three eastside tributaries and LSJR. However, conditions in the southern Delta are also influenced by river inflow, tidal action, water export facilities and local pump diversions, and agricultural and municipal return flows (Moyle 2002).

Environmental Stressors

The distribution of fish in the southern Delta is determined by tidal flows, tidally averaged (nontidal) net flows, and directed swimming of the fish. The largest flows in the southern Delta are tidal flows, which far exceed other flows in most Delta channels. The tidal flows tend to move small, weak-swimming fish, such as fish larvae, upstream and downstream, dispersing them into neighboring channels without imparting any net directional movement (Kimmerer and Nobriga 2008). Nontidal flows determine the net direction of water movement (i.e., net flows) and of fish larvae and other weak swimmers suspended in the water (Kimmerer 2008; Kimmerer and Nobriga 2008; Monsen et al. 2007). Baseline stressors that affect aquatic resources in the southern Delta include alteration of the natural Delta inflows and hydrodynamics, habitat alteration due to channelization, diversions and entrainment, water quality (e.g., temperature and pollutants) and predation.

Delta Inflows and Hydrodynamics

Recent fisheries investigations in the southern Delta (e.g., Vernalis Adaptive Management ~~Program~~ Plan [VAMP]) have focused on the survival of Chinook salmon smolts in relation to SJR inflows, Delta exports, and barrier installation at the head of Old River (HORB). A review of the VAMP studies and other investigations and their findings is presented in Appendix C, Chapter 3, *Scientific Basis for Developing Alternate San Joaquin River Flow Objectives.*

Changes in delta smelt habitat quality in the San Francisco estuary can be indexed by changes in X2. The abundance of many local species has tended to increase in years when flows into the estuary are high and the 2 ppt isohaline is pushed seaward (Jassby et al. 1995), implying that over the range of historical experience, the quantity or suitability of estuarine habitat increases when outflows are high (USBR 2008). Because large volumes of water are drawn from the estuary, water exports and inadvertent fish entrainment at the CVP and SWP export facilities are among the best studied top-down effects in the San Francisco estuary (Sommer et al. 2007). The export facilities are known to entrain most species of fish inhabiting the Delta (Brown et al. 1996) and are of particular concern in dry years, when the distributions of delta smelt and longfin smelt shift upstream, closer to the diversions (Stevens et al. 1985; Sommer et al. 1997).

Habitat Alteration

Prior to development and channelization, the Bay-Delta provided hospitable habitat for rearing and migrating salmonids. Historical floodplain areas were dynamic areas that generally contained complex, heterogeneous habitat types (e.g., grassland, riparian, tidal and nontidal marsh, and agriculture). Inundation of surrounding floodplains provided refuge, warmer temperatures, and abundant food supplies for rearing juvenile Chinook salmon, enabling them to grow faster than by solely migrating through riverine and southern Delta corridors. These smolts grew quickly and migrated out to the ocean sooner, ultimately resulting in higher survival rates in the ocean (Stillwater Sciences 2003).

Currently, the LSJR flow into the southern Delta is influenced by existing channels. From Vernalis, the Old River channel diverges from the LSJR downstream of Mossdale and connects with Middle River and Grant Line Canal. About 50 percent of the LSJR flow splits into the Old River channel, and the other 50 percent continues down the LSJR channel toward Stockton. Channel pathways affect migration of juvenile Chinook salmon. Temporary barriers or agricultural barriers in the Middle River, Grant Line Canal, and Old River can block access, restrict passage to rearing habitat, or redirect migration for adult and juvenile fall-run Chinook salmon. Specifically, the HORB has been installed in April and May of many years (not in years with flows above 7,000 cfs) to improve juvenile Chinook fish migration from the SJR Basin.

The current channelization and other southern Delta developments make the Bay-Delta less hospitable for Chinook salmon as compared to the historical Bay-Delta conditions. Central Valley salmonids and other native fishes use tidal marsh directly or indirectly for at least one if not several of their life stages. Tidal marsh provides spawning and rearing areas for Sacramento splittail and rearing habitat for salmonids. However, much of the historical riparian forests that support suitable habitat for these species has been converted to agricultural uses (Moyle 2002). This conversion has reduced the amount of floodplains and habitat and increased surface water temperatures.

Diversions and Entrainment

The two major water diversions in the southern Delta are the SWP (Banks Pumping Plant) and the CVP (Jones Pumping Plant). The Contra Costa Water District also diverts water from the southern Delta. Many small agricultural diversions (siphons and pumps) divert water from throughout the Delta during the spring and summer irrigation season. These diversions affect fish species by physically entraining them and altering flow such that migration cues are modified.

CVP and SWP export pumping is controlled under the 2006 Bay-Delta Plan objectives (State Water Board's Water Right Decision 1641 [D-1641] [revised March 15, 2000]). Both the CVP and the SWP have maximum permitted pumping (or diversion) rates. Delta outflow requirements may limit pumping if the combined Delta inflow is not enough to satisfy the in-Delta agricultural diversions and the full capacity CVP and SWP pumping. When pumping is limited, the cooperative operating agreement (COA) governs the CVP and SWP share in reservoir releases and Delta pumping. The CVP and SWP typically increase their rate of pumping approximately 10–40 percent during April and May.

Changes in the direction of channel flows, due to export pumping at the CVP and SWP pumping plants, strongly affect net flow patterns in the southern Delta. These altered flow patterns also influence how fish are distributed in the southern and interior Delta and how long the fish remain there (NMFS 2009a; Kimmerer and Nobriga 2008; Monsen et al. 2007). These flows can lead to increased straying away from the main channel of the SJR and towards the southern Delta via reverse OMR flows (USBR 2008; Kimmerer and Nobriga 2008; Mesick 2001). Reverse OMR flows occur because the major freshwater source, the Sacramento River, enters on the northern side of the Bay-Delta while the two major pumping facilities, the CVP and SWP, are located in the south. This results in a net water movement across the Delta in a north to south direction along a network of channels, including OMR (see Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*).

Water is drawn from the central Delta through lower OMR to the pumps in the southern Delta when combined pumping exceeds the incoming flow from the LSJR. This situation causes reverse flows in OMR. Reverse flows in the southern Delta make fish more vulnerable to entrainment at the pumps and delay migrations through or from the southern Delta. However, SJR inflow generally counteracts the effects of reverse OMR flows by providing higher inflows, which tend to result in movement of fish and larvae away from the southern Delta. In addition to the pumps, there are hundreds of agricultural diversions throughout the southern Delta that entrain small fish. These diversions not only entrain fish, but also affect them indirectly by altering flow patterns, food supply, and habitat.

The CVP and SWP pumping facilities are known to entrain various fish species in the southern Delta nearly year-round. The CVP and SWP fish facilities report entrainment of adult delta smelt during spawning migration December–April (USFWS 2008) while juveniles are entrained primarily April–June. Longfin smelt are primarily observed in the salvage operations during the spring (March–May) as juveniles, although larger subadult longfin smelt are also observed in the salvage operations during early winter. Young-of-year splittail are entrained April–August when fish are moving downstream into the Bay-Delta (Meng and Moyle 1995). Juvenile Chinook salmon are entrained in all months but primarily November–June when juveniles are migrating downstream. Green sturgeon are rarely entrained at the CVP and SWP fish facilities (probably due to low abundance in the southern Delta); however, entrainment has occurred in every month, indicating the presence of green sturgeon year-round (USBR 2009). Juvenile Central Valley steelhead from the SJR Basin are vulnerable to entrainment and salvage operations at the CVP and SWP export facilities, primarily March–May (Kimmerer 2008).

Pumping in the southern Delta may disorient salmonids and cause delayed outmigration of salmonids. While recent studies (Newman and Brandes 2010) indicate that spring water exports are not significantly impacting SJR outmigrating smolts under certain export conditions, there could be significant impacts on salmonids if exports are outside of the range tested. For example, in addition to creating false migration pathway, as discussed previously, strong negative flows in OMR can confuse outmigrating and rearing salmonids. Pumping-related impacts could affect salmonids between March and June but could vary with water year type. When exports are high relative to SJR flows, it is likely that little, if any, SJR Basin water reaches the San Francisco Bay. It is necessary for the scent of the SJR Basin to enter the bay in order for adult salmonids to find their way back to their natal streams. Specifically, Mesick (2001) observed that reduction, or even the elimination, of this scent trail is likely to increase the likelihood for fall-run Chinook salmon to stray from the SJR Basin and into the adjacent Mokelumne River or Sacramento River Basins.

There are over 2,200 small water diversions within the Delta, the majority of which are unscreened (Herren and Kawasaki 2001). These unscreened diversions have the potential to directly remove fish from the channels and alter local movement patterns (Kimmerer and Nobriga 2008; CDFG 2011a). Removal of fish and alteration of movement patterns take place throughout the year and are highest during fall, winter, and spring (CDFG 2011a). April–September is the high irrigation season and diversion period. Agricultural diversions have the ~~limited~~ potential to remove spring-run and winter-run Chinook salmon adults, juveniles, or fry, or any life stage of Central Valley steelhead from the Bay-Delta. It is undocumented how many juvenile Central Valley steelhead are entrained at the unscreened small water diversions in the Bay-Delta. However, because Central Valley steelhead are moderately large (more than 200 mm fork length), typically older, and relatively strong swimmers when outmigrating, the effects of small in-Delta agricultural water diversions on steelhead are thought to be lower than those on Central Valley Chinook salmon. Longfin smelt and delta smelt are typically present in the Delta primarily November–June. Since exports are typically greater when inflows from the Sacramento River and LSJR are greater in spring and summer, longfin smelt and delta smelt are expected to be affected by diversions.

Other smaller diversions, such as drawing cooling water for power generation plants and small agricultural diversions, also affect migrating Chinook salmon, but not to the extent of the CVP and SWP pumping facilities. Drawing cooling water from the Bay-Delta through power generation plants can remove fish and kill them due to mechanical and thermal trauma. These effects are potentially greatest on pelagic larvae of longfin smelt and delta smelt, one or both of which could be adjacent to the power plants in the western Delta during late December through July. Fall-run Chinook salmon fry may also be present and somewhat vulnerable late December through February during high-outflow years. Juvenile and adult smelt are present also during all other times of year but are less vulnerable because of greater mobility. The western Delta power plants are called to operate during times of high power demand, which are most apt to occur during peak summer temperatures July–September.

Water Quality

Because the southern Delta receives a substantial portion of its water from the LSJR, the influence of the relatively poor LSJR water quality is greatest in the southern Delta channels. Currently, the LSJR, Delta, and San Francisco Bay are listed under Section 303(d) of the federal Clean Water Act (CWA) as impaired for a variety of toxic contaminants that may contribute to reduced population abundance of important fishes and invertebrates.

Agricultural and urban runoff and domestic WWTP discharges in the southern Delta can cause direct and chronic toxicity to eggs, larvae, and adults of pelagic fish species. Some other contaminants that can affect pelagic fishes (delta smelt and longfin smelt) in the southern Delta are mercury, copper, oil and grease, selenium, pesticides, herbicides, and ammonia. These contaminants have the potential to affect fish or the food webs that support them and typically result from in-river activities (mining and dredging), urban runoff, urban sewage, municipal and industrial discharges, and agricultural drain water.

In addition, turbidity in the southern Delta is low, which may reduce habitat for delta smelt and other species (Feyrer 2004; Feyrer and Healey 2003; Feyrer et al. 2007; Monsen et al. 2007; Nobriga et al. 2008). Therefore, flow patterns that cause delta smelt to move into the southern Delta could negatively affect the population. ~~-~~During the fall adult salmon migration season, when LSJR inflows to the Bay-Delta are less than 1,500 cfs, low DO levels in the SJR at the Stockton Deep Water Ship Channel (e.g., less than 6 ppm) create a ~~chemical~~ migration barrier to upstream migrating adult salmon. Failure of SJR Basin salmon to reach the spawning grounds results in negative spawning impacts on the SJR fall-run Chinook salmon population (CDFG 2011a).

Unsuitable salinity gradients can cause physiological stress for many aquatic species in the Bay-Delta. Inflow from the LSJR to the Bay-Delta helps to establish the location in the Bay-Delta of the low salinity zone (LSZ), an area often referenced by X2 that historically has had high prey densities and other favorable habitat conditions for rearing juvenile delta smelt, striped bass, and other fish species (USBR 2008). However, changes in Delta inflows from the LSJR have the potential to alter LSZ salinity gradients and the location of X2, which can influence temperature, turbidity, and other habitat characteristics (Moyle et al. 2010). These alterations can potentially create an environment that is physiologically stressful to most organisms that utilize the Bay-Delta and X2, including Chinook salmon and Central Valley steelhead.

Agricultural diversions also influence the typical salinity gradients that migrating smolts encounter. Typically, outmigrating smolts would perceive a steadily increasing salinity gradient as the ocean grew closer. However, today, outmigrating fall-run Chinook salmon smolts encounter agricultural return flows that are of elevated temperature, nutrient and pesticide load, and salinity concentration (State Water Board 1999) in the Bay-Delta. As juveniles enter the southern Delta, the salinity (or electrical conductivity [EC][14]) at the three southern Delta compliance stations downstream of Vernalis (SJR at Brandt Bridge [P-12], Old River at Middle River [C-8], and Old River at Tracy Boulevard [C-6]) is generally slightly higher than the Vernalis EC. This is largely due to agricultural drainage and municipal discharges~~. As juveniles orient themselves and begin the last leg of their outmigration, they encounter a plume of low salinity Sacramento River water from the Delta Cross Channel, which is shuttled across the interior Bay-Delta.~~

Water temperature is determined by a number of factors, such as quantity and quality of water, channel geometry, and ambient air temperatures (TBI 2010). In general, the special-status fish species listed in Table 7-2 require lower water temperatures than the recreationally important fish species listed in Table 7-3. Water temperatures in the southern Delta show temperatures generally increase as a function of distance downstream within the mainstem of the LSJR (SJRGA 2010). Sites sampled on the mainstem of the LSJR as it enters the southern Delta (e.g., Durham Ferry, Mossdale, and Old River at HORB) were within a range considered to be suitable during April and May (typically < 68°F) for emigrating juvenile Chinook salmon (SJRGA 2010). Temperatures are slightly higher, but generally under 68°F further downstream within the southern Delta (e.g., Old River-Indian Slough Confluence) during this time (SJRGA 2010). However, water temperatures during early June were within the range (> 68°F) considered to be stressful for juvenile Chinook salmon (SJRGA 2010). Lethal temperatures for Chinook salmon and Central Valley steelhead juveniles are not reached under baseline conditions at Vernalis until August, and at that time these fishes typically are not present in the Bay-Delta.

Introduced Species and Predation

Predation rates in the southern Delta are believed to be higher than in other parts of the Bay-Delta. This is due to a variety of reasons, including: (1) turbidity is generally lower in the southern Delta, which increases visibility for predators (Nobriga et al. 2008; Feyrer et al. 2007); (2) many of the structures and facilities in the southern Delta support excellent conditions for predators by providing suitable habitat and flows, especially the Clifton Court Forebay and fish louver screens at the CVP and SWP facilities; and (3) recent invasions by the submerged plant, Brazilian water weed *Egeria densa* (Nobriga et al. 2008; Feyrer et al. 2007). The Brazilian water weed is an invasive,

[14] In this document, EC is *electrical conductivity*, which is generally expressed in deciSiemens per meter (dS/m). Measurement of EC is a widely accepted indirect method to determine the salinity of water, which is the concentration of dissolved salts (often expressed in parts per thousand or parts per million). EC and salinity are therefore used interchangeably in this document.

nonnative freshwater species that grows in denser stands than native submerged aquatic vegetation, providing rearing habitat for nonnative fish species, including bass. Brazillian water weed filters sediment and nutrients from the water column resulting in decreased turbidity in the southern Delta, which historically provided cover and habitat for outmigrating smolts but now provides cover for larger predatory fishes (Ferrari et al. 2013).

Based on their review of the VAMP studies, Dauble et al. (2010) concluded that predation appears to be having a variable effect on survival of smolts moving through the Delta (Grossman et al. 2013), which may in part account for the low survival of tagged fish in recent years as measured in the SJR at Vernalis (Dauble et al. 2010).

7.3 Regulatory Background

For a broad summary of relevant statutory and regulatory provisions, see Chapter 1, *Introduction*. For a more specific description of regulatory requirements set as existing and historical instream flow prescriptions on the LSJR and the three eastside tributaries, see Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*.

7.3.1 Federal

Relevant federal programs, policies, plans, or regulations related to aquatic resources are described below.

Clean Water Act

The CWA generally applies to all navigable waters of the United States and is discussed in Chapter 5, *Surface Hydrology and Water Quality.*

Central Valley Project Improvement Act

The Central Valley Project Improvement Act (CVPIA) was enacted in 1992 to balance the needs of fish and wildlife resources with other uses of CVP water. The purposes of the CVPIA are as follows.

- Protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River Basins of California.
- Address impacts of the CVP on fish, wildlife, and associated habitats.
- Improve the operational flexibility of the CVP.
- Increase water-related benefits provided by CVP to the State of California through expanded use of voluntary water transfers and improved water conservation.
- Contribute to California's interim and long-term efforts to protect the Bay-Delta Estuary.
- Achieve a reasonable balance among competing demands for use of CVP water, including the requirements of fish and wildlife, agricultural, municipal and industrial, and power contractors.

The CVPIA added mitigation, protection, and restoration of fish and wildlife to the purposes of the CVP, dedicated 800,000 AF of CVP yield for the primary purpose of implementing fish, wildlife, and habitat restoration, and created a Central Valley Project Restoration Fund to carry out CVPIA programs, projects, plans, and habitat restoration, improvement, and acquisition provisions. Among the CVPIA programs that benefit salmonids and other fish species is the AFRP, the Anadromous Fish Screen Program (AFSP), and the Water Acquisition Program (WAP). The AFRP conducts monitoring, education, and restoration projects directed toward recovery of anadromous fish species in the Central Valley. Restoration projects funded through the AFRP include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The AFSP combines federal funding with state and private funds to prioritize and construct fish screens on major water diversions mainly in the Upper Sacramento River. The goal of the WAP is to acquire water supplies to meet the habitat restoration and enhancement goals of the CVPIA and to improve the DOI's ability to meet regulatory water quality requirements.

Endangered Species Act

The purpose of the ESA is to protect and recover imperiled species and the ecosystems upon which they depend. ESA is administered by USFWS and NMFS. In general, NMFS is responsible for protecting ESA-listed threatened or endangered marine species and anadromous fishes, while other listed species (e.g., freshwater and terrestrial species) are under USFWS jurisdiction. An *endangered species* is defined as "… any species which is in danger of extinction throughout all or a significant portion of its range." (16 U.S.C., § 1532, subd. (6).) A *threatened species* is defined as "… any species that 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, subd. (20).) ESA Section 9 makes it illegal to *take* (i.e., harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in such conduct) any endangered fish or wildlife species. (16 U.S.C., §§ 1538; 1532, subd. (19).) For threatened fish and wildlife species, ESA Section 4(d) allows for the adoption of protective regulations, including provisions extending the Section 9 take prohibition to that species. (16 U.S.C., § 1538, subd. (d).)

ESA also requires the designation of critical habitat for listed species. *Critical habitat* is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to a species' conservation, and those features may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation (NMFS 2011; NMFS 2009a; ICF International 2012).

If a federal agency believes that its action will jeopardize a listed species or destroy or adversely modify critical habitat, the agency must request formal consultation with USFWS or NMFS, as appropriate, under Section 7 of the ESA. (16 U.S.C., § 1536.) The USFWS or NMFS then issues a BO as to whether the action is likely to jeopardize a listed species or to destroy or adversely modify its critical habitat. If an action will result in jeopardy, the USFWS or NMFS will provide the consulting federal agency with reasonable and prudent alternative actions to avoid jeopardy. For any non-federal action otherwise prohibited by Section 9, the applicant must apply to the Secretaries for an incidental take permit under ESA Section 10 (16 U.S.C., § 1539.) Species that are candidates for listing are not protected under ESA; however, USFWS advises that a candidate species could be elevated to listed status at any time, and, therefore applicants should regard these species with special consideration.

Long-Term Central Valley Project Operations Criteria and Plan and Biological Opinions

The *Long-Term Central Valley Project – Operations Criteria and Plan* (OCAP) is a baseline description of the facilities and operating environment of the CVP and SWP and identifies the many factors influencing the physical and institutional conditions and decision-making processes under which the USBR and the California Department of Water Resources (DWR) operate the integrated SWP and CVP system, including how the CVP and the SWP divert, store, and convey water consistent with applicable law (USBR 2008).

U.S. Fish and Wildlife Service Biological Opinion

Pursuant to the ESA, USBR requested a biological opinion from the USFWS as to whether its operations, as described in the OCAP, would jeopardize listed species. The 2008 USFWS BO concurred with USBR's determination that the coordinated operations of the SWP and CVP are not likely to adversely affect listed species, with the exception of delta smelt (USFWS 2008). The USFWS concluded that the coordinated operations of the SWP and CVP, as proposed, were likely to jeopardize the continued existence of delta smelt and adversely modify delta smelt critical habitat. Consequently, USFWS developed a reasonable and prudent alternative (RPA) to the project as described in the OCAP, consisting of a number of operational changes and other actions to avoid the likelihood of jeopardizing the continued existence of delta smelt or destroying or adversely modifying delta smelt critical habitat. These actions include: (1) preventing/reducing entrainment of delta smelt at the Jones and Banks Pumping Plants, (2) providing adequate habitat conditions that will allow adult delta smelt to successfully migrate and spawn in the Bay-Delta, (3) providing adequate habitat conditions that will allow larvae and juvenile delta smelt to rear, and (4) providing suitable habitat conditions that will allow successful recruitment of juvenile delta smelt to adulthood. In addition, USFWS specified that it is essential to monitor delta smelt abundance and distribution through continued sampling programs through the Interagency Ecological Program (IEP). The RPA restricted pump operations and limited deliveries of water to SWP and CVP contractors south of the Delta.

Various parties, including SWP and CVP contractors, brought suit in federal court challenging the USFWS 2008 BO. Years of litigation followed, and in March 2014, the United States Court of Appeals, Ninth Circuit, upheld the biological opinion and concluded that USBR must comply with the National Environmental Policy Act to evaluate the effects of the USBR's adoption and implementation of the 2008 BO.

National Marine Fisheries Service Biological Opinion

The NMFS BO (NMFS 2009a) concluded that the joint operations of the CVP and SWP, as described in the OCAP, were likely to jeopardize the continued existence of the following species.

- Sacramento River winter-run Chinook salmon.
- Central Valley spring-run Chinook salmon.
- Central Valley steelhead.
- Southern DPS of North American green sturgeon.
- Southern resident killer whale.

NMFS (2009a) also concluded that CVP and SWP operations, as described in the OCAP, were likely to destroy or adversely modify the designated critical habitats of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and green sturgeon. The actions included in the RPA to USBR's proposed action are summarized below relevant to the plan area (NMFS 2009a).

- New OMR reverse flow levels to limit the strength of reverse flows and reduce entrainment at the SWP and CVP facilities.
- Additional technological measures at the SWP and CVP facilities to enhance screening and increase survival of fish.
- Additional measures to improve survival of steelhead smolts, including increased SJR flows and export curtailments, and a new study of acoustic tagged fish in the SJR Basin to evaluate and refine these measures.
- A year-round minimum flow regime on the Stanislaus River necessary to minimize project effects on each life stage of steelhead, including new springtime flows that will support rearing habitat formation and inundation, and create pulses that allow salmon to outmigrate successfully.

Various parties challenged the 2009 BO in federal court. In December 2014, the United States Court of Appeals, Ninth Circuit, upheld the BO in its entirety.

Recovery Plan for Sacramento–San Joaquin Delta Native Fish Species

The *Recovery Plan for the Sacramento–San Joaquin Delta Native Fishes* was released in 1996 by USFWS with the basic goal of establishing self-sustaining populations of species of concern. The plan specifically focused on delta smelt, longfin smelt, Sacramento splittail, and Sacramento perch.

National Wildlife Refuge System Improvement Act of 1997

Comprehensive conservation plans (CCPs) are prepared by USFWS and are required under the National Wildlife Refuge System Improvement Act of 1997. In 2006 the USFWS prepared a final CCP for the San Joaquin River National Wildlife Refuge to guide the management of the refuge for the next 15 years. The primary goals of the refuge are to accomplish the following: conserve and protect the natural diversity of migratory birds, resident wildlife, fish, and plants through restoration and management of riparian, upland, and wetland habitats on refuge lands; contribute to the recovery of threatened and endangered species, as well as the protection of populations of special-status wildlife and plant species and their habitats; provide optimum wintering habitat for Aleutian Canada geese to ensure the continued recovery from threatened and endangered species status; coordinate the natural resource management of the San Joaquin River National Wildlife Refuge in the context of the larger Central Valley-San Francisco ecoregion; and provide the public with opportunities for compatible, wildlife-dependent visitor services to enhance understanding, appreciation, and enjoyment of natural resources at the San Joaquin River National Wildlife Refuge (USBR 2011).

Federal Power Act

Under the Federal Power Act (FPA), the FERC is responsible for determining under what conditions to issue licenses, or relicense, non-federal hydroelectric projects. Under the provisions of Section 10(j) of the FPA, each hydroelectric license issued by FERC is required to include conditions for the protection, mitigation, or enhancement of fish and wildlife resources affected by the project. These required conditions are to be based on recommendations of federal and state fish and wildlife agencies. FERC may reject or alter the recommendations on several grounds, including if FERC determines they are inconsistent with the purposes and requirements of the FPA or other applicable law. The State Water Board exercises authority over hydropower projects through Section 401 of the Clean Water Act, which requires an applicant for a federal license or permit that conducts an activity that results in a discharge into the navigable waters of the United States to apply for a certification from the state that the discharge will comply with state and federal water quality standards. The certification will include conditions requiring compliance with the Bay-Delta Plan's water quality objectives, including the LSJR flow requirements. FERC does not have authority to review or set aside the water quality certification.

7.3.2 State

Relevant state programs, policies, plans, or regulations related to aquatic resources are described below. Descriptions of the *2006 San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality Control Plan* (Bay-Delta Plan), Porter-Cologne Act, California's water rights system, and State Water Board authorities are described in Chapter 1, *Introduction*.

California Endangered Species Act of 1970

CESA (Fish & G. Code, § 2050 et seq.), expresses state policy to conserve, protect, restore, and enhance any endangered or threatened species or its habitat. The Act generally prohibits the take (hunt, pursue, catch, capture, or kill) of listed species, although it may allow for take incidental to otherwise lawful activities. (Fish & G. Code, § 2080 et seq.) Under CESA, the California Fish and Game Commission has the responsibility for maintaining a list of threatened and endangered species (Fish & G. Code, § 2070), and CDFW may authorize take that is otherwise prohibited (by permits, agreements, etc.) or pursue enforcement actions for unauthorized take.

California Department of Fish and Wildlife Species Designations

CDFW maintains an informal list of "species of special concern." The intent of the designation is to focus on plant and wildlife species that are at conservation risk, stimulate research on poorly known species, and achieve conservation and recovery of species before they are listed under CESA. Species of special concern have factors in common such as small isolated populations, marked population decline, fragmented habitat, and association with habitats that are declining in California.

Salmon, Central Valley Steelhead Trout, and Anadromous Fisheries Program Act

The 1988 Salmon, Central Valley Steelhead Trout, and Anadromous Fisheries Program Act was enacted in response to reports that the natural production of salmon and steelhead in California had declined dramatically since the 1940s. The Act expressed the State's policy to significantly increase the natural production of salmon and steelhead trout by the end of the century. CDFW was charged with developing a plan and program that strives to double the then-current natural production of the fishery. (Fish & Game Code, § 6902, subd. (c).)

7.3.3 Regional or Local

Relevant regional or local programs, policies, plans, or regulations related to aquatic resources are described below. Although local policies, plans, and regulations are not binding on the State of California, below is a description of relevant ones.

County General Plans

As required by state law, counties must develop their own general plans. Within the plan area, applicable general plans include the *Calaveras County General Plan* (1996), the *Tuolumne County General Plan* (1996), the *Mariposa County Wide General Plan* (2010), and the *San Joaquin County Wide General Plan* (2005). These plans have policies that can preserve and protect open space and natural resources, such as rivers and reservoirs and the lands adjacent to them.

San Joaquin County Multi-Species Habitat Conservation and Open Space Plan

The *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan*, approved and adopted in November 2000, includes compensation measures to offset the effects of development on special-status plant, fish, and wildlife species throughout San Joaquin County, including the LSJR. The plan's purpose is to provide a strategy for balancing the need to conserve open space and the need to convert open space to non-open space uses while protecting the region's agricultural economy and preserving landowner property rights. The plan also is to provide for the long-term management of plant, fish, and wildlife species, especially those that are currently listed or may be listed in the future under ESA or CESA (County of San Joaquin 2012).

7.4 Impact Analysis

This section identifies the thresholds or significance criteria used to evaluate the potential impacts on aquatic resources. It further describes the methods of analysis used to evaluate the potential impacts and to determine the significance of those impacts. Measures to mitigate (i.e., avoid, minimize, rectify, reduce, eliminate, or compensate for) significant impacts accompany the impact discussion if any significant impacts are identified.

7.4.1 Thresholds of Significance

The thresholds for determining the significance of impacts for this analysis are based on the State Water Board's Environmental Checklist in Appendix A of the Board's CEQA regulations. (Cal. Code Regs., tit. 23, §§ 3720–3781.) The thresholds derived from the checklist(s) have been modified, as appropriate, to meet the circumstances of the alternatives. (Cal. Code Regs., tit. 23, § 3777, subd. (a)(2).) Impacts on aquatic biological resources were identified as potentially significant in the State Water Board's Environmental Checklist (see Appendix B, *State Water Board's Environmental Checklist*) and, therefore, are discussed in this analysis as to whether the alternatives could result in the following.

- Cause significant changes in spawning success and habitat availability for warmwater species resulting from changes in reservoir water levels.
- Cause significant changes in availability of coldwater species reservoir habitat resulting from changes in reservoir storage.
- Cause significant changes in quantity/quality of physical habitat for spawning and rearing resulting from changes in flow.
- Cause significant changes in exposure of fish to suboptimal water temperatures resulting from changes in reservoir storage and releases.
- Cause significant changes in exposure to pollutants resulting from changes in flow.
- Cause significant changes in exposure to suspended sediment and turbidity resulting from changes in flow.
- Cause significant changes in redd dewatering resulting from flow fluctuations.
- Cause significant changes in spawning and rearing habitat quality resulting from changes in peak flows.
- Cause significant changes in food availability resulting from changes in flow and floodplain inundation.
- Cause significant changes in predation risk resulting from changes in flow and water temperature.
- Cause significant changes in disease risk resulting from changes in water temperature.
- Cause significant changes in southern Delta and estuarine habitat resulting in changes in SJR inflows and export effects.

A significant impact under these thresholds would result in a significant impact on aquatic resources. Where appropriate, specific quantitative or qualitative criteria are described in Section 7.4.2, *Methods and Approach*, for evaluating these thresholds.

7.4.2 Methods and Approach

This section describes the methods and approach for analyzing the effects of the LSJR and SDWQ alternatives.

LSJR Alternatives

This chapter evaluates the potential aquatic resource impacts associated with the LSJR alternatives. Each LSJR alternative includes a February–June unimpaired flow[15] requirement and methods for adaptive implementation to reasonably protect fish and wildlife beneficial uses, as described in Chapter 3, *Alternatives Description*. The impact analysis for aquatic resources evaluates expected aquatic species responses to changes in environmental conditions under the LSJR alternatives.

[15] *Unimpaired flow* represents the water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. It differs from natural flow because unimpaired flow is the flow that occurs at a specific location under the current configuration of channels, levees, floodplain, wetlands, deforestation and urbanization.

Impacts were evaluated based on expected changes in the environment relative to the temporal and spatial occurrence of indicator species and applicable life stages for which impact mechanisms and environmental requirements, or tolerances, are sufficiently understood to support an analysis. In addition, a minimum base flow is required at Vernalis at all times during this period. The base flow may be adaptively implemented as described below and in Chapter 3. State Water Board approval is required before any method can be implemented, as described in Appendix K, *Revised Water Quality Control Plan*. All methods may be implemented individually or in combination with other methods, may be applied differently to each tributary, and could be in effect for varying lengths of time, so long as the flows are coordinated to achieve beneficial results in the LSJR related to the protection of fish and wildlife beneficial uses. The methods used in the analysis varied by geographic area, species life stages, and environmental conditions, and depended largely on the best available scientific information.

For purposes of impact assessment, the plan area has been divided into the following geographic areas.

- The major reservoirs: New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure.
- The three eastside tributaries: Stanislaus, Tuolumne, and Merced Rivers.
- LSJR (Merced River confluence with the SJR downstream to Vernalis).
- The southern Delta.

Because impacts have been evaluated based on predicted effects on indicator species and their specific life stages, each impact discussion is organized by the relevant life stage of the indicator species in the three eastside tributaries and LSJR, as appropriate. These species include coldwater reservoir fish (i.e., rainbow trout[16]), anadromous fish (i.e., fall-run Chinook salmon and steelhead), and warmwater reservoir fish (i.e., largemouth bass). Specific indicator species were selected because they are either native species whose populations in California are declining and/or have received a special-status designation by federal or state resource agencies, or they are recreationally important game fish species. Additionally, these indicator species would be sensitive to the environmental changes expected to result from the LSJR alternatives in each of the geographic areas comprising the plan area. Furthermore, these species have utility in evaluating broader ecosystem and community-level effects of these changes on aquatic resources. For example, the results of the impact analysis on Chinook salmon and steelhead are considered indicative of effects on other native fishes because of the broad ecological benefits of natural flow variability restoration efforts aimed at anadromous salmonids on other native fish communities. A general discussion of the potential responses of, and impacts on, other fish species under the LSJR alternatives are qualitatively discussed where appropriate (i.e., Impacts AQUA-3, AQUA-4, and AQUA-10).

In order to analyze the potential impacts from the LSJR alternatives on indicator species relative to the thresholds discussed above, the impact analysis focuses on the effects of changes in flows and reservoir levels and resultant environmental conditions on indicator species. Changes in flow or reservoir levels directly relate to the quantity and quality of available habitat for various life stages of aquatic species and, therefore, also to population distribution, numbers, and dynamics (see Appendix C, *Technical Analysis on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*).

[16] For the purposes of this document, rainbow trout refers to *O. mykiss* populations above impassable dams while steelhead refers to *O. mykiss* populations below these dams.

Each LSJR alternative includes a February–June unimpaired flow requirement (i.e., 20, 40, or 60 percent) from February–June and adaptive implementation, as described in Chapter 3, *Alternatives Description*. Adaptive implementation could change the volume, rate, or timing of water released February–June. While the adaptive implementation approaches are common to all alternatives, the specific changes vary between the alternatives and may vary by the adaptive implementation approach being implemented, as described in Appendix K. As discussed in Chapter 3, the intent of adaptive implementation is to provide flexibility in meeting biological goals based on monitoring and data collection, to best support ecosystem functions from February–June, as well as support biological needs outside of that time frame. Quantitative or qualitative evaluations were performed in this chapter to evaluate the impacts of the LSJR alternatives. The evaluations used a variety of data sources, such as results from the Water Supply Effects (WSE) models of diversions, reservoir operations, streamflow, and results from the water temperature model. Details of the models and results are presented in Chapter 5, *Surface Hydrology and Water Quality*; Appendix F.1, *Hydrologic and Water Quality Modeling*; and Appendix F.2, *Evaluation of Historical Flow and Salinity Measurements of the Lower San Joaquin River and Southern Delta*.

In this chapter, hydrologic conditions related to aquatic resources are often described using cumulative distribution tables. The cumulative distribution of a particular variable (e.g., flow at a location or temperature at a location) provides a basic summary of the distribution of values. The percentile (i.e., percent cumulative distribution) associated with each value indicates the percent of time that the values were less than the specified value. For example, a 10th percentile value of 2 indicates that 10 percent of the time, the values were less than 2. The 0th percentile is the minimum value, the 50th percentile is the median value, and the 100th percentile is the maximum value. The 10th and 90th percentiles represent relatively low and relatively high values and are representative of multiple years rather than the 1 year with the highest value and the 1 year with the lowest value.

Impacts on indicator species were evaluated by applying one or more of the following general methods.

- Comparison of quantitative simulations: Quantitative output from modeling tools were used for direct comparisons between baseline conditions and the LSJR alternatives to identify effects on aquatic resources.
- Interpretation/extrapolation from quantitative simulations: Output of quantitative models were interpreted/extrapolated to describe effects on aquatic resources.
- Interpretation/extrapolation and qualitative assessment: Existing data and information from previous studies were used to interpret/extrapolate the effects on aquatic resources and to provide a qualitative assessment.

Table 7-7 summarizes the criteria that were evaluated and the habitat variables, biological criteria, and the modeling tools or data used.

Table 7-7. A Summary of the Impact Thresholds, Variables, Criteria, and Data or Methods Used (see also Table 7-1)

Impact Thresholds	Environmental or Habitat Variable	Impact Criteria	Data and Method Used
Impact AQUA-1: Changes in spawning success and habitat availability for warmwater species resulting from changes in reservoir water levels	• Frequency/magnitude of reservoir drawdowns during primary spawning and rearing periods	• Reservoir level fluctuations of 15 feet or more	• Hydrologic/reservoir operations model (Water Supply Effects [WSE] model) • Relationships between reservoir storage and water surface elevation
Impact AQUA-2: Changes in availability of coldwater species reservoir habitat resulting from changes in reservoir storage	• Reservoir storage (end-of-September)	• Storage (water volume) used as an indicator of changes in coldwater habitat availability	• Hydrologic/reservoir operations model (WSE model)
Impact AQUA-3 : Changes in quantity/quality of physical habitat for spawning and rearing resulting from changes in flow	• Frequency/magnitude of changes in spawning and rearing weighted usable area (WUA) • Frequency/magnitude of changes in floodplain inundation area	• WUA and floodplain inundation area	• WUA-discharge relationships • Floodplain inundation area-flow relationships
Impact AQUA-4: Changes in exposure of fish to suboptimal water temperatures resulting from changes in reservoir storage and releases	• Frequency of 7-day averages of the daily maximum water temperatures exceeding criteria	• Water temperature criteria (USEPA criteria)	• Hydrologic/reservoir operation model (WSE model) • River temperature model
Impact AQUA-5: Changes in exposure to pollutants resulting from changes in flow	• Dilution effect of flow on pollutant concentrations • Effect of water temperature on exposure/sensitivity of fish to pollutants	• 50% increase in baseline concentrations	• Published literature • Qualitative evaluation
Impact AQUA-6: Changes in exposure to suspended sediment and turbidity resulting from changes in flow	• Frequency of sediment-mobilizing flows	• Flow thresholds for mobilization of gravel and fine sediment	• Published literature • Qualitative evaluation

Impact Thresholds	Environmental or Habitat Variable	Impact Criteria	Data and Method Used
Impact AQUA-7: Changes in redd dewatering resulting from flow fluctuations	• Frequency/magnitude of flow reductions exceeding depth thresholds during primary spawning and incubation periods	• Habitat suitability criteria (spawning depth preferences and egg pocket depths)	• Hydrologic/reservoir operations model (WSE model) • Flow-depth relationships • Habitat suitability criteria
Impact AQUA-8: Changes in spawning and rearing habitat quality resulting from changes in peak flows	• Frequency/magnitude of gravel-mobilizing flows	• Flow thresholds for gravel mobilization	• Hydrologic/reservoir operations model (WSE model)
Impact AQUA-9: Changes in food availability resulting from changes in flow and floodplain inundation	• Frequency/magnitude of floodplain inundation	• Floodplain inundation area	• Published literature • Qualitative evaluation
Impact AQUA-10: Changes in predation risk resulting from changes in flow and water temperature	• Frequency/magnitude of habitat availability and suboptimal water temperatures	• WUA, floodplain inundation area, and USEPA water temperature criteria for juvenile rearing and outmigration life stages	• Impact AQUA-3 and Impact AQUA-4 results • Published literature • Qualitative evaluation
Impact AQUA-11: Changes in disease risk resulting from changes in water temperature	• Water temperatures associated with increased incidence of disease	• Temperature thresholds for disease incidence in indicator species	• Published literature • Qualitative evaluation • Impact AQUA-4 results
Impact AQUA-12: Changes in southern Delta and estuarine habitat resulting in changes in SJR inflows and export effects	• Change in magnitude of Delta exports in relation to SJR inflows	• Potential effect on fish distribution, entrainment risk, and estuarine habitat quality	• Hydrologic/reservoir operations model (WSE model) • Rules and objectives governing Delta operations • Qualitative evaluation

The Stanislaus, Tuolumne, and Merced Working Group (STM Working Group) will assist with implementation, monitoring, and assessment activities for the flow objectives and with developing biological goals to help evaluate the effectiveness of the flow requirements and adaptive implementation actions. The STM Working Group may recommend adjusting the flow requirements through adaptive implementation if scientific information supports such changes to reasonably protect fish and wildlife beneficial uses. Scientific research may also be conducted within the adaptive range to improve scientific understanding of measures needed to protect fish and wildlife and reduce scientific uncertainty through monitoring and evaluation. Further details describing the methods, the STM Working Group, and the approval process are included in Chapter 3 and Appendix K.

Without adaptive implementation, flow must be managed such that it tracks the daily unimpaired flow percentage based on a running average of no more than 7 days. The four methods of adaptive implementation are described briefly below.

1. Based on best available scientific information indicating that more flow is needed or less flow is adequate to reasonably protect fish and wildlife beneficial uses, the specified annual February–June minimum unimpaired flow requirement may be increased or decreased to a percentage within the ranges listed below. For LSJR Alternative 2 (20 percent unimpaired flow), the percent of unimpaired flow may be increased to a maximum of 30 percent. For LSJR Alternative 3 (40 percent unimpaired flow), the percent of unimpaired flow may be decreased to a minimum of 30 percent or increased to a maximum of 50 percent. For LSJR Alternative 4 (60 percent unimpaired flow), the percent of unimpaired flow may be decreased to a minimum of 50 percent.
2. Based on best available scientific information indicating a flow pattern different from that which would occur by tracking the unimpaired flow percentage would better protect fish and wildlife beneficial uses, water may be released at varying rates during February–June. The total volume of water released under this adaptive method must be at least equal to the volume of water that would be released by tracking the unimpaired flow percentage from February–June.
3. Based on best available scientific information, release of a portion of the February–June unimpaired flow may be delayed until after June to prevent adverse effects to fisheries, including temperature, which would otherwise result from implementation of the February–June flow requirements. The ability to delay release of flow until after June is only allowed when the unimpaired flow requirement is greater than 30 percent. If the requirement is greater than 30 percent but less than 40 percent, the amount of flow that may be released after June is limited to the portion of the unimpaired flow requirement over 30 percent. For example, if the flow requirement is 35 percent, 5 percent may be released after June. If the requirement is 40 percent or greater, then 25 percent of the total volume of the flow requirement may be released after June. As an example, if the requirement is 50 percent, at least 37.5 percent unimpaired flow must be released in February–June and up to 12.5 percent unimpaired flow may be released after June. See Chapter 3 and Appendix K for further details.
4. Based on best available scientific information indicating that more flow is needed or less flow is adequate to reasonably protect fish and wildlife beneficial uses, the February–June Vernalis base flow requirement of 1,000 cfs may be modified to a rate between 800 and 1,200 cfs.

The operational changes made using the adaptive implementation methods above may be approved if the best available scientific information indicates that the changes will be sufficient to support and maintain the natural production of viable native SJR Watershed fish populations migrating through the Delta and meet any biological goals. The changes may take place on either a short-term (for example monthly or annually) or longer-term basis. Adaptive implementation is intended to foster coordinated and adaptive management of flows based on best available scientific information in order to protect fish and wildlife beneficial uses. Adaptive implementation could also optimize flows to achieve the objective, while allowing for consideration of other beneficial uses, provided that these other considerations do not reduce intended benefits to fish and wildlife. While the measures and processes used to decide upon adaptive implementation actions must achieve the narrative objective for the reasonable protection of fish and wildlife beneficial uses, adaptive implementation could result in flows that would benefit or reduce impacts on other beneficial uses that rely on water. For example, terrestrial riparian species could benefit by receiving additional flows during key germination times in the late spring.

The quantitative results included in the figures, tables, and text of this chapter present WSE modeling of the specified unimpaired flow requirement for each LSJR alternative (i.e., 20, 40, or 60 percent). The modeling results also reflect some adjustments in the allocation of flows (as might occur under adaptive implementation method 3 above) to prevent adverse temperature effects in years in which strict adherence to the unimpaired flow percentages results in predicted water temperatures that exceed the significance thresholds for sensitive life stages in the summer and fall (e.g., Chinook salmon spawning and incubation). In practice, such allocations would be implemented in accordance with the adaptive implementation process described above, which would consider a full range of potential flow management methods (methods 1, 2, 3, and 4 above) to maximize fisheries benefits while balancing the needs of other beneficial uses. For more information regarding the modeling methodology and quantitative flow and temperature modeling results, see Appendix F.1, *Hydrologic and Water Quality Modeling.*

The below subsections provide additional information regarding specific methodologies used for Impact AQUA-3 (changes in quantity/quality of physical habitat for spawning and rearing resulting from changes in flow) and Impact AQUA-4 and Impact AQUA-11 (changes in disease risk resulting from changes water temperature), as well as for Impact AQUA-6 and Impact AQUA-8 (changes in spawning and rearing habitat quality resulting from changes in peak flows).

Physical Habitat Availability

Changes in flow under the LSJR alternatives could affect the quantity and quality of Chinook salmon and steelhead spawning and rearing habitat through changes in the extent of suitable water depths, velocities, substrate types, and other physical attributes of the stream environment. The effects of flow on Chinook salmon and steelhead physical habitat availability were evaluated using two flow-based habitat indices: weighted usable area (WUA) and floodplain inundation area. Both indices were necessary to address changes in habitat availability for the juvenile rearing life stages over the full range of modeled flows.

WUA is a measure of the quantity and quality of habitat for a given species and life stage and is generally defined as the surface area of a stream having a certain combination of water depths, velocities, and other physical attributes that define suitable habitat for that species and life stage. The relationship between WUA and streamflow is a key element of the Instream Flow Incremental Methodology (IFIM) (Bovee et al. 1998). WUA is expressed in terms of square feet or square feet per unit distance (e.g., square feet per 1,000 linear feet of stream). WUA-discharge relationships were developed for Chinook salmon and steelhead spawning, fry rearing, and juvenile rearing life stages as part of a number of instream flow studies conducted on the Stanislaus, Tuolumne, and Merced Rivers (Bowen et al. 2012; MID 2013; Stillwater Sciences 2013). WUA-discharge relationships were available for all three Chinook salmon and steelhead life stages, except for the Stanislaus River, where a WUA-discharge relationship for steelhead spawning was not available. For Impact AQUA-3, existing WUA-discharge relationships were applied to the WSE modeling results to evaluate changes in the quantity and quality of Chinook salmon and steelhead spawning and rearing habitat in key months over the 82-year modeling period.

Since the WUA-discharge relationships are limited to the range of flows that generally fall within the bankfull width of the channel, the floodplain inundation-flow relationships were used to evaluate potential changes in juvenile rearing habitat within the upper range of flows that inundate adjacent floodplains. The primary sources for the floodplain inundation-flow relationships were USFWS 2008; USFWS 2011, 2012, 2013; and cbec 2010 (see Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30*, Section 19.3, *Floodplain Inundation*). These relationships define changes in wetted floodplain inundation area (above bankfull thresholds) as a function of flow.

Peak Flows

Potential effects of the LSJR alternatives on the frequency and magnitude of flow events capable of inducing sediment transport in the upper and lower reaches of the Stanislaus, Tuolumne, and Merced Rivers were evaluated to determine the potential for changes in exposure of fish to increases in suspended sediment concentrations and turbidity (Impact AQUA-6) and changes in spawning gravel quality resulting from gravel mobilization (Impact AQUA-8). Under baseline conditions, gravel transport is estimated to occur at flows between 5,000 and 8,000 cfs in the Stanislaus River (Kondolf et al. 2001), between 7,050 and 9,800 cfs in the upper reaches of the Tuolumne River (McBain and Trush 2000), and at flows greater than 4,800 cfs in the upper reaches of the Merced River (Stillwater Sciences 2001; Kondolf et al. 1996). Flows below these levels (above approximately 2,000–3,000 cfs) can mobilize finer sediment in the mid- to lower sand-bedded portions of these tributaries, potentially increasing suspended sediment and turbidity in the lower reaches of the three eastside tributaries and the LSJR. These flows served as thresholds for evaluating the potential for impacts on indicator species and aquatic habitat resulting from changes in the frequency and magnitude of bed-mobilizing flows in the Stanislaus, Tuolumne, and Merced Rivers.

Water Temperature and Dissolved Oxygen

Impacts of changes in water temperatures on indicator species were evaluated using the San Joaquin River Basin-Wide Water Temperature Model (temperature model) developed by Resource Management Associates for CALFED using the USACE HEC-5Q simulation model (CALFED 2009). The temperature model provides a basin-wide evaluation of temperature response at 6-hour intervals for alternative conditions. The geographic extent of the model includes the Stanislaus, Tuolumne, and Merced River systems from their confluences with the LSJR to upstream of the major reservoirs (New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure, respectively). The downstream extent of the model is Mossdale on the LSJR. See Appendix F.1, *Hydrologic and Water Quality Modeling*, for a full discussion of this model and its application.

Daily water temperature model results of LSJR Alternatives 2, 3, and 4 were quantitatively assessed to determine the changes in the frequency of potentially stressful water temperatures at key locations and months during the 1970–2003 temperature modeling period. The months and locations generally coincide with the occurrence of each life stage and the maximum water temperatures potentially encountered by individual life stages within each geographic area. This information is incorporated into Impact AQUA-4.

Although wWater temperature can affect DO levels, and both factors are related to apparent blockage and delays in migration of adult salmon in the Delta (see Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*)., adverse effects associated with low DO levels have not been documented in reaches of the SJR or the three eastside tributaries. Based on the general relationship between water temperature and Therefore, DO levels, are expected to remain within acceptable levels and could potentially increase in response to higher flows and cooler water tempertures under the LSJR alterantives are assumed to result inand lower DOcooler temperatures und levels in the LSR tributaries, or the LSJR, and Delta alternatives, as discussed under Impact AQUA-4.

Extended Plan Area

The analysis of the extended plan area generally identifies how the impacts may be similar to or different from the impacts in the plan area (i.e., downstream of the rim dams) depending on the similarity of the impact mechanism (e.g., changes in reservoir levels, reduced water diversions, and additional flow in the rivers) or location of potential impacts in the extended plan area. Where appropriate, the program of implementation is discussed to help contextualize the potential impacts in the extended plan area.

SDWQ Alternatives

In general, most fish species identified in Table 7-2 spend the majority or a significant portion of their life history in the Bay-Delta and are accustomed to variations in salinity. Specific salinity information for fish species is presented in Section 7.2.1, *Fish Species*. Indicator species are able to tolerate salinity changes within the range of 0.2 dS/m (0.134 ppt) and 1.2 dS/m, (0.768 ppt), as these salinity levels are within the general historical salinity conditions of the southern Delta. As described in Chapter 5, *Surface Hydrology and Water Quality*, reservoir releases are currently increased in order to meet the existing salinity objectives of maintaining EC below 1.000 dS/m (1,000 μS/cm) (0.67 ppt) for September–March and below 0.700 dS/m (700 μS/cm) (0.37 ppt), for April–August in the SJR at Vernalis. Changes in EC that may occur downstream of Vernalis are dependent on conditions at Vernalis and within the Delta. Under the SDWQ alternatives, there would be no change in operations affecting Delta salinity relative to baseline. This is because EC at Vernalis would be maintained at or below 0.7 dS/m (0.37 ppt) April–August and 1.0 dS/m (0.67 ppt) September–March through the program of implementation, as it is under the current objectives. However, under the SDWQ alternatives, the Vernalis and southern Delta salinity objectives would be changed to a year-round value of either 1.0 dS/m (0.67 ppt) or 1.4 dS/m (0.94 ppt), under SDWQ Alternative 2 or 3, respectively. This would provide some assimilative capacity downstream of Vernalis and protect beneficial agricultural uses. Therefore, the general historic range of salinity (between 0.200 [0.134 ppt] and 1.200 dS/m [0.77 ppt]) would remain unchanged under SDWQ Alternatives 2 and 3. These changes are not expected to increase exposure of sensitive fish species to salinity levels that may adversely affect migration conditions or spawning habitat suitability in the LSJR due to their low levels of salinity. The modeling results indicated that under SDWQ

Alternatives 2 or 3, exceedances (described in Section 7.3.2, *State [Regulatory Background]*) would not increase relative to baseline and the salinity in the LSJR and southern Delta would remain similar to baseline or be reduced (Appendix F.1, Section F.1.5.2, *Salinity Modeling Results*). Consequently, there would be little to no change from baseline; therefore, the SDWQ alternatives are not discussed further in this chapter.

7.4.3 Impacts and Mitigation Measures

Impact AQUA-1: Changes in spawning success and habitat availability for warmwater species resulting from changes in reservoir water levels

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

Reservoir water level changes associated with the flow releases under the LSJR alternatives could impact recreationally important warmwater reservoir species due to resultant changes in the availability of habitat. The three eastside tributary reservoirs (New Melones, New Don Pedro, and Lake McClure) support several warmwater species that inhabit surface waters and shallow areas near shore (the littoral zone) (USBR 2011). Water level fluctuations resulting from reservoir operations (for irrigation, power generation, reservoir recharge, flood control, downstream flow releases, etc.) can impact habitat quantity and quality, particularly in the shallow-water areas.

Water level fluctuations can have a direct effect on largemouth bass and other warmwater fish that construct their nests in shallow water habitat (USBR 2011). Nearshore spawning species can be affected when reservoir levels rise with snowmelt capture. Rising water levels result in increased water depth of largemouth bass nests, potentially exposing them to water temperatures that may be too cold for the developing eggs (USBR and DWR 2003). Cold water slows the development of the eggs and larvae and, because eggs and larvae are highly vulnerable to predation or infection by fungi, longer development times can substantially reduce survival (USBR 2011). Extensive drawdown of reservoir water levels can also result in declines in reservoir fish species populations through direct effects on spawning success (due to nest abandonment or stranding) and habitat availability for spawning and rearing life stages. Water level fluctuations also inhibit development of shoreline vegetation, which provides cover and feeding substrates for many warmwater fish species in reservoirs. Vegetation also stabilizes shoreline sediments, reducing erosion and sedimentation. Consequently, increases in water level fluctuations could affect reservoir fish species indirectly through effects on vegetation (USBR and DWR 2003).

To assess impacts on warmwater fish species due to changes in reservoir levels under the LSJR alternatives, changes in the frequency and magnitude of reservoir level fluctuations were evaluated during the months of April–September. This period corresponds to the primary spawning, incubation, and early rearing period for largemouth bass and other warmwater species and, thus, the period when these species are most sensitive to reservoir level fluctuations. During this period, a monthly drop in elevation of 15 ft or more was used to evaluate the frequency of events that could have adverse effects on warmwater fish species based on the spawning preferences of largemouth bass. Typical spawning depths for largemouth bass range from the surface to about 15 ft (PG&E 2000; USBR 2011). Therefore, a drop in elevation of 15 ft per month during the spawning season could result in substantial effects on spawning success. It was also assumed that fluctuations of this magnitude (increases or decreases in reservoir levels) could also adversely affect spawning and rearing success through effects on water temperature, vegetation success, and shallow water habitat availability. A 10 percent increase in the occurrence of 15 foot fluctuations compared to baseline conditions was considered to be significant. A decrease in the occurrence of water level fluctuations of this magnitude would result in a more stable environment for the spawning and rearing life stages of warmwater species and, consequently, would not be considered a significant impact.

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, the percentage of months in which water level fluctuations of 15 ft or more would occur at New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure during April–September would be reduced compared to baseline conditions (Tables 7-8a, 7-8b, and 7-8c). These results generally reflect more stable habitat conditions during the largemouth bass spawning and rearing season (April–September), resulting in improved habitat conditions for largemouth bass and other warmwater species. Therefore, adverse impacts on warmwater reservoir species would be less than significant.

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, the percentage of months in which water level fluctuations of 15 ft or more would occur at New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure during April–September would be further reduced compared to LSJR Alternative 2 (Tables 7-8a, 7-8b, and 7-8c). Overall, more stable reservoir levels through the spawning and rearing season for largemouth bass and other warmwater species would further improve habitat conditions and result in beneficial effects on these species. Therefore, adverse impacts on warmwater reservoir species would be less than significant.

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, the percentage of months in which water level fluctuations of 15 ft or more would occur at New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure during April–September would be further reduced compared to LSJR Alternative 3 (Tables 7-8a, 7-8b, and 7-8c). Overall, spawning and rearing habitat conditions for largemouth bass and other warmwater species would be further improved, resulting in beneficial effects on these species. Therefore, adverse impacts on warmwater reservoir species would be less than significant.

Table 7-8a. Percent of Time Greater than or Equal to 15-foot Change in Elevation from Previous Month for New Melones Reservoir (Average)

	Apr	May	Jun	Jul	Aug	Sep
Baseline	13	27	12	17	7	1
LSJR Alternative 2	5	18	6	2	0	0
Change from Baseline	-8	-9	-6	-15	-7	-1
LSJR Alternative 3	2	9	4	4	1	0
Change from Baseline	-11	-18	-8	-13	-6	-1
LSJR Alternative 4	0	0	0	1	0	0
Change from Baseline	-13	-27	-12	-16	-7	-1
Note: Negative numbers indicate a reduction in 15-foot fluctuations.						

Table 7-8b. Percent of Time Greater than or Equal to 15-foot Change in Elevation from Previous Month for New Don Pedro Reservoir (Average)

	Apr	May	Jun	Jul	Aug	Sep
Baseline	4	21	22	48	26	0
LSJR Alternative 2	4	18	16	40	26	0
Change from Baseline	0	-3	-6	-8	0	0
LSJR Alternative 3	2	9	12	28	22	0
Change from Baseline	-2	-12	-10	-20	-4	0
LSJR Alternative 4	0	5	5	6	5	0
Change from Baseline	-4	-16	-17	-42	-21	0
Note: Negative numbers indicate a reduction in 15-foot fluctuations.						

Table 7-8c. Percent of Time Greater than or Equal to 15-foot Change in Elevation from Previous Month for Lake McClure (Average)

	Apr	May	Jun	Jul	Aug	Sep
Baseline	42	74	22	81	93	26
LSJR Alternative 2	35	62	5	72	87	9
Change from Baseline	-7	-12	-17	-9	-6	-17
LSJR Alternative 3	23	46	7	61	77	11
Change from Baseline	-19	-28	-15	-20	-16	-15
LSJR Alternative 4	11	18	6	21	48	13
Change from Baseline	-31	-56	-16	-60	-45	-13
Note: Negative numbers indicate a reduction in 15-foot fluctuations.						

Impact AQUA-2: Changes in availability of coldwater species reservoir habitat resulting from changes in reservoir storage

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

Changes in reservoir storage resulting from the LSJR alternatives could change the volume of cold water (hypolimnetic zone) in the reservoirs and the availability of coldwater habitat for recreationally important salmonids such as rainbow trout and kokanee. The hypolimnetic zone forms in the deepest levels of reservoirs during thermal stratification that occurs during spring, summer, and early fall months. Surface water warmed by the air and solar radiation during the spring and summer floats on top of the cooler, denser water of the hypolimnetic zone. The depth of the warmer surface water layer can vary but is generally 15–30 ft deep in most California reservoirs (including New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure) (EA EST 1999). Thus, reservoir drawdown can affect the volume of cold water below this surface layer, potentially limiting the availability of usable habitat for coldwater reservoir fishes.

In order to evaluate impacts on coldwater storage and resulting habitat for coldwater fish species, end-of-September storage levels in New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure were compared to baseline. The end-of-September storage was used as a basis for comparison because it typically represents the month at the end of the summer irrigation season when reservoir storage and coldwater habitat availability are at their lowest levels. While the amount of actual habitat cannot be quantified, the end-of-September storage levels are utilized as an indicator of the amount of summer habitat available to coldwater reservoir species. In the absence of quantitative information relating reservoir storage to effects on habitat availability for coldwater fish, the potential for significant impacts was assumed to exist if reservoir storage levels in September are reduced by 10 percent or more relative to baseline conditions. This is considered a reasonable criterion given the large seasonal and annual fluctuations in reservoir storage experienced by fish in reservoirs and the dependence of the reservoir fisheries on hatchery trout and salmon stocking programs. Tables 7-9a, 7-9b, and 7-9c show the changes in end-of-September elevation for the three reservoirs compared to baseline.

Table 7-9a. Percent Change in End-of-September Storage from Baseline for New Melones Reservoir

Percentile	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Minimum	-5	-23	-47
10	0	-16	-29
20	0	-9	-21
30	3	-3	-16
40	4	-1	-6
50	7	1	-2
60	12	5	3
70	18	17	13
80	27	33	37
90	81	84	92
Maximum	582	573	534
Average	42	39	33

Note: Negative percentages indicate a decrease in storage levels relative to baseline conditions.

Table 7-9b. Percent Change in End-of-September Storage from Baseline for New Don Pedro Reservoir

Percentile	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Minimum	-16	-29	-37
10	-5	-18	-26
20	-3	-15	-22
30	-2	-13	-18
40	-2	-11	-14
50	0	-5	-7
60	0	-1	-3
70	0	0	0
80	2	3	10
90	7	8	16
Maximum	33	30	44
Average	1	-6	-6

Note: Negative percentages indicate a decrease in storage levels relative to baseline conditions.

Table 7-9c. Percent Change in End-of-September Storage from Baseline for Lake McClure

Percentile	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Minimum	-12	-32	-39
10	-1	-21	-27
20	0	-14	-20
30	0	-3	-10
40	0	-1	-2
50	4	0	0
60	15	14	19
70	35	38	29
80	91	82	60
90	139	142	122
Maximum	157	206	181
Average	36	31	23

Note: Negative percentages indicate a decrease in storage levels relative to baseline conditions.

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, modeled September storage levels in New Melones Reservoir were equal to or higher than baseline levels in most years; average September storage is predicted to increase by 48 percent with annual levels ranging from little or no change to a 582-percent increase compared to baseline levels (Table 7-9a). In New Don Pedro Reservoir, modeled September storage levels differed only slightly from baseline levels in most years, averaging 1 percent over the 82-year modeling period (Table 7-9b). In Lake McClure, average September storage is predicted to increase by 36 percent with annual levels ranging from a 12 percent decrease to a 157 percent increase compared to baseline levels (Table 7-9c). Therefore, average summer storage levels in New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure under LSJR Alternative 2 would be similar to or higher than baseline levels, resulting in no long-term adverse impacts on coldwater fish habitat. Negative impacts on coldwater fish species would be less than significant.

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, no substantial long-term impacts on the availability of coldwater fish habitat in New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure are expected to occur. Differences in average September reservoir storage from baseline levels ranged from a 6 percent decrease in New Don Pedro Reservoir to a 39 percent increase in New Melones Reservoir (Tables 7-9a, 7-9b, and 7-9c). Adverse impacts on coldwater fish species would be less than significant.

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, no substantial long-term adverse impacts on the availability of coldwater fish habitat in New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure are expected to occur. Differences in average September reservoir storage from baseline levels ranged from a 6 percent decrease in New Don Pedro Reservoir to a 33 percent increase in New Melones Reservoir

(Tables 7-9a, 7-9b, and 7-9c). Adverse impacts on coldwater fish species would be less than significant.

Impact AQUA-3: Changes in the quantity/quality of physical habitat for spawning and rearing resulting from changes in flow

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

The LSJR alternatives could affect the quantity and quality of Chinook salmon and steelhead spawning and rearing habitat through changes in the extent of suitable water depths, velocities, substrate types, and other physical attributes of the stream environment. The following assessment focuses on potential impacts of the alternatives on Chinook salmon and steelhead populations because of their sensitivity to flow and other flow-related variables (e.g., water temperature) and because of their utility as key indicators of the responses of other native fish species to altered flow regimes in regulated rivers. As previously discussed in Section 7.4.2, *Methods and Approach*, the results of this assessment are considered indicative of effects on other native fishes; however, a general qualitative discussion of the potential responses of other fish species to the proposed alternatives is provided below.

As described in Section 7.4.2, the effects of flow on Chinook salmon and steelhead physical habitat availability were evaluated using two flow-based habitat indices: WUA and floodplain inundation. The WUA-flow relationships were used to evaluate changes in spawning and rearing habitat within the lower range of flows that generally fall within the bankfull width of the channel while the floodplain inundation-flow relationships were used to evaluate potential changes in rearing habitat within the upper range of flows that inundate adjacent floodplains. Table 7-10 summarizes the flow ranges used to evaluate changes in spawning and rearing WUA and floodplain inundation for each of the three eastside tributaries.

Table 7-10. Flow Ranges used to Evaluate Changes in Weighted Usable Area (WUA) and Floodplain Inundation under the LSJR Alternatives for the Stanislaus, Tuolumne, and Merced Rivers

	WUA Flow Range (cfs)	WUA Flow Range (cfs)	Floodplain Inundation Flow Range (cfs)
Stanislaus River	Spawning	25–1,300	1,000–5,000
	Fry/juvenile rearing	250–1,500	
Tuolumne River	Spawning	50–1,200	1,100–5,000
	Fry/juvenile rearing	50–1,200	
Merced River	Spawning	75–1,250	
	Fry/juvenile rearing	75–1,250	1,000–5,000

Impacts on Chinook salmon and steelhead spawning and rearing habitat were evaluated by comparing the magnitude and frequency of WUA and floodplain inundation area under each of the LSJR alternatives to baseline conditions over the 82-year modeling period. The analysis first presents modeled baseline flows and associated habitat metrics for the indicator species, followed by conditions under each LSJR alternative. Reductions in average WUA of 10 percent or more were considered sufficient to result in a significant impact on fry and juvenile production. Because modeled winter and spring flows frequently exceeded the range of flows for which WUA values could be determined, impact determinations for effects on fry and juvenile rearing habitat also considered predicted changes in floodplain inundation and water temperatures (see Impact AQUA-4) associated with these higher flows. To address uncertainties in floodplain inundation duration associated with the use of monthly modeled flows, reductions of 10 percent or more in the frequency of floodplain inundation areas of 50 acres or more were considered sufficient to result in a significant impact on fry and juvenile production. A criterion of 10 percent change, in combination with professional judgment, is used to determine whether impacts are significant. Due to lack of quantitative relationships between a given change in environmental conditions and relevant population metrics (e.g., survival or abundance), 10 percent was selected because that value is assumed to be high enough to reveal significant change to a condition while a lessor amount of change could be due in error in the various analytical and modeling techniques. Therefore, 10 percent provides a conservative qualitative basis to evaluate whether adverse effects to sensitive species at the population level will occur.

Baseline

Modeled baseline flows and associated habitat conditions for the indicator species and their key life stages are summarized below. As described in Chapter 5, *Surface Hydrology and Water Quality*, modeled baseline flows reflect current flow management operations and regulatory requirements in each of three eastside tributaries. Tables 7-11a, 7-11b, and 7-16c summarize baseline habitat conditions as well as expected changes from baseline conditions under each of the LSJR alternatives (discussed in subsequent sections).

Spawning

Chinook Salmon Spawning

Under baseline conditions, WUA values for Chinook salmon spawning in the Stanislaus, Tuolumne, and Merced Rivers in October averaged 47 percent, 80 percent, and 87 percent, respectively, of maximum WUA (Tables 7-11a, 7-11b, and 7-11c). These values reflect current operations that include the release of pulse flows in October for adult salmon attraction. Following these attraction flows, flows are generally maintained near optimal levels for spawning; monthly WUA values in the Stanislaus, Tuolumne, and Merced Rivers averaged 82–94 percent of maximum WUA values in November and December (Tables 7-11a, 7-11b, and 7-11c).

Steelhead Spawning

WUA-discharge relationships for steelhead spawning are only available for the Tuolumne and Merced Rivers. Based on those years in which WUA values could be evaluated (approximately 50–80 percent of the years had modeled flows within the range of the WUA-discharge relationships), average WUA values in January-March were 77–80 percent of maximum WUA for the Tuolumne River and 90–95 percent of maximum WUA for the Merced River (Tables 7-12a and 7-12b).

Table 7-11a. Distribution of October–December Weighted Usable Area (WUA in square feet) Values for Chinook Salmon Spawning on the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	October				November				December			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	474,370	433,632	197,130	197,130	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917
20	481,334	477,852	223,308	223,308	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917
30	492,192	488,692	261,075	261,075	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917
40	511,207	508,925	282,107	282,107	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917
50	520,714	518,813	341,388	341,388	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917
60	736,112	526,419	404,990	404,990	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917
70	747,448	739,051	462,599	462,599	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917
80	823,236	757,105	496,408	501,506	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917
90	827,960	827,487	613,735	614,040	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917	1,117,917
Max	855,490	855,490	855,490	855,490	1,299,496	1,299,496	1,299,496	1,299,496	1,299,496	1,299,496	1,299,496	1,299,496
Average	610,299	596,082	387,419	388,672	1,126,466	1,128,736	1,123,000	1,124,627	1,111,863	1,108,741	1,096,405	1,107,432
% Max WUA	47	46	30	30	87	87	86	87	86	85	84	85
Change	—	-14,217	-222,880	-221,627	—	2,270	-3,466	-1,839	—	-3,121	-15,458	-4,431
% Change	—	-2	-37	-36	—	0	0	0	—	0	-1	0

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-11b. Distribution of October–December Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for Chinook Salmon Spawning on the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	October				November				December			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	11,109	11,109	9,855	9,855	13,072	13,072	7,959	7,959	7,020	10,475	13,071	13,071
20	11,336	11,336	10,893	10,893	13,072	13,072	10,880	10,880	13,071	13,071	13,071	13,071
30	13,353	13,353	11,219	11,219	13,072	13,072	13,072	13,072	13,071	13,071	13,071	13,071
40	16,777	16,777	11,843	11,843	15,232	15,232	13,072	13,072	13,071	13,071	15,232	15,232
50	16,777	16,777	13,505	13,505	15,530	15,530	13,072	13,072	15,232	15,232	15,530	15,530
60	16,823	16,823	16,399	16,399	18,817	18,817	15,137	15,137	15,453	15,530	18,817	18,817
70	16,853	16,853	16,853	16,853	18,817	18,817	15,232	15,232	18,817	18,817	18,817	18,817
80	16,901	16,901	16,901	16,901	18,817	18,817	18,817	18,817	18,817	18,817	18,817	18,817
90	17,206	17,206	17,206	17,206	18,817	18,817	18,817	18,817	18,817	18,817	18,817	18,817
Max	17,380	17,380	17,380	17,380	18,817	18,817	18,817	18,817	18,817	18,817	18,817	18,817
Average	14,961	14,961	13,708	13,708	16,209	16,230	13,971	13,971	15,410	15,528	16,203	16,079
% Max WUA	80	80	73	73	86	86	74	74	82	83	86	85
Change	—	0	-1,253	-1,253	—	20	-2,238	-2,238	—	118	793	668
% Change	—	0	-8	-8	—	0	-14	-14	—	1	5	4

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-11c. Distribution of October–December Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for Chinook Salmon Spawning on the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	October				November				December			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	6,004	6,004	5,923	4,437	—	—	—	—	—	—	—	—
10	17,697	17,501	8,826	8,368	19,906	19,906	10,104	9,229	7,844	7,216	19,906	19,906
20	17,697	17,697	10,780	9,312	19,906	19,906	12,242	10,417	19,906	19,906	19,906	19,906
30	17,697	17,697	17,697	17,697	19,906	19,906	19,906	19,906	19,906	19,906	19,906	19,906
40	17,697	17,697	17,697	17,697	19,906	19,906	19,906	19,906	19,906	19,906	19,906	19,906
50	17,949	17,909	17,795	17,795	19,906	19,906	19,906	19,906	19,906	19,906	19,906	19,906
60	18,311	18,292	18,212	18,212	19,906	19,906	19,906	19,906	19,906	19,906	19,906	19,906
70	18,544	18,531	18,493	18,493	19,906	19,906	19,906	19,906	19,906	19,906	19,906	19,906
80	18,891	18,884	18,877	18,877	19,906	19,906	19,906	19,906	19,906	19,906	19,906	19,906
90	19,383	19,363	19,363	19,363	19,906	19,906	19,906	19,906	19,906	19,906	19,906	19,906
Max	20,185	20,185	20,185	20,185	20,323	20,323	19,906	19,906	20,361	20,361	19,906	20,339
Average	17,755	17,717	15,995	15,728	19,315	19,118	17,365	16,985	18,854	18,885	19,898	19,716
% Max WUA	87	87	78	77	94	93	85	83	92	92	97	96
Change	—	-39	-1,761	-2,027	—	-197	-1,950	-2,330	—	32	1,045	862
% Change	—	0	-10	-11	—	-1	-10	-12	—	0	6	5

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-12a. Distribution of January–March Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for *O. mykiss* Spawning in the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	January				February				March			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—	—	—	—	—
20	27,813	27,813	27,813	27,813	—	—	—	—	—	—	—	—
30	27,813	27,813	27,813	27,813	—	—	—	—	—	—	—	—
40	27,813	27,813	27,813	27,813	27,220	27,343	30,481	11,011	—	—	—	—
50	30,186	30,186	30,186	30,186	27,814	27,814	37,201	37,357	—	28,213	37,637	—
60	30,588	30,588	34,742	37,512	27,814	30,320	37,512	38,229	27,956	30,780	38,677	37,789
70	37,512	37,512	37,512	37,512	30,187	37,168	38,690	40,046	28,528	34,565	40,740	38,667
80	37,512	37,512	37,512	37,512	37,179	37,512	40,251	40,751	30,749	37,662	41,111	39,856
90	38,163	37,512	37,512	37,512	37,512	40,415	41,010	41,329	37,759	38,142	41,350	40,772
Max	41,429	41,259	39,690	38,271	41,402	41,453	41,486	41,467	40,658	41,396	41,478	41,429
Average	33,062	32,824	32,886	33,091	32,003	34,009	37,558	38,542	31,907	34,975	39,265	39,290
% Max WUA	80	79	79	80	77	82	91	93	77	84	95	95
Change	—	-238	-176	29	—	2,006	5,555	6,539	—	3,068	7,358	7,383
% Change	—	-1	-1	0	—	6	17	20	—	10	23	23

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-12b. Distribution of January—March Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for *O. mykiss* Spawning in the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	January				February				March			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	20,005	—	1,979	20,797	—	—	—	—	—	—	—	—
20	30,285	27,294	30,285	30,285	—	—	—	—	29,098	29,098	24,766	22,665
30	30,285	30,285	30,285	30,285	27,189	27,189	26,437	20,397	31,319	32,014	30,476	25,628
40	30,285	30,285	30,285	30,285	30,285	30,285	30,285	28,972	33,031	33,031	32,259	27,213
50	30,285	30,285	30,285	30,285	30,285	30,285	30,285	30,285	33,031	33,031	32,938	29,691
60	30,285	30,285	30,285	30,285	30,285	30,285	30,285	30,415	33,031	33,031	33,031	31,262
70	30,285	30,285	30,285	30,285	30,285	30,285	30,521	31,961	33,031	33,031	33,031	31,991
80	30,285	30,285	30,285	30,285	30,550	31,214	31,350	32,574	33,031	33,031	33,129	32,621
90	30,285	30,285	30,285	30,285	32,138	32,295	32,497	32,984	33,031	33,031	33,225	33,031
Max	33,105	31,745	30,742	31,085	33,059	33,059	33,294	33,319	33,324	33,324	33,332	33,278
Average	29,866	29,719	29,951	30,148	30,244	30,430	29,974	30,591	31,821	31,902	31,469	29,482
% Max WUA	90	89	90	90	91	91	90	92	95	96	94	88
Change	—	-147	85	282	—	186	-270	347	—	81	-351	-2,339
% Change	—	0	0	1	—	1	-1	1	—	0	-1	-7

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Juvenile Rearing

Chinook Salmon Rearing

In the Stanislaus River, baseline WUA values during the primary Chinook salmon fry rearing period (January–March) could not be evaluated in most years because modeled flows were frequently lower than the lowest flow defined by the WUA-discharge relationship (250 cfs) (Table 7-13a). However, minimum modeled flows in these months were between 200 and 250 cfs, indicating that physical habitat for fry was near maximum WUA levels in most years. In the Tuolumne and Merced Rivers, average WUA values for fry rearing in January–March were 67–69 percent of maximum WUA in the Tuolumne River and 73–79 percent of maximum WUA in the Merced River (Tables 7-13b and 7-13c). During the spring (April–May), average WUA values for juvenile rearing were 93 percent of maximum in the Stanislaus River, 71–73 percent of maximum WUA in the Tuolumne River, and 77–79 percent of maximum WUA in the Merced River (Tables 7-14a, 7-14b, and 7-14c).

Based on floodplain inundation area-flow relationships, the frequency of floodplain inundation in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR generally peaks in spring. Under baseline conditions, floodplain inundation events of 50 acres occurred less than 10 percent (February) to 50 percent of the time (April) in the Stanislaus River, 20–50 percent of the time in the Tuolumne River, and less than 10 percent to 20 percent of the time in the Merced River (Tables 7-15a, 7-15b, and 7-15c). In the LSJR between the Stanislaus River and Mossdale, floodplain inundation events of 50 acres or more occurred approximately 50–70 percent of the time during the winter and spring months (Table 7-15d). Over the 82-year modeling period, average floodplain inundation areas ranged from 25–58 acres in the Stanislaus River, 140–288 acres, 11–61 acres in the Merced River, and 257–368 acres in the LSJR.

Steelhead Rearing

Under modeled baseline conditions, average WUA values for steelhead fry rearing in April–May were 79–80 percent of maximum WUA in the Stanislaus River, 60 percent of maximum WUA in the Tuolumne River, and 71 percent of maximum WUA in the Merced River (Tables 7-16a, 7-16b, and 7-16c). During summer (July–September), WUA values for juvenile rearing in the Stanislaus, Tuolumne, and Merced Rivers were near maximum WUA levels (88–99 percent) in the majority of years (Tables 7-17a, 7-17b, and 7-17c). Spring floodplain inundation, which serves as an indicator of floodplain habitat availability for Chinook salmon (as discussed previously), may also benefit juvenile steelhead.

Table 7-13a. Distribution of January—March Weighted Usable Area (WUA in square feet) Values for Chinook Salmon Fry Rearing on the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	January				February				March			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—	—	—	—	299,483
40	—	—	—	—	—	—	1,019,710	1,042,568	—	—	1,028,557	1,053,507
50	—	—	—	—	—	—	1,064,986	1,062,669	—	—	1,157,761	1,078,586
60	—	—	—	—	1,018,481	1,191,481	1,156,870	1,106,239	—	—	1,236,945	1,123,387
70	—	—	—	—	1,251,467	1,304,354	1,264,011	1,225,446	1,061,696	758,151	1,292,039	1,165,445
80	—	—	—	—	1,378,961	1,375,240	1,360,222	1,313,920	1,192,306	1,324,535	1,325,634	1,247,715
90	1,151,203	955,960	—	1,116,986	1,415,577	1,412,503	1,387,049	1,400,040	1,329,759	1,400,644	1,370,218	1,347,493
Max	1,428,081	1,428,081	1,428,081	1,428,081	1,440,002	1,438,466	1,436,392	1,434,682	1,436,584	1,439,713	1,441,726	1,430,761
Average	1,373,521	1,338,934	1,373,537	1,358,813	1,323,857	1,331,339	1,239,735	1,216,413	1,244,847	1,345,838	1,255,020	1,174,619
%MaxWUA	95	93	95	94	92	92	86	84	86	93	87	81
Change	—	-34,587	17	-14,708	—	7,483	-84,121	-107,444	—	100,991	10,173	-70,228
% Change	—	-3	0	-1	—	1	-6	-8	—	8	1%	-6

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-13b. Distribution of January–March Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for Chinook Salmon Fry Rearing on the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	January				February				March			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—	—	—	—	—
20	14,976	15,070	19,427	19,427	—	—	—	—	—	—	—	—
30	19,427	19,427	19,427	19,427	—	—	—	—	—	—	—	—
40	19,427	19,427	19,427	19,427	14,967	15,585	15,092	5,970	—	—	—	—
50	19,427	19,427	19,427	19,427	19,427	17,759	16,061	15,198	—	15,035	14,938	—
60	23,795	23,795	23,795	23,795	22,162	19,427	17,595	15,683	19,133	17,773	15,033	15,065
70	24,033	24,033	24,033	24,033	24,033	22,299	19,408	16,776	23,641	19,368	15,567	16,010
80	25,415	25,415	25,415	25,415	25,415	24,033	19,427	17,626	24,860	22,145	17,167	16,721
90	25,415	25,415	25,415	25,415	25,415	25,415	20,906	19,427	25,277	23,785	19,186	17,541
Max	25,415	25,415	25,415	25,415	25,748	25,748	25,575	25,575	25,415	25,415	24,999	23,690
Average	21,943	22,176	22,266	22,170	22,641	21,295	18,704	17,662	22,716	20,554	16,952	16,668
% Max WUA	67	67	68	67	69	65	57	54	69	62	52	51
Change	—	232	322	227	—	-1,346	-3,937	-4,979	—	-2,162	-5,764	-6,048
% Change	—	1	1	1	—	-6	-17	-22	—	-10	-25	-27

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table7-13c. Distribution of January–March Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for Chinook Salmon Fry Rearing on the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	January				February				March			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	14,236	—	1,426	14,246	—	—	—	—	—	—	—	—
20	15,880	16,277	16,927	16,927	—	—	—	—	15,251	14,599	14,235	14,138
30	16,927	16,927	16,927	16,927	14,412	14,381	14,999	14,149	15,251	15,251	14,497	14,185
40	16,927	16,927	16,927	16,927	15,889	15,674	15,616	14,659	15,251	15,251	14,641	14,328
50	16,927	16,927	16,927	16,927	16,804	16,477	16,343	15,119	15,251	15,251	14,908	14,565
60	16,927	16,927	16,927	16,927	16,927	16,927	16,764	15,614	15,251	15,251	15,245	15,065
70	16,927	16,927	16,927	16,927	16,927	16,927	16,927	16,105	15,251	15,251	15,251	15,251
80	16,927	16,927	16,927	16,927	16,927	16,927	16,927	16,924	15,251	15,251	15,251	15,382
90	16,927	16,927	16,927	16,927	16,927	16,927	16,927	16,927	16,397	16,131	15,939	16,215
Max	18,076	18,076	18,076	18,076	17,962	17,962	17,962	17,962	17,643	17,643	17,643	18,106
Average	16,714	16,785	16,865	16,872	16,487	16,413	16,345	15,880	15,462	15,339	15,072	15,065
% Max WUA	79	79	79	79	77	77	77	75	73	72	71	71
Change	—	71	150	158	—	-74	-142	-607	—	-123	-390	-397
% Change	—	0	1	1	—	0	-1	-4	—	-1	-3	-3

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-14a. Distribution of April–May Weighted Usable Area (WUA in square feet) Values for Chinook Salmon Juvenile Rearing on the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—
40	—	971,855	—	—	380,917	970,449	—	—
50	976,003	976,279	974,344	—	962,140	995,181	—	—
60	979,154	979,045	986,858	—	997,721	998,312	960,821	—
70	995,523	1,059,687	1,015,866	971,357	1,000,756	1,000,667	998,152	—
80	1,081,724	1,100,114	1,060,045	1,007,751	1,060,480	1,057,038	1,040,421	971,892
90	1,098,041	1,104,825	1,100,217	1,062,885	1,078,859	1,062,724	1,064,422	1,050,303
Max	1,106,958	1,106,958	1,105,873	1,106,068	1,105,972	1,098,514	1,105,688	1,106,079
Average	1,032,093	1,036,895	1,029,708	1,028,204	1,024,737	1,018,267	1,029,138	1,030,211
% Max WUA	93	94	93	93	93	92	93	93
Change	—	4,802	-2,385	-3,889	—	-6,471	4,400	5,474
% Change	—	0	0	0	—	-1	0	1

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-14b. Distribution of April–May Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for Chinook Salmon Juvenile Rearing on the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—
30	—	—	—	—	9,375	—	—	—
40	—	—	—	—	31,253	—	—	—
50	31,271	31,276	—	—	31,421	31,250	—	—
60	33,517	32,664	—	—	32,574	31,303	—	—
70	39,045	33,687	—	—	39,725	31,705	—	—
80	40,621	37,792	31,333	—	41,270	33,851	—	—
90	45,256	40,630	32,361	—	45,660	39,844	31,263	—
Max	48,644	48,525	42,956	34,518	49,155	49,155	37,943	31,639
Average	38,677	36,354	33,130	32,398	37,553	35,006	32,279	31,609
% Max WUA	73	69	63	61	71	66	61	60
Change	—	-2,323	-5,547	-6,279	—	-2,547	-5,274	-5,944
% Change	—	-6	-14	-16	—	-7	-14	-16

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-14c. Distribution of April–May Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for Chinook Salmon Juvenile Rearing on the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—
10	16,505	16,515	16,493	—	—	—	—	—
20	17,291	17,821	16,502	—	16,963	16,492	—	—
30	18,026	18,945	16,560	—	17,460	16,584	—	—
40	18,207	20,449	16,735	—	18,819	16,897	—	—
50	22,750	21,509	16,934	16,501	21,506	17,320	—	—
60	26,268	22,821	17,560	16,642	24,763	17,863	16,532	—
70	28,867	24,924	18,014	17,097	27,984	18,821	16,880	—
80	28,867	26,998	18,998	17,572	28,867	20,801	17,252	—
90	28,867	28,604	19,968	18,051	28,867	24,143	17,898	16,837
Max	29,898	29,860	29,616	24,966	29,315	28,867	27,964	23,868
Average	23,105	22,297	18,151	17,490	23,627	19,281	17,728	17,522
% Max WUA	77	75	61	58	79	64	59	59
Change	—	-808	-4,955	-5,616	—	-4,346	-5,899	-6,105
% Change	—	-3	-21	-24	—	-18	-25	-26

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-15a. Distribution of February–May Monthly Floodplain Inundation Area (acres) on the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	February				March				April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
20	0	0	0	0	0	0	0	0	0	0	0	40	0	0	1	66
30	0	0	0	0	0	0	0	0	0	0	20	67	0	0	47	104
40	0	0	0	0	0	0	0	0	0	0	52	90	0	45	67	175
50	0	0	0	0	0	0	0	0	62	63	65	108	48	47	96	228
60	0	0	0	0	0	0	0	6	87	67	82	142	80	48	114	299
70	0	0	0	16	23	80	21	64	91	88	88	163	93	93	158	333
80	0	0	13	92	80	80	80	81	98	90	91	188	100	96	178	376
90	0	21	58	170	81	98	81	134	107	94	98	241	156	131	246	475
Max	600	600	600	731	760	760	760	760	141	100	211	437	223	207	489	789
Avg	25	28	35	54	40	42	35	53	52	47	58	121	58	53	114	241
Change		3	10	29		3	-4	13		-6	6	68		-5	56	183

Note: Gray shading indicates areas of floodplain inundation events of 50 acres (or more).

Table 7-15b. Distribution of February–May Monthly Floodplain Inundation Area (acres) on the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	February				March				April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	0	0	0	-5	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	73	0	0	6	256
20	0	0	0	0	0	0	0	0	0	0	0	172	0	0	200	445
30	0	0	0	0	0	0	0	0	0	0	72	296	0	0	301	537
40	0	0	0	0	0	0	0	7	0	0	111	346	0	0	349	600
50	0	0	0	0	80	7	0	63	0	0	233	378	0	0	425	668
60	0	0	0	35	279	183	118	173	71	66	289	456	0	87	469	716
70	276	271	85	331	556	556	382	442	335	330	363	509	34	160	522	765
80	538	498	316	478	629	629	532	541	534	534	498	545	113	243	579	803
90	767	708	634	651	747	732	732	709	708	708	708	617	727	743	730	877
Max	955	955	938	941	1,384	1,384	1,384	1,384	1,090	1,090	1,090	1,090	1,131	1,131	1,131	1,122
Avg	210	200	156	202	288	275	228	247	210	206	266	388	140	180	409	624
Change		-10	-54	-8		-13	-60	-40		-4	57	179		40	269	484

Note: Gray shading indicates areas of floodplain inundation events of 50 acres (or more).

Table 7-15c. Distribution of February–May Monthly Floodplain Inundation Area (acres) on the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	February				March				April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91
30	0	0	0	0	0	0	0	0	0	0	0	2	0	0	10	163
40	0	0	0	0	0	0	0	0	0	0	0	28	0	0	56	199
50	0	0	0	0	0	0	0	0	0	0	0	52	0	0	100	243
60	0	0	0	0	0	0	0	0	0	0	0	89	0	0	134	288
70	0	0	0	48	0	0	0	0	0	0	0	129	0	0	166	310
80	92	103	72	130	0	0	0	0	0	0	19	160	9	44	220	358
90	228	268	219	204	118	118	118	128	0	0	54	194	292	290	293	387
Max	497	492	477	477	473	475	518	473	516	516	516	516	577	577	577	561
Avg	61	64	49	59	33	35	35	39	11	11	21	84	52	56	122	228
Change		3	-12	-2		1	2	6		0	11	73		5	71	176

Note: Gray shading indicates areas of floodplain inundation events of 50 acres (or more).

Table 7-15d. Distribution of February–May Monthly Floodplain Inundation Area (acres) on the Lower San Joaquin River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	February				March				April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	9	9	9	9	0	0	0	0	0	4	4	15	0	1	15	30
10	19	17	19	22	12	12	16	33	12	20	51	92	10	30	67	113
20	25	22	25	35	33	18	39	65	35	41	88	131	34	56	119	210
30	33	31	34	48	36	39	50	81	71	63	108	167	62	73	161	275
40	48	39	45	64	74	58	71	94	96	82	134	219	76	107	202	353
50	78	83	61	87	78	82	97	136	127	111	163	260	125	122	269	460
60	119	124	165	226	172	158	162	210	155	147	193	295	154	169	311	585
70	205	212	231	323	293	294	234	298	206	196	245	351	154	198	384	675
80	398	384	364	438	346	391	354	432	304	325	346	436	254	318	446	749
90	902	868	623	856	764	764	753	736	649	706	731	773	719	815	966	1,349
Max	3,732	3732	3732	3732	7,056	7056	7056	7056	2,346	2346	2462	2702	2,216	2216	2486	3121
Avg	310	313	303	347	368	368	357	389	257	258	296	380	271	296	408	622
Change		4	-7	37		1	-11	21		1	39	123		25	137	352

Note: Gray shading indicates areas of floodplain inundation events of 50 acres (or more).

Table 7-16a. Distribution of April–May Weighted Usable Area (WUA in square feet) Values for *O. mykiss* Fry Rearing on the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—
40	—	880,929	—	—	346,765	909,509	—	—
50	887,756	886,526	883,451	—	909,807	910,402	—	—
60	984,578	1,018,843	903,609	—	989,735	913,794	879,851	—
70	1,020,728	1,029,690	952,175	880,130	1,027,233	999,610	911,532	—
80	1,040,858	1,034,426	1,024,032	921,562	1,087,910	1,081,429	982,710	882,247
90	1,168,376	1,093,836	1,038,817	992,975	1,191,052	1,159,138	1,029,114	983,524
Max	1,199,719	1,189,427	1,179,879	1,167,557	1,207,082	1,205,837	1,203,347	1,203,347
Average	1,027,420	1,000,879	973,700	960,654	1,037,516	1,009,116	990,151	967,386
% Max WUA	79	77	75	74	80	77	76	74
Change	—	-26,541	-53,720	-66,766	—	-28,400	-47,365	-70,131
% Change	—	-3	-5	-6	—	-3	-5	-7

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-16b. Distribution of April–May Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for *O. mykiss* Fry Rearing on the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—
30	—	—	—	—	9,199	—	—	—
40	—	—	—	—	31,371	—	—	—
50	30,708	30,708	—	—	31,563	30,643	—	—
60	31,395	31,089	—	—	32,189	31,370	—	—
70	31,824	31,460	—	—	33,437	31,713	—	—
80	33,428	32,756	31,110	—	33,666	32,384	—	—
90	33,554	33,554	32,552	—	33,757	33,437	30,915	—
Max	35,802	35,688	34,475	34,448	36,296	36,296	34,500	34,261
Average	32,579	32,151	32,260	32,794	32,842	32,289	33,133	33,074
% Max WUA	60	59	59	60	60	59	61	60
Change	—	-428	-319	214	—	-553	291	232
% Change	—	-1	-1	1	—	-2	1	1

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-16c. Distribution of April–May Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for *O. mykiss* Fry Rearing on the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—
10	17,646	17,371	17,290	—	—	—	—	—
20	17,735	17,683	17,473	—	17,464	17,369	—	—
30	17,829	17,812	17,880	—	17,681	17,598	—	—
40	18,758	18,092	18,338	—	18,225	17,773	—	—
50	19,700	18,404	19,281	18,723	18,596	18,251	—	—
60	20,698	19,011	19,802	19,702	20,000	18,605	17,875	—
70	21,549	19,644	20,505	20,878	21,496	19,080	18,972	—
80	21,549	20,577	21,091	22,072	21,549	20,307	20,807	—
90	21,549	21,549	22,358	23,169	21,549	21,551	22,300	21,080
Max	27,965	23,487	23,755	23,629	23,093	23,177	23,715	23,625
Average	19,996	19,064	19,649	21,080	19,771	19,177	20,571	20,955
% Max WUA	71	68	70	75	71	68	73	75
Change	—	-932	-347	1,083	—	-594	800	1,184
% Change	—	-5	-2	5	—	-3	4	6

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-17a. Distribution of July–September Weighted Usable Area (WUA in square feet) Values for *O. mykiss* Juvenile Rearing on the Stanislaus River under Modeled Baseline Conditions and LSJR Alternative 2, 3, and 4

	July				August				September			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—	—	—	—	—
20	—	1,050,765	1,033,694	1,022,273	—	202,751	1,054,778	1,055,222	—	—	—	—
30	1,061,869	1,062,598	1,047,271	1,042,178	1,054,778	1,063,984	1,063,984	1,063,984	—	—	—	—
40	1,062,598	1,062,598	1,054,702	1,051,833	1,063,984	1,063,984	1,063,984	1,065,708	—	—	—	—
50	1,063,407	1,067,201	1,062,598	1,064,900	1,064,100	1,068,587	1,068,587	1,068,587	1,056,988	977,834	1,035,331	—
60	1,067,201	1,067,201	1,067,201	1,070,056	1,068,587	1,068,587	1,068,587	1,071,719	1,066,194	1,066,194	1,043,164	1,033,503
70	1,067,201	1,067,432	1,070,493	1,071,805	1,068,587	1,068,587	1,069,211	1,073,191	1,066,194	1,066,194	1,054,951	1,041,167
80	1,071,805	1,071,805	1,071,805	1,071,805	1,073,191	1,073,191	1,073,191	1,073,191	1,070,797	1,070,797	1,066,194	1,053,387
90	1,071,805	1,071,805	1,071,805	1,071,805	1,073,191	1,073,191	1,073,191	1,073,191	1,070,797	1,070,797	1,070,797	1,070,337
Max	1,073,259	1,073,259	1,073,259	1,073,259	1,073,422	1,073,422	1,073,422	1,073,652	1,073,184	1,073,184	1,071,990	1,071,036
Average	1,062,643	1,061,923	1,059,941	1,056,510	1,067,275	1,067,358	1,067,738	1,066,118	1,067,766	1,059,031	1,056,969	1,052,946
%MaxWUA	99	99	99	98	99	99	99	99	99	99	98	98
Change	—	-721	-2,702	-6,133	—	82	462	-1,157	—	-8,735	-10,797	-14,821
% Change	—	0	0	-1	—	0	0	0	—	-1	-1	-1

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-17b. Distribution of July–September Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for *O. mykiss* Juvenile Rearing on the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	July				August				September			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	—	—	—	40,296	55,361	55,361	52,596	52,596	52,462	52,462	42,236	42,236
20	45,270	47,005	40,496	41,216	55,361	55,361	55,361	55,361	54,535	54,535	44,123	44,123
30	55,750	55,750	55,681	55,681	55,911	55,911	55,361	55,361	54,535	54,535	54,023	54,023
40	55,750	55,750	55,750	55,750	55,911	55,911	55,451	55,451	56,139	56,139	54,535	54,535
50	55,885	55,885	55,885	55,885	55,911	55,911	55,911	55,911	56,139	56,139	54,535	54,535
60	55,939	55,939	55,939	55,939	55,911	55,911	55,911	55,911	56,139	56,139	56,139	56,139
70	55,939	55,939	55,939	55,939	55,991	55,991	55,911	55,911	56,247	56,247	56,222	56,222
80	57,497	57,497	57,497	57,497	57,187	57,187	57,187	57,187	56,743	56,743	56,743	56,743
90	57,497	57,497	57,497	57,497	57,187	57,187	57,187	57,187	56,743	56,743	56,743	56,743
Max	57,497	57,497	57,497	57,497	57,187	57,187	57,187	57,187	56,743	56,743	56,743	56,743
Average	55,701	55,831	53,663	52,895	56,105	56,105	55,631	55,631	55,414	55,414	52,440	52,440
% Max WUA	95	95	91	90	95	95	95	95	94	94	89	89
Change	—	130	-2,038	-2,806	—	0	-473	-473	—	0	-2,974	-2,974
% Change	—	0	-4	-5	—	0	-1	-1	—	0	-5	-5

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

Table 7-17c. Distribution of July–September Weighted Usable Area (WUA in square feet per 1,000 linear feet) Values for *O. mykiss* Juvenile Rearing on the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	July				August				September			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	—	—	—	—	—	—	—	—	—	—	—	—
10	—	—	—	—	22,475	22,475	22,477	22,595	—	—	—	—
20	—	—	—	25,801	22,527	22,658	23,054	24,359	22,806	22,806	23,477	23,451
30	28,204	35,367	30,736	28,951	23,221	23,530	28,386	27,022	27,122	27,294	26,925	25,711
40	36,116	36,449	35,881	35,881	35,356	35,596	35,222	35,222	30,475	30,475	28,174	27,019
50	37,051	37,130	36,574	36,574	36,401	36,325	36,210	36,210	34,687	34,687	34,836	34,836
60	37,130	37,130	37,130	37,130	37,114	37,052	36,680	36,680	35,226	35,226	35,915	35,915
70	37,130	37,130	37,130	37,130	37,130	37,130	37,130	37,130	36,274	35,915	36,460	36,460
80	37,130	37,130	37,130	37,130	37,130	37,130	37,130	37,130	36,677	36,461	37,086	37,086
90	37,130	37,130	37,130	37,130	37,130	37,130	37,130	37,130	37,130	37,111	37,130	37,130
Max	37,225	37,225	37,381	37,381	37,378	37,378	37,407	37,407	37,322	37,322	37,385	37,385
Average	35,533	36,006	35,468	34,469	32,762	32,975	33,398	33,462	33,358	33,355	33,144	32,625
%MaxWUA	95	96	95	92	88	88	89	89	89	89	89	87
Change	—	473	-65	-1,064	—	213	636	700	—	-3	-214	-733
% Change	—	1	0	-3	—	1	2	2	—	0	-1	-2

Note: Table shows the percent of time that a WUA value of equal or lower value occurs.

LSJR Alternative 2 (Less than significant)

Spawning

Under LSJR Alternative 2, spawning habitat availability for Chinook salmon, steelhead, and other fish species on the Stanislaus, Tuolumne, and Merced Rivers would remain unchanged or increase compared to baseline conditions. Adverse impacts would be less than significant.

Chinook Salmon Spawning

Under LSJR Alternative 2, modeled flows and associated WUA values indicate that there would be little or no change in the availability of spawning habitat for Chinook salmon relative to baseline conditions on the three eastside tributaries (Tables 7-11a, 7-11b, and 7-11c). Therefore, adverse impacts would be less than significant.

Steelhead Spawning

In the Tuolumne River, average WUA values for steelhead spawning would remain unchanged in January and increase by 6 percent in February and 10 percent in March compared to baseline conditions (Table 7-12a). In the Merced River, little or no change in steelhead spawning habitat availability is predicted to occur (Table 7-12b). Therefore, adverse impacts would be less than significant.

Other Fish Species (Spawning)

Based on the relatively small changes in Chinook salmon and steelhead spawning habitat under LSJR Alternative 2, no major changes in habitat availability for other native and nonnative species in the Stanislaus, Tuolumne, and Merced Rivers are expected. Therefore, adverse impacts would be less than significant.

Juvenile Rearing

Under LSJR Alternative 2, no substantial changes are expected in the quantity and quality of Chinook salmon and steelhead fry and juvenile rearing in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR compared to baseline conditions. Fry and juvenile rearing habitat for Chinook salmon on the Stanislaus River or LSJR would remain unchanged. While WUA for Chinook salmon fry and juvenile rearing would decrease in the Tuolumne and Merced Rivers, floodplain habitat would increase and water temperatures would decrease in response to higher spring flows. Therefore, adverse impacts would be less than significant.

Chinook Salmon Rearing

Under LSJR Alternative 2, modeled Stanislaus River flows (i.e., Goodwin Dam releases) during the Chinook salmon fry and juvenile rearing period (January–May) frequently fell outside the range of flows that could be evaluated using the WUA-discharge relationship (250–1,500 cfs). However, for those years in which flows were within this range, no substantial changes were evident in the magnitude of WUA values compared to baseline conditions (Tables 7-13a and 7-14a). In the Tuolumne River, increases in flows would reduce average WUA for fry and juvenile rearing by 6–10 percent in February–May (Tables 7-13b and 7-14b) but would increase the frequency of floodplain inundation events of 50 acres or more by approximately 20 percent in May (Table 7-15b) and decrease average water temperatures at the confluence by 1.7°F in May (Table 7-22b in Impact

AQUA-4). In the Merced River, increases in flows would primarily affect juvenile rearing habitat in May by reducing average WUA by 18 percent (Table 7-14c). However, overall increases in flow in May were accompanied by an average decrease in water temperature of 2.1°F at the confluence of the Merced (Table 7-22c), representing an overall improvement in habitat quality throughout the river. In addition, higher flows in the LSJR in May would increase the frequency of floodplain inundation events of 50 acres by 10 percent (Table 7-15d). Overall, the quantity and quality of rearing habitat for Chinook salmon fry and juvenile salmon, as measured by WUA, floodplain inundation area, and water temperature, would not change substantially relative to baseline conditions. Therefore, flow-related impacts on the quantity and quality of Chinook salmon rearing habitat would be less than significant.

Steelhead Rearing

Under LSJR Alternative 2, no substantial differences were evident in the magnitude of WUA values for steelhead fry and juvenile rearing compared to baseline conditions (Tables 7-16a, 7-16b, 7-16c, and 7-17a, 7-17b, and 7-17c). Therefore, adverse impacts would be less than significant.

Other Fish Species (Rearing)

Based on the conclusions above for Chinook salmon and steelhead juvenile rearing habitat, no major changes in habitat availability for other native and nonnative species in the Stanislaus, Tuolumne, and Merced Rivers are expected. Therefore, adverse impacts would be less than significant.

LSJR Alternative 3 (Less than significant)

Spawning

Under LSJR Alternative 3, the quantity and/or quality of spawning habitat for Chinook salmon, steelhead, and other fish species in the Stanislaus, Tuolumne, and Merced Rivers would be improved relative to baseline conditions. Negative impacts on the quantity and quality of spawning habitat would be less than significant.

Chinook Salmon Spawning

Under LSJR Alternative 3, average WUA values for Chinook salmon spawning in the Stanislaus River would decrease by 37 percent in October and remain unchanged in November and December relative to baseline conditions (Table 7-11a). Reductions in average WUA of 8–14 percent are also predicted to occur in the Tuolumne and Merced Rivers in October and November (Tables 7-11b and 7-11c). However, these reductions are associated with higher flows, which are expected to improve flow and temperature conditions for attraction, migration, and spawning (see Impact AQUA-4, LSJR Alternative 3) and potentially increase the longitudinal extent of suitable spawning habitat below the dams. Additionally, it is important to note that WUA for this life-stage does not take into account a number of other benefits associated with higher flows, including improved substrate (e.g., mobilization of fine sediment) and hyporheic (e.g., DO in redds) conditions. Finally, analyses of juvenile and adult production in relation to fall flows suggest that spawning habitat is not a major limiting factor for Chinook salmon populations in the LSJR tributaries (Mesick et al. 2007). Therefore, flow-related impacts on Chinook salmon spawning habitat would not have a significant adverse impact on Chinook salmon populations in the Stanislaus, Tuolumne, and Merced Rivers.

Steelhead Spawning

Under LSJR Alternative 3, average WUA values for steelhead spawning in the Tuolumne River would decrease by 1 percent in January, increase by 17 percent in February, and increase by 24 percent in March (Table 7-12a). In the Merced River, only slight changes would occur in spawning WUA relative to baseline conditions (Table 7-12b). Therefore, flow-related impacts on steelhead spawning habitat availability in the Stanislaus, Tuolumne, and Merced Rivers would be less than significant.

Other Fish Species (Spawning)

Under LSJR Alternative 3, increases in magnitude of spring flows in the Stanislaus, Tuolumne, and Merced Rivers and associated increases in floodplain habitat availability and decreases in water temperatures would benefit other (non-salmonid) native species and negatively affect nonnative species such as largemouth bass and other warmwater species that prey on or compete with native fishes. Based on reported changes in the abundance and distribution of native and nonnative resident species in the Tuolumne River and other Central Valley streams, higher spring flows and cooler water temperatures that mimic the natural flow regime provide more appropriate spawning conditions for native species (Brown and Ford 2002). Potential mechanisms include increases in water velocity that benefit native resident species that spawn in high-velocity habitats (e.g., riffle spawners such as Sacramento sucker, Sacramento pikeminnow, and riffle sculpin) and negatively affect nonnative species that spawn in low-velocity habitats (e.g., largemouth bass) (Brown and Ford 2002; Kiernan et al. 2012).

Increases in spring flows will also improve spawning conditions for splittail, sturgeon, striped bass, and other fishes, as well as improve water quality (e.g., water temperature and salinity) in the Stanislaus, Tuolumne, and Merced Rivers and in the LSJR (see Impact AQUA-4, LSJR Alternative 3). Therefore, LSJR Alternative 3 would have beneficial effects on other native fishes in the Stanislaus, Tuolumne and Merced Rivers and LSJR.

Juvenile Rearing

Under LSJR Alternative 3, fry and juvenile rearing conditions for Chinook salmon, steelhead, and other fish species in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR would be substantially improved compared to baseline conditions. Therefore, adverse impacts would be less than significant.

Chinook Salmon Rearing

Under LSJR Alternative 3, no substantial differences are evident in the magnitude of WUA values for Chinook salmon fry and juvenile rearing in the Stanislaus River compared to baseline conditions (Tables 7-13a and 7-14a). Flows exceeding the range of the WUA-discharge relationship (250–1,500 cfs) would increase in frequency, increasing potential floodplain rearing opportunities for juvenile salmon under this alternative. In April and May, floodplain inundation events of 50 acres or more in the Stanislaus River are predicted to increase by approximately 10–20 percent, corresponding to average increases in floodplain inundation area of 6 acres in April and 56 acres in May (Table 7-15a).

In the Tuolumne River, average WUA values for Chinook salmon rearing are predicted to decrease by 17 percent in February and 25 percent in March (fry rearing) and by 14 percent in April and May (juvenile rearing) compared to baseline conditions (Tables 7-13b and 7-14b). During these months, floodplain inundation events of 50 acres or more are predicted to decrease in frequency by approximately 10 percent in March and increase in frequency by 30 percent in April and 60 percent in May (Table 7-15b). These changes correspond to a decrease in average floodplain inundation area of 60 acres in March and increases in average floodplain inundation areas of 57 acres in April and 269 acres in May. Although habitat availability for fry would decrease in March, the capacity of the river for juvenile rearing would increase in April and May in response to higher spring flows, cooler water temperatures, and greater floodplain rearing opportunities. Higher spring flows and associated reductions in water temperatures are expected to increase the downstream extent and duration of suitable rearing temperatures throughout the river in many years (see Impact AQUA-4, LSJR Alternative 3). Overall, improvements in water temperatures and floodplain habitat availability later in the season (April and May) would likely enhance juvenile growth and survival, potentially increasing the number of juveniles that successfully emigrate from the river as smolts.

In the Merced River, LSJR Alternative 3 would not substantially affect Chinook salmon fry habitat availability in January–March as measured by WUA (Table 7-13c). During the juvenile rearing season (April–May), average WUA values are predicted to decrease by 21 percent in April and 25 percent in May compared to baseline conditions (Table 7-14c). However, similar to the Tuolumne River, LSJR Alternative 3 would result in substantial increases in the frequency and magnitude of floodplain inundation in April and May. Over the 82-year modeling period, the frequency of floodplain inundation events of 50 acres or more would increase in frequency by 10 percent in April and 50 percent in May, corresponding to increases in average floodplain inundation areas of 11 acres in April and 71 acres in May (Table 7-15c). Increases in floodplain rearing opportunities in April and May would also be accompanied by reductions in water temperatures throughout the Merced River (see Impact AQUA-4, LSJR Alternative 3). Overall, this alternative is expected to increase juvenile salmon production in the Stanislaus, Tuolumne, and Merced Rivers.

Under LSJR Alternative 3, higher flow contributions from the tributaries are also expected to increase the availability of floodplain habitat in the LSJR for juvenile Chinook salmon that leave the tributaries as fry or juveniles. Over the 82-year modeling period, the frequency of floodplain inundation events of 50 acres or more would increase by approximately 20 percent in April and May, corresponding to increases in average floodplain inundation areas of 39 acres in April and 137 acres in May (Table 7-15d).

Steelhead Rearing

Under LSJR Alternative 3, no substantial changes would occur in steelhead fry and juvenile rearing habitat availability (as measured by WUA) in the Stanislaus, Tuolumne, and Merced Rivers during the spring and summer rearing periods (Tables 7-16a, 7-16b, 7-17a, and 7-17b). However, steelhead fry and juveniles would benefit from increases in floodplain habitat availability and decreases in water temperatures in April and May as described for Chinook salmon. Therefore, flow-related adverse impacts on steelhead rearing habitat availability in the Stanislaus, Tuolumne, and Merced Rivers would be less than significant.

Other Fish Species (Rearing)

As discussed above under spawning, increases in spring flows will also improve rearing conditions for splittail, sturgeon, striped bass, and other fishes, as well as improve water quality (e.g., water temperature and salinity) in the Stanislaus, Tuolumne, and Merced Rivers, and in the LSJR and the

Delta (See Impact AQUA-4, LSJR Alternative 3). For example, increases in the frequency, magnitude, and duration of spring floodplain inundation could enhance spawning and rearing success of migratory species such as Sacramento splittail that depend on relatively long periods of seasonal floodplain inundation to achieve strong year classes (Sommer et al. 2001). Therefore, LSJR Alternative 3 would have beneficial effects on other native fishes in the Stanislaus, Tuolumne, and Merced Rivers.

LSJR Alternative 4 (Less than significant)

Spawning

Under LSJR Alternative 4, suitable spawning habitat for Chinook salmon, steelhead, and other fish species in the Stanislaus, Tuolumne, and Merced Rivers would substantially improve compared to baseline conditions. Adverse impacts would be less than significant.

Chinook Salmon and Steelhead Spawning

Under LSJR Alternative 4, predicted changes in WUA values for Chinook salmon and steelhead spawning in the Stanislaus, Tuolumne, and Merced Rivers would be similar in magnitude to those predicted under LSJR Alternative 3 (Tables 7-11a, 7-11b, and 7-11c and 7-12a, 7-12b, and 7-12c). Therefore, flow-related impacts on Chinook salmon spawning habitat would not have a significant negative impact on Chinook salmon populations in the Stanislaus, Tuolumne, and Merced Rivers.

Other Fish Species (Spawning)

Under LSJR Alternative 4, further increases in the frequency, magnitude, and duration of spring flows compared to those occurring under LSJR Alternative 3 are expected to further increase the quantity and quality of habitat for native fish species and result in long-term increases in spawning success of other native fish species in the Stanislaus, Tuolumne, and Merced Rivers. The proposed flow regime, which is characterized by further increases in monthly modeled flows relative to LSJR Alternative 3, would further improve spawning conditions for splittail, sturgeon, striped bass, and other fishes, as well as improve water quality (e.g., water temperature and salinity) in the Stanislaus, Tuolumne, and Merced Rivers and in the LSJR and the Delta. Associated increases in the frequency, magnitude, and duration of floodplain inundation would further increase aquatic productivity (see Impact AQUA-9, LSJR Alternative 4) and the quantity of suitable spawning and rearing habitat for floodplain-dependent species such as Sacramento splittail. Similar to LSJR Alternative 3, this flow regime would also be expected to reduce the distribution and abundance of nonnative fishes as well as their negative impacts (e.g., predation) on other native fishes (see Impact AQUA-10, LSJR Alternative 4). Therefore, LSJR Alternative 4 would have beneficial effects on other native fishes in the Stanislaus, Tuolumne, and Merced Rivers.

Juvenile Rearing

Under LSJR Alternative 4, fry and juvenile rearing conditions for Chinook salmon, steelhead, and other fish species in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR would be substantially improved compared to baseline conditions. Therefore, adverse impacts would be less than significant.

Chinook Salmon and Steelhead Rearing

Under LSJR Alternative 4, predicted changes in average WUA values for Chinook salmon and steelhead fry and juvenile rearing in the Stanislaus, Tuolumne, and Merced Rivers would be similar to those predicted under LSJR Alternative 3 (Tables 7-13a, 7-13b, 7-13c; 7-14a, 7-14b, 1-14c; 7-16a, 7-16b, 7-16c; and 7-17a, 7-17b, 7-17c). However, higher spring flows under this alternative would further increase the rearing capacity of these rivers by expanding the area of inundated floodplain habitat and downstream extent of suitable water temperatures especially in April and May (see Impact AQUA-4, Alternative LSJR 4). Over the 82-year modeling period, the frequency of floodplain inundation events of 50 acres or more in the Stanislaus, Tuolumne, and Merced Rivers would increase by 20–50 percent in April and 40–70 percent in May, corresponding to increases in average floodplain inundation areas of 68–179 acres in April and 176–484 acres in May (Tables 7-15a, 7-15b, and 7-15c). Therefore, LSJR Alternative 4 would substantially improve rearing conditions for Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers.

Under LSJR Alternative 4, higher spring flows in the LSJR relative to LSJR Alternative 3 would further increase the availability of floodplain habitat for juvenile Chinook salmon that leave the tributaries as fry or juveniles. Over the 82-year modeling period, floodplain inundation area under LSJR Alternative 4 would increase by 123 acres in April and 352 acres in May compared to baseline conditions (Table 7-16d).

Other Fish Species (Rearing)

As discussed for spawning, LSJR Alternative 4 would further increase the frequency, magnitude, and duration of spring flows compared to LSJR Alternative 3. The resulting increases in the quantity and quality of habitat for native fish species would result in long-term increases in rearing success of other native fish species in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR. Therefore, LSJR Alternative 4 would have beneficial effects on other native fishes in the three eastside tributaries and the LSJR.

Impact AQUA-4: Changes in exposure of fish to suboptimal water temperatures resulting from changes in reservoir storage and releases

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

The LSJR alternatives would affect river temperatures through changes in reservoir storage and flow on the three eastside tributaries and in the LSJR; this would affect the extent of suitable water temperatures for Chinook salmon and steelhead in the river environment below the dams. The following assessment focuses on potential impacts of the alternatives on Chinook salmon and steelhead populations because of their sensitivity to water temperature, which is a flow-related variable, and their utility as key indicators of the responses of other native fish species to altered flow regimes in regulated rivers. Where appropriate, the Chinook salmon and steelhead analyses are combined. As previously discussed in Section 7.4.2, *Methods and Approach*, the results of this assessment are considered indicative of effects on other fish species; however, a general discussion of the potential responses of other fish species to the proposed alternatives is provided below.

The suitability of water temperatures for fish can generally be defined by optimal, suboptimal, and lethal ranges based on the chronic and acute responses of fish to thermal stress under laboratory and field conditions. Optimal water temperatures are those that cause no significant impacts, suboptimal temperatures are associated with chronic effects and cause increasing thermal stress as water temperatures approach lethal levels, and lethal temperatures are those that cause acute effects (e.g., severe impairment or death). The duration of exposure to suboptimal and lethal temperatures must also be considered in determining the potential for significant impacts.

Changes in water temperatures in the three eastside tributaries and mainstem LSJR associated with each of the LSJR alternatives were evaluated using the CALFED temperature model described in Section 7.4.2, *Methods and Approach* (CALFED 2009). The temperature thresholds used in this analysis are based on the U.S. Environmental Protection Agency's (USEPA's) recommended temperature criteria for protection of salmonids (USEPA 2003). The recommended metric for these criteria is the 7-day average of the daily maximum (7DADM). This metric is recommended because it describes maximum temperatures in a stream but is not overly influenced by the maximum temperature of a single day. Thus, it reflects an average of maximum temperatures that fish are exposed to over weekly periods. Since this metric is based on daily maximum temperatures, it can be used to protect against acute effects, such as lethality and migration blockage conditions, and can also be used to protect against sublethal or chronic effects such as temperature effects on growth, disease, smoltification, and competition (USEPA 2003).

USEPA's recommended criteria were used to define the upper limits of the optimal temperature ranges for adult migration, spawning and incubation, juvenile rearing, smolt outmigration, and summer rearing (Tables 7-18 and 7-19). These criteria serve as benchmarks to evaluate the frequency with which water temperatures exceed optimum water temperatures and potentially result in adverse chronic or acute effects on specific life stages. Predicted changes in exposure of Chinook salmon and steelhead to suboptimal water temperatures were evaluated by comparing the frequency and magnitude of 7DADM values (calculated as a running average of 7-day maximum daily temperatures during the modeled 1970–2003 period) under modeled baseline conditions and the LSJR alternatives. Significant impacts were identified based on changes of 10 percent or more in the frequency of water temperatures exceeding the USEPA criteria, and/or changes in average 7DADM water temperature of 1°F or more. These thresholds in combination with consideration of the potential exposure of Chinook and steelhead populations to suboptimal water temperatures at key locations and months (Tables 7-18 and 7-19) were used to determine whether impacts are significant. Due to lack of quantitative relationships between a given change in environmental conditions and relevant population metrics (e.g., survival or abundance), 10 percent was selected because that value is assumed to be high enough to reveal significant change to a condition while a lessor amount of change could be due to error in the various analytical and modeling techniques. Therefore, 10 percent provides a conservative qualitative basis to evaluate whether adverse effects to sensitive species at the population level will occur.

Table 7-18 and Table 7-19 summarize the water temperature criteria and the primary locations and months that were used to evaluate potential temperature impacts on Chinook salmon and steelhead life stages. The primary evaluation locations and months are based on the general distribution, abundance, and timing of each life stage in the eastside tributaries and LSJR. For example, water temperatures at locations approximately three-quarters of the distance from the mouth of each tributary to the first impassable dam were used to characterize water temperatures in the primary Chinook salmon and steelhead spawning reaches. This location was selected because it generally represents conditions in the majority of the spawning reaches and, therefore, reflects changes in both the downstream extent and quality of suitable water temperatures for spawning and incubation.

Table 7-18. Water Temperature Thresholds and Primary Locations and Months Used to Evaluate Potential Temperature Impacts on Chinook Salmon and Steelhead Life Stages in the Eastside Tributaries

Evaluation Time Period	Primary Life Stage (fall-run Chinook and steelhead)	Temperature Evaluation Thresholds (°C)	Temperature Evaluation Thresholds (°F)	Primary Evaluation Locations
September–October	Adult Migration	18 (7DADM)	64.4 (7DADM)	Confluence
October–March	Spawning and Incubation	13 (7DADM)	55.4 (7DADM)	¾ River
March–May	Juvenile Rearing (Chinook)	16 (7DADM)	60.8 (7DADM)	Confluence
April–June	Smoltification	14 (7DADM)	57.2 (7DADM)	Confluence
July–August	Summer Rearing (steelhead)	18 (7DADM)	64.4 (7DADM)	¾ River

Note: Each tributary was divided into quarters, with ¼, ½, and ¾ representing the fractional distances from the confluence to the first impassable dam.

Table 7-19. Water Temperature Thresholds and Primary Locations and Months Used to Evaluate Potential Temperature Impacts on Chinook Salmon and Steelhead Life Stages in the LSJR

Evaluation Time Period	Primary Life Stage (fall-run Chinook and steelhead composite)	Temperature Evaluation Thresholds (°C)	Temperature Evaluation Thresholds (°F)	Primary Evaluation Locations
September–October	Adult Migration	18 (7DADM)	64.4 (7DADM)	Vernalis
~~January–~~March–May	Juvenile Rearing	16 (7DADM)	60.8 (7DADM)	Vernalis
April–June	Smoltification	14 (7DADM)	57.2 (7DADM)	Vernalis

~~Although w~~Water temperature can affect DO levels, and both factors are related to apparent blockage and delays in migration of adult salmon in the Delta (see Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*).~~,~~

~~adverse effects associated with low DO levels have not been documented in other reaches of the SJR and its tributaries.~~ Therefore, DO levels would ~~remain within acceptable levels and~~ potentially increase in response to higher flows and cooler temperatures under the LSJR alternatives.

Baseline

Water temperature is recognized as a primary stressor for Chinook salmon and steelhead in the SJR Basin. Exposure of these species to elevated water temperatures can cause thermal stress and lead to reductions in survival through a number of direct and indirect effects. These effects can be generally characterized as: (1) chronic effects related to changes in growth, disease resistance, swimming performance, and other biological functions over relatively long periods; and (2) acute effects related to the thermal tolerance of fish to lethal temperatures over relatively short periods (Sullivan et al. 2000). Water temperatures in the LSJR are typically in equilibrium with air temperatures during the hottest summer months. In the spring and fall, LSJR temperatures are influenced to some extent by inflows and water temperatures from the three eastside tributaries. Reservoir operations can lead to elevated water temperatures in the spring, which have been identified as a major factor contributing to reduced survival and abundance of juveniles and subsequent returns of spawning adults to the LSJR and the three eastside tributaries. Excessively warm summer temperatures in the tributaries act to limit steelhead abundance by restricting suitable summer rearing habitat to the cooler uppermost reaches of accessible habitat immediately downstream of the rim dams. Consequently, the amount of suitable habitat may be insufficient to sustain healthy steelhead populations (CDFG 2007).

Modeled baseline temperatures and associated habitat conditions for the indicator species and their key life stages are summarized in text below. Modeled baseline temperature conditions are summarized in Tables 7-20a–7-20d through Tables 7-24a–7-24d for each river. These tables also provide a summary of expected temperatures under the LSJR alternatives.

Adult Migration

Potential exposure of adult salmon and steelhead to suboptimal water temperatures during their upstream migration was evaluated based on modeled September and October water temperatures in the SJR at Vernalis and at the mouths of the Stanislaus, Tuolumne, and Merced Rivers. Upstream migration of adult salmon into the SJR and its tributaries generally begins in September, although most of the run enters after September, with peak migration typically occurring in late October and early November following the onset of declining fall temperatures and managed pulse flows (CFS 2007a; CDFG 2001; CDFG 2002). It is assumed that adult steelhead also begin their upstream migration into the tributaries in early fall, with most migration occurring in late fall and winter. The USEPA criteria for salmon and trout migration (64.4°F 7DADM) was used to define the upper limit of the optimal temperature range for adult migration.

Under modeled baseline conditions, suitable water temperatures for adult migration in the SJR and eastside tributaries typically do not occur until October. In the Stanislaus River, 7DADM water temperatures exceeding 64.4°F at the mouth of the Stanislaus River occurred approximately 90 percent of the time in September and 20 percent of the time in October, and average 7DADM water temperatures were 69.6°F and 62.0°F, respectively (Table 7-20a). Water temperatures in the Tuolumne and Merced Rivers in September and October were generally warmer; 7DADM water temperatures exceeding 64.4°F at the mouths of the Tuolumne and Merced Rivers occurred approximately 90 percent of the time in September and 60-70 percent of the time in October

(Tables 7-20b and 7-20c). Modeled 7DADM water temperatures in September and October averaged 75.5°F and 67.5°F in the Tuolumne River and 72.2°F and 65.9°F in the Merced River. At Vernalis, 7DADM water temperatures exceeding 64.4°F occurred approximately 90 percent of the time in September and 50 percent of the time in October (Table 7-20d). Average 7DADM temperatures were 72.4°F in September and 64.8°F in October.

Table 7-20a. Distribution of September–-October 7DADM Water Temperatures in Relation to USEPA Criteria for Salmon and Steelhead Adult Migration (64.4˚ F) at the Confluence of the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	September				October			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	55.3	55.4	57.4	57.5	53.3	53.5	54.5	55.0
10	64.5	64.7	64.2	64.7	57.4	57.4	57.1	57.4
20	67.4	67.2	65.5	65.9	58.2	58.1	57.8	58.1
30	68.4	68.3	67.2	67.5	59.0	58.9	58.4	58.9
40	69.3	69.1	68.6	69.0	60.0	59.8	59.2	59.5
50	70.0	69.8	69.5	69.9	61.2	60.8	60.1	60.3
60	70.9	70.6	70.5	70.7	62.8	61.8	61.0	61.2
70	71.7	71.5	71.5	71.8	64.2	63.0	62.1	62.3
80	73.1	72.6	72.7	72.9	66.1	64.7	63.7	64.0
90	74.3	73.9	73.8	74.0	68.2	67.0	66.2	66.4
Max	77.9	77.1	77.1	77.2	73.7	72.9	72.9	72.9
Avg	69.6	69.3	69.1	69.4	62.0	61.4	60.9	61.1
Change		-0.2	-0.5	-0.1		-0.6	-1.2	-0.9

Notes: Table shows the percent of time that a temperature of equal or lower value occurs.
Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-20b. Distribution of September–-October 7DADM Water Temperatures in Relations to USEPA Criteria for Salmon and Steelhead Adult Migration (64.4˚ F) at the Confluence of the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	September				October			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	59.6	59.6	59.6	59.6	56.2	56.2	56.6	56.6
10	70.7	70.7	67.4	67.6	61.9	61.9	61.4	61.5
20	72.8	72.8	69.7	69.8	63.7	63.7	62.9	63.2
30	74.0	74.0	72.4	72.4	64.9	64.9	64.2	64.3
40	75.0	75.0	73.7	73.9	65.9	65.9	65.5	65.5
50	76.1	76.1	75.3	75.3	67.1	67.1	66.4	66.6
60	77.0	77.0	76.7	76.7	68.6	68.6	67.7	67.8
70	77.9	77.9	77.6	77.7	70.3	70.3	69.5	69.5
80	78.8	78.8	78.5	78.6	71.6	71.6	71.1	71.2
90	80.1	80.1	80.1	80.1	73.6	73.6	73.1	73.2
Max	83.8	83.8	83.8	83.8	78.1	78.1	78.1	78.1
Avg	75.5	75.5	74.4	74.5	67.5	67.5	67.0	67.0
Change		0.0	-1.1	-1.0		0.0	-0.5	-0.5

Notes: Table shows the percent of time that a temperature of equal or lower value occurs.
Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-20c. Distribution of September–-October 7DADM Water Temperatures in Relation to USEPA Criteria for Salmon and Steelhead Adult Migration (64.4˚ F) at the Confluence of the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	September				October			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	62.2	62.2	62.2	62.2	57.4	57.4	57.5	57.9
10	67.0	67.0	66.9	67.3	61.4	61.4	61.2	61.3
20	69.0	69.0	68.7	68.9	62.7	62.5	62.2	62.2
30	70.1	70.0	70.1	70.0	63.5	63.3	63.0	63.0
40	71.3	71.3	71.3	71.3	64.5	64.2	63.8	63.9
50	72.8	72.7	72.7	72.6	65.5	64.9	64.7	64.8
60	73.9	73.8	73.8	73.9	66.6	65.9	65.7	66.1
70	74.8	74.8	74.6	74.7	67.8	67.1	66.7	67.2
80	75.5	75.5	75.4	75.5	68.9	68.3	68.0	68.5
90	76.8	76.7	76.8	76.8	70.9	70.3	70.4	70.9
Max	80.6	80.4	80.5	80.6	75.0	74.9	74.9	75.1
Avg	72.2	72.2	72.1	72.2	65.9	65.5	65.2	65.5
Change		0.0	-0.1	0.0		-0.4	-0.7	-0.4

Notes: Table shows the percent of time that a temperature of equal or lower value occurs.
Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-20d. Distribution of September–-October 7DADM Water Temperatures in Relation to USEPA Criteria for Salmon and Steelhead Adult Migration (64.4˚ F) in the San Joaquin River at Vernalis under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	September				October			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	59.5	59.5	62.2	62.3	56.1	56.1	56.5	56.6
10	68.3	68.2	67.5	67.9	60.3	60.2	60.0	60.2
20	70.2	70.1	69.6	69.8	61.2	61.2	60.9	61.1
30	71.0	70.9	70.5	70.7	62.4	62.1	61.7	61.9
40	72.0	72.0	71.4	71.7	63.5	63.1	62.5	62.7
50	73.0	73.0	72.5	72.6	64.4	64.0	63.3	63.5
60	73.8	73.7	73.5	73.6	65.5	65.0	64.4	64.6
70	74.3	74.2	74.1	74.2	66.8	66.4	65.7	65.9
80	75.0	75.0	75.0	75.0	68.3	67.9	67.0	67.1
90	75.9	75.8	75.9	75.9	70.3	69.9	69.3	69.5
Max	79.3	79.0	79.0	79.0	74.0	73.8	73.8	73.8
Avg	72.4	72.3	72.1	72.2	64.8	64.5	64.0	64.1
Change		-0.1	-0.3	-0.1		-0.3	-0.8	-0.6

Notes: Table shows the percent of time that a temperature of equal or lower value occurs.
Gray shading indicates temperatures that exceed USEPA criteria.

Spawning and Incubation

Potential exposure of Chinook salmon and steelhead spawning and incubation life stages to suboptimal water temperatures was evaluated based on modeled water temperatures at RM 43.7 on the Stanislaus River, RM 38.3 on the Tuolumne River, and RM 37.8 on the Merced River. These stations are located approximately three-quarters of the distance from the mouth of each tributary to the first impassable dam, and generally characterize water temperatures in the primary Chinook salmon and steelhead spawning reaches. Chinook salmon spawning and incubation generally extends from October–March while steelhead spawning and incubation extends from January–March.

Under modeled baseline conditions, suitable water temperatures for Chinook salmon spawning and incubation in the Stanislaus, Tuolumne, and Merced Rivers generally do not occur until early to late November in most years. In the Stanislaus River, 7DADM temperatures exceeding the USEPA criterion for salmon and trout spawning (55.4°F) occurred approximately 80 percent of the time in October and over 50 percent of the time in November (Table 7-21a). Water temperatures generally decline in October and November, reach annual lows (typically less than 55.4°F) from December–February, and begin increasing in February and March. The same general pattern is observed in the Tuolumne and Merced Rivers although modeled water temperatures at comparable locations downstream of the dams are typically warmer than those on the Stanislaus River (Tables 7-21b and 7-21c).

Under modeled baseline conditions, water temperatures in the Stanislaus, Tuolumne, and Merced Rivers are nearly always suitable for steelhead spawning and incubation in January (Table 7-21a, 7-21b, and 7-21c). Water temperatures exceeding the USEPA spawning and incubation criterion (55.4°F) begin to increase in frequency in February and occur approximately 20 percent of the time in the Stanislaus River, 40 percent of the time in the Tuolumne River, and 70 percent of the time in the Merced River by March (Tables 7-21a, 7-21b, and 7-21c).

Table 7-21a. Distribution of October–March 7DADM Water Temperatures in Relation to USEPA Criteria for Salmonid Spawning, Egg Incubation, and Fry Emergence (55.4˚F) at RM 43.7 on the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

October					November					December				
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	51.5	51.7	52.4	53.3	Min	49.4	49.6	49.7	50.9	Min	47.4	47.4	47.3	46.6
10	54.8	54.9	54.7	55.1	10	53.1	53.0	53.2	53.5	10	49.0	49.1	49.1	49.2
20	55.6	55.6	55.5	56.0	20	53.9	54.0	54.1	54.4	20	49.9	49.7	49.7	50.0
30	56.3	56.1	55.9	56.4	30	54.6	54.5	54.5	54.8	30	50.5	50.4	50.5	50.6
40	56.9	56.8	56.7	57.1	40	55.1	54.9	55.0	55.3	40	51.1	50.9	51.0	51.1
50	57.6	57.5	57.3	57.7	50	55.6	55.3	55.5	55.7	50	51.7	51.5	51.6	51.7
60	58.4	58.1	57.8	58.1	60	56.3	55.8	56.0	56.1	60	52.2	52.0	52.1	52.3
70	59.8	58.9	58.6	58.7	70	57.0	56.4	56.5	56.7	70	52.8	52.5	52.6	52.8
80	61.3	59.7	59.3	59.6	80	58.1	57.2	57.2	57.3	80	53.3	53.1	53.2	53.3
90	66.1	60.9	60.5	60.9	90	60.2	58.2	58.1	58.2	90	54.5	53.8	53.9	54.0
Max	70.7	66.2	66.3	66.7	Max	65.9	60.6	60.2	60.7	Max	58.8	55.7	55.6	56.1
Avg	58.7	57.7	57.5	57.9	Avg	56.2	55.5	55.5	55.8	Avg	51.8	51.5	51.5	51.6
Change		-1.0	-1.2	-0.8			-0.7	-0.7	-0.4			-0.3	-0.3	-0.1
January					**February**					**March**				
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	45.3	45.3	45.2	45.2	Min	45.6	45.3	45.3	45.4	Min	48.4	48.8	48.7	48.7
10	47.4	47.4	47.4	47.4	10	48.5	48.3	48.1	48.0	10	50.3	50.3	50.2	49.9
20	48.2	48.2	48.3	48.3	20	49.1	49.1	48.8	48.6	20	51.2	50.8	50.9	50.5
30	48.7	48.8	48.8	48.8	30	49.6	49.4	49.2	49.1	30	51.9	51.5	51.6	51.1
40	49.2	49.2	49.2	49.3	40	50.1	49.9	49.6	49.5	40	52.6	52.2	52.0	51.6
50	49.6	49.5	49.6	49.6	50	50.6	50.4	50.2	49.9	50	53.2	53.0	52.6	52.3
60	50.0	49.9	49.9	49.9	60	51.1	51.0	50.8	50.6	60	53.9	53.9	53.3	52.8
70	50.4	50.3	50.3	50.4	70	51.6	51.5	51.4	51.2	70	54.6	54.6	54.1	53.5
80	50.9	50.7	50.7	50.8	80	52.2	52.1	51.9	51.7	80	55.5	55.6	54.7	54.0
90	51.7	51.5	51.6	51.6	90	53.2	53.2	53.0	52.5	90	56.5	56.8	55.5	54.7
Max	53.6	53.5	53.5	53.6	Max	55.6	56.0	55.7	55.1	Max	60.3	60.3	58.0	57.5
Avg	49.6	49.5	49.5	49.5	Avg	50.7	50.6	50.4	50.2	Avg	53.4	53.3	52.8	52.3
Change		-0.1	-0.1	0.0			-0.1	-0.3	-0.5			-0.1	-0.6	-1.0

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-21b. Distribution of October–March 7DADM Water Temperatures in Relation to USEPA Criteria for Salmonid Spawning, Egg Incubation, and Fry Emergence (55.4˚F) at RM 38.3 on the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

October					November					December				
Percentile	Baseline	LSJR Alt2	LSJR Alt3	LSJR Alt4	Percentile	Baseline	LSJR Alt2	LSJR Alt3	LSJR Alt4	Percentile	Baseline	LSJR Alt2	LSJR Alt3	LSJR Alt4
Min	54.6	54.6	55.6	55.6	Min	51.6	51.9	51.9	51.5	Min	49.2	49.3	49.3	49.1
10	56.9	57.1	57.1	57.5	10	54.3	54.3	54.7	54.7	10	51.5	51.5	51.7	51.5
20	58.0	58.1	57.9	58.5	20	55.0	55.0	55.2	55.5	20	52.0	52.1	52.3	52.3
30	58.9	59.0	58.8	59.2	30	55.6	55.6	55.7	55.9	30	52.5	52.5	52.7	52.8
40	59.9	60.0	59.5	59.7	40	55.9	55.9	56.0	56.4	40	52.9	52.9	53.1	53.3
50	60.6	60.6	60.2	60.2	50	56.4	56.4	56.5	56.7	50	53.3	53.3	53.4	53.6
60	61.7	61.7	61.2	61.3	60	57.1	57.1	57.0	57.1	60	53.6	53.6	53.8	53.9
70	62.7	62.6	62.5	62.6	70	57.6	57.6	57.5	57.5	70	54.0	53.9	54.2	54.2
80	64.2	64.0	64.1	64.1	80	58.4	58.2	58.3	58.2	80	54.4	54.3	54.6	54.8
90	67.0	66.7	66.8	66.7	90	59.7	59.5	59.3	59.1	90	55.1	55.0	55.2	55.4
Max	74.1	74.0	74.0	74.0	Max	62.0	61.5	61.7	61.5	Max	57.8	57.5	57.6	57.5
Avg	61.3	61.3	61.2	61.3	Avg	56.7	56.6	56.7	56.8	Avg	53.3	53.3	53.5	53.5
Change		0.0	-0.1	0.0			0.0	0.0	0.1			0.0	0.2	0.2

January					February					March				
Percentile	Baseline	LSJR Alt2	LSJR Alt3	LSJR Alt4	Percentile	Baseline	LSJR Alt2	LSJR Alt3	LSJR Alt4	Percentile	Baseline	LSJR Alt2	LSJR Alt3	LSJR Alt4
Min	48.4	48.4	48.4	48.3	Min	48.2	48.3	48.2	48.2	Min	48.7	48.7	48.7	48.6
10	50.2	50.2	50.5	50.4	10	49.8	49.8	49.7	49.7	10	50.0	50.1	50.0	49.9
20	50.9	51.0	51.1	51.0	20	50.3	50.3	50.4	50.0	20	50.5	50.7	50.7	50.4
30	51.4	51.5	51.5	51.5	30	51.1	51.1	51.1	50.4	30	51.0	51.2	51.1	50.8
40	51.8	51.9	51.9	52.0	40	52.0	51.9	51.7	51.4	40	51.6	51.9	51.6	51.3
50	52.2	52.2	52.3	52.4	50	53.2	52.8	52.4	51.9	50	53.0	52.9	52.5	51.8
60	52.5	52.6	52.8	52.8	60	54.1	53.6	53.1	52.4	60	56.2	54.2	53.6	52.7
70	53.0	53.1	53.2	53.3	70	54.7	54.4	53.9	53.3	70	57.5	56.2	54.4	53.2
80	53.5	53.5	53.7	53.8	80	55.5	55.3	54.6	53.8	80	58.7	57.4	55.3	54.1
90	54.1	54.1	54.3	54.3	90	56.7	56.8	55.5	55.0	90	60.6	58.6	56.5	55.3
Max	55.7	55.7	55.6	55.8	Max	60.1	60.1	59.8	59.8	Max	63.9	62.0	60.2	60.1
Avg	52.2	52.2	52.3	52.4	Avg	53.1	53.0	52.6	52.1	Avg	54.5	53.8	52.9	52.3
Change		0.0	0.2	0.2			-0.1	-0.5	-1.0			-0.8	-1.6	-2.2

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-21c. Distribution of October–March 7DADM Water Temperatures in Relation to USEPA Criteria for Salmonid Spawning, Egg Incubation, and Fry Emergence (55.4˚F) at RM 37.8 on the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

October					November					December				
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	57.5	57.5	57.6	57.6	Min	52.6	52.7	53.1	52.7	Min	48.9	48.9	48.7	48.5
10	60.4	60.3	60.2	60.4	10	55.5	55.4	55.4	55.6	10	50.7	50.7	50.7	50.8
20	61.4	61.3	61.0	61.2	20	56.7	56.4	56.3	56.7	20	51.5	51.4	51.5	51.6
30	62.3	62.2	62.0	62.1	30	57.5	57.2	57.0	57.4	30	52.1	52.0	52.1	52.3
40	63.2	62.7	62.7	62.8	40	58.3	57.9	57.6	58.1	40	52.7	52.6	52.7	52.8
50	64.0	63.5	63.2	63.5	50	59.2	58.6	58.6	58.8	50	53.3	53.1	53.1	53.3
60	64.9	64.2	63.9	64.3	60	60.1	59.4	59.3	59.4	60	53.7	53.5	53.6	53.8
70	66.5	65.0	64.8	65.3	70	61.1	60.2	59.9	60.0	70	54.5	54.1	54.1	54.4
80	68.4	66.1	66.2	67.3	80	62.0	61.0	60.6	61.0	80	55.3	54.8	54.7	54.9
90	70.9	68.5	68.5	70.5	90	64.4	62.0	61.7	62.4	90	56.7	55.4	55.5	55.9
Max	80.2	79.2	79.4	80.5	Max	68.8	64.4	64.5	68.8	Max	60.3	59.1	59.0	60.4
Avg	64.9	64.0	63.8	64.5	Avg	59.6	58.7	58.5	59.0	Avg	53.5	53.1	53.2	53.4
Change		-0.9	-1.0	-0.4			-0.9	-1.1	-0.6			-0.4	-0.3	-0.1

January					February					March				
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	46.8	46.8	46.8	46.7	Min	46.9	46.9	46.9	46.8	Min	48.5	48.5	48.5	48.5
10	49.3	49.3	49.3	49.2	10	50.1	50.3	50.2	49.4	10	51.6	51.4	51.2	50.8
20	49.9	50.1	50.0	49.9	20	51.1	51.3	51.4	50.6	20	53.9	53.9	53.8	53.2
30	50.4	50.6	50.6	50.5	30	52.1	52.2	52.2	51.7	30	55.5	55.7	55.2	54.2
40	50.8	51.1	51.1	50.9	40	52.6	52.9	52.8	52.5	40	56.5	56.7	56.1	55.2
50	51.2	51.5	51.5	51.4	50	53.2	53.6	53.3	53.2	50	57.5	57.7	57.0	56.1
60	51.7	51.9	51.9	51.9	60	54.0	54.4	54.0	53.9	60	58.3	58.5	57.7	56.9
70	52.2	52.3	52.3	52.3	70	54.9	55.2	54.8	54.4	70	59.0	59.2	58.5	57.6
80	52.9	52.9	52.9	52.9	80	55.8	56.0	55.9	55.5	80	59.9	60.1	59.3	58.5
90	53.7	53.7	53.7	53.7	90	57.4	57.6	57.5	57.0	90	61.0	61.2	60.3	59.5
Max	56.8	56.9	57.0	56.9	Max	60.8	61.2	61.2	61.1	Max	65.9	64.7	63.4	61.9
Avg	51.4	51.5	51.5	51.4	Avg	53.5	53.7	53.6	53.2	Avg	57.0	57.1	56.5	55.7
Change		0.1	0.1	0.1			0.2	0.1	-0.3			0.1	-0.5	-1.3

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Juvenile Rearing

Potential exposure of Chinook salmon rearing life stages to suboptimal water temperatures was evaluated based on modeled water temperatures at the mouths of the Stanislaus, Tuolumne, and Merced Rivers. These stations were selected because juvenile salmon rearing in the tributaries may occur as far downstream as the tributary mouths following their emergence as fry in the winter and early spring (although some proportion of these fry migrate beyond the confluences to complete their freshwater rearing phases in the LSJR and/or Delta; see *LSJR* in Section 7.2.2. *Reservoirs, Tributaries, and LSJR*). Chinook salmon rearing in the tributaries generally occurs from January–May; however, the primary months of concern with respect to temperature are March–May. In contrast, the evaluation of potential water temperature effects on steelhead rearing focused on the summer months (July–August) at stations located three quarters of the distance from the confluence to the first impassable dam, which generally marks the downstream limit of summer rearing (CALFED 2009; NMFS 2009c).

Under modeled baseline conditions, exposure of juvenile salmon to suboptimal water temperatures (as defined by the USEPA criterion of 60.8°F) in the Stanislaus, Tuolumne, and Merced Rivers and LSJR increases through the spring. In the Stanislaus River, 7DADM water temperatures exceeding this threshold occurred 10 percent of the time in March, 20 percent of the time in April, and 40 percent of the time in May (Table 7-22a). Modeled 7DADM temperatures in these months averaged 56.5°F, 58.5°F, and 61.5°F, respectively. Higher water temperatures are predicted to occur in the Tuolumne and Merced Rivers. In the Tuolumne River, 7DADM water temperatures exceeding the USEPA criterion are predicted to occur approximately 30 percent of the time in March, 40 percent of the time in April, and 70 percent of the time in May (Table 7-22b). Modeled 7DADM water temperatures in these months averaged 58.5°F, 61.7°F, and 65.9°F. In the Merced River, 7DADM water temperatures exceeding the USEPA criterion are predicted to occur approximately 30 percent of the time in March, 70 percent of the time in April, and 90 percent of the time in May (Table 7-22c). Modeled 7DADM water temperatures in these months averaged 58.6°F, 64.0°F, and 68.2°F. In the SJR at Vernalis, 7DADM water temperatures exceeding the USEPA criterion are predicted to occur approximately 10 percent of the time in March, 50 percent of the time in April, and 90 percent of the time in May (Table 7-22d). Modeled 7DADM water temperatures in these months averaged 58.0°F, 61.6°F, and 65.7°F.

During the summer, juvenile steelhead frequently experience suboptimal water temperatures (as defined by the USEPA criterion of 64.4°F) in the Stanislaus, Tuolumne, and Merced Rivers under baseline conditions. In the Stanislaus River at RM 43.7, 7DADM water temperatures exceeding the USEPA criterion are predicted to occur approximately 50 percent of the time in July and August (Table 7-23a). Modeled 7DADM temperatures in these months averaged 64.8°F and 65.0°F, respectively. Higher water temperatures are predicted to occur at similar locations in the Tuolumne and Merced Rivers, exceeding the USEPA criterion 70 percent of the time in July and 80–90 percent of the time in August (Tables 7-23b and 7-23c). Modeled 7DADM temperatures in July and August averaged 69.8°F and 71.1°F in the Tuolumne River, and 73.3°F and 73.2°F in the Merced River.

Table 7-22a. Distribution of March–May 7DADM Water Temperatures in Relation to USEPA Criteria for Salmonid Juvenile Rearing (60.8˚F) at the Confluence of the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

March

Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	49.5	49.6	49.5	49.5
10	52.2	52.1	52.1	51.7
20	53.7	53.1	53.1	52.5
30	54.8	54.1	54.0	53.2
40	55.7	55.2	54.9	54.1
50	56.4	56.3	55.8	54.9
60	57.2	57.3	56.4	55.7
70	58.0	58.2	57.2	56.4
80	59.3	59.4	58.2	57.3
90	60.6	60.9	59.8	58.4
Max	65.4	65.4	63.3	62.2
Avg	56.5	56.4	55.8	55.0
Change		-0.1	-0.7	-1.5

April

Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	51.2	51.2	51.2	51.1
10	54.7	54.9	54.9	54.2
20	55.7	55.9	55.8	55.1
30	56.6	56.7	56.5	55.9
40	57.3	57.4	57.2	56.7
50	58.1	58.1	57.9	57.3
60	58.9	59.1	58.7	58.1
70	59.9	60.0	59.6	58.9
80	61.2	61.6	60.7	59.6
90	63.1	63.2	61.7	60.7
Max	67.1	66.9	66.3	66.2
Avg	58.5	58.6	58.2	57.4
		0.1	-0.3	-1.1

May

Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	54.3	54.3	54.3	53.7
10	57.6	57.9	57.4	56.2
20	58.7	59.1	58.4	57.1
30	59.5	59.8	59.0	57.6
40	60.0	60.4	59.5	58.1
50	60.7	60.9	60.1	59.0
60	61.5	61.6	60.9	59.7
70	62.7	62.7	61.8	60.6
80	64.7	64.0	62.9	61.8
90	66.4	66.2	65.0	64.2
Max	72.9	71.7	70.8	67.8
Avg	61.5	61.5	60.7	59.5
		0.0	-0.8	-2.1

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-22b. Distribution of March–May 7DADM Water Temperatures in Relation to USEPA Criteria for Salmonid Juvenile Rearing (60.8˚F) at the Confluence of the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

March				
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	51.7	51.7	51.7	51.6
10	53.0	53.1	53.2	53.0
20	53.9	54.2	54.3	53.9
30	54.8	55.0	55.1	54.5
40	55.8	56.0	55.9	55.0
50	57.4	57.4	56.8	55.7
60	59.6	58.9	57.9	56.6
70	61.5	60.5	59.3	57.8
80	63.2	62.3	60.5	58.7
90	65.5	64.1	61.8	60.0
Max	69.5	69.0	65.8	64.9
Avg	58.5	58.1	57.3	56.3
Change		-0.4	-1.2	-2.2

April				
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	52.7	52.7	52.7	52.7
10	55.5	55.6	55.3	54.9
20	56.9	56.9	56.6	55.9
30	58.0	58.0	57.5	56.8
40	59.3	59.4	58.3	57.4
50	60.7	60.8	59.2	57.7
60	62.6	62.3	59.8	58.2
70	65.1	63.5	60.7	58.8
80	66.9	64.9	61.5	59.4
90	69.0	66.5	62.9	60.5
Max	74.0	73.5	71.4	67.7
Avg	61.7	61.0	59.2	57.9
		-0.7	-2.5	-3.8

May				
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	55.7	55.7	55.6	55.6
10	59.4	59.2	58.1	57.8
20	61.0	60.8	58.9	58.8
30	62.3	61.7	59.6	59.3
40	63.6	62.5	60.2	59.8
50	65.4	63.6	60.7	60.4
60	67.3	64.7	61.1	61.1
70	69.4	66.3	61.9	61.7
80	71.1	67.9	63.1	62.3
90	73.2	70.2	65.2	63.2
Max	77.6	75.1	69.1	66.0
Avg	65.9	64.2	61.1	60.5
		-1.7	-4.8	-5.4

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-22c. Distribution of March–May 7DADM Water Temperatures in Relation to USEPA Criteria for Salmonid Juvenile Rearing (60.8˚F) at the Confluence of the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

Mar					Apr					May				
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	49.9	49.9	49.9	49.8	Min	52.1	52.1	52.2	52.2	Min	55.9	55.8	55.8	55.1
10	53.3	53.3	53.3	52.9	10	58.2	58.3	57.6	55.9	10	61.2	61.3	60.0	58.5
20	54.8	54.9	54.8	54.3	20	60.5	60.7	59.5	57.5	20	63.7	63.0	61.1	59.9
30	56.7	56.8	56.3	55.4	30	62.0	62.2	60.6	58.9	30	65.3	64.0	62.1	60.6
40	57.8	57.9	57.4	56.5	40	63.0	63.2	61.3	59.7	40	67.0	65.0	62.9	61.4
50	58.7	58.7	58.5	57.6	50	64.0	63.9	61.9	60.4	50	68.8	66.0	63.6	62.1
60	59.9	59.9	59.5	58.4	60	65.0	64.7	62.5	61.1	60	70.0	67.0	64.5	62.9
70	60.8	60.8	60.3	59.4	70	66.4	65.4	63.2	61.7	70	71.3	68.1	65.5	64.0
80	61.9	61.9	61.3	60.2	80	67.6	66.3	63.8	62.4	80	72.6	69.5	66.7	65.2
90	63.4	63.3	62.3	61.4	90	69.6	67.6	64.9	63.5	90	74.3	70.6	68.5	67.0
Max	66.7	66.9	65.5	64.0	Max	73.2	73.9	73.4	71.7	Max	78.1	75.2	72.2	71.5
Avg	58.6	58.6	58.1	57.3	Avg	64.0	63.5	61.7	60.2	Avg	68.2	66.1	63.9	62.5
Change		0.0	-0.4	-1.2			-0.5	-2.2	-3.8			-2.1	-4.3	-5.7

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-22d. Distribution of March–May 7DADM Water Temperatures in Relation to USEPA Criteria for Salmonid Juvenile Rearing (60.8˚F) in the San Joaquin River near Vernalis under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

March				
Mar	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	53.0	53.0	53.0	52.8
10	54.5	54.4	54.5	54.5
20	55.4	55.4	55.5	55.2
30	56.2	56.5	56.3	55.8
40	57.0	57.2	57.0	56.5
50	57.8	57.8	57.6	57.1
60	58.5	58.6	58.3	57.7
70	59.4	59.5	59.1	58.4
80	60.5	60.6	60.1	59.2
90	61.9	62.1	61.1	60.3
Max	65.2	65.8	65.3	63.5
Avg	58.0	58.1	57.8	57.2
Change		0.1	-0.2	-0.8

April				
Apr	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	54.7	54.7	54.7	54.6
10	58.0	58.1	57.8	57.6
20	59.1	59.3	59.1	58.4
30	59.9	60.0	59.8	59.0
40	60.7	60.8	60.3	59.6
50	61.5	61.6	61.0	60.1
60	62.2	62.3	61.6	60.6
70	63.1	63.1	62.2	61.0
80	63.9	63.8	62.8	61.7
90	65.5	65.3	63.7	62.6
Max	69.9	68.8	69.3	68.3
Avg	61.6	61.6	60.9	60.1
Change		0.0	-0.7	-1.5

May				
May	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	59.6	59.8	58.8	57.8
10	61.7	61.8	60.8	60.2
20	63.1	63.1	61.7	61.0
30	64.0	63.9	62.4	61.4
40	64.6	64.5	63.0	62.0
50	65.3	65.1	63.7	62.7
60	66.2	65.8	64.2	63.3
70	67.1	66.5	65.1	64.0
80	68.4	67.5	66.0	64.8
90	69.9	69.0	67.4	66.0
Max	75.0	74.2	71.3	68.9
Avg	65.7	65.3	63.9	62.9
Change		-0.3	-1.8	-2.8

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-23a. Distribution of July–August 7DADM Water Temperatures in Relation to USEPA Criterion for Summer Rearing (64.4˚F) at RM 43.7 on the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	July				August			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LJR Alt 3	LSJR Alt 4
Min	53.6	53.6	53.8	53.2	54.7	54.7	55.0	57.0
10	59.6	59.7	59.4	59.0	60.2	61.0	61.5	61.3
20	62.1	62.5	60.2	60.0	62.9	62.8	62.7	62.9
30	63.6	63.3	61.4	61.1	63.6	63.5	63.3	63.8
40	64.2	64.0	62.9	62.8	64.1	63.9	63.9	64.4
50	65.0	64.8	64.1	64.2	64.6	64.4	64.5	65.1
60	65.7	65.6	65.3	65.8	65.5	65.2	65.4	66.2
70	66.7	66.3	66.6	66.9	66.5	66.1	66.5	67.2
80	68.3	67.6	67.7	67.9	68.2	67.3	67.4	67.8
90	69.4	68.9	68.8	69.1	70.3	68.6	68.5	68.7
Max	73.8	71.6	71.6	71.7	74.5	71.7	71.7	71.8
Avg	64.8	64.5	63.9	64.0	65.0	64.5	64.7	65.2
Change		-0.3	-0.9	-0.8		-0.6	-0.3	0.2

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-23b. Distribution of July–August 7DADM Water Temperatures in Relation to USEPA Criterion for Summer Rearing (64.4˚F) at RM 38.3 on the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	July				August			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	54.0	54.1	53.8	54.1	56.8	56.7	56.7	57.6
10	56.2	56.2	56.4	57.2	64.9	64.9	62.2	63.2
20	59.8	59.2	58.2	59.5	66.3	66.3	64.8	65.2
30	66.3	64.6	59.5	60.7	66.8	66.9	66.1	66.4
40	67.6	67.3	63.2	62.9	67.5	67.5	67.1	67.3
50	68.9	68.3	67.9	67.9	69.1	69.2	68.2	68.4
60	76.3	74.3	71.3	70.0	75.2	75.2	75.3	75.3
70	77.4	76.7	76.6	76.4	76.3	76.3	76.4	76.4
80	78.4	77.9	77.8	77.7	77.2	77.2	77.3	77.3
90	79.3	79.1	79.1	79.1	78.6	78.6	78.6	78.7
Max	82.6	82.6	82.6	82.6	82.1	82.1	82.1	82.2
Avg	69.8	69.0	67.9	68.2	71.1	71.1	70.7	70.9
Change		-0.8	-2.0	-1.7		0.0	-0.4	-0.2

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-23c. Distribution of July–August 7DADM Water Temperatures in Relation to USEPA Criterion for Summer Rearing (64.4˚F) at RM 37.8 on the Merced River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	July				August			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	56.3	56.3	56.3	57.0	60.2	60.2	60.2	60.3
10	60.0	60.0	60.4	62.0	63.8	63.9	64.1	65.0
20	62.8	63.1	64.9	66.6	64.5	64.5	65.0	66.6
30	74.0	67.9	68.1	68.1	65.7	66.0	67.9	67.9
40	75.9	75.1	71.4	70.6	74.3	74.4	73.9	74.3
50	76.6	76.2	75.2	75.3	75.6	75.5	75.3	75.7
60	77.3	77.2	76.6	76.8	76.5	76.5	76.2	76.6
70	78.0	77.9	77.5	77.8	77.8	77.7	77.7	78.1
80	79.1	78.9	78.7	79.1	79.1	78.7	78.8	79.5
90	81.3	80.6	80.7	81.3	80.7	80.3	80.6	81.3
Max	87.1	87.0	86.9	87.0	85.5	84.9	85.2	86.2
Avg	73.3	72.8	72.4	72.9	73.2	73.2	73.2	73.8
Change		-0.5	-0.9	-0.4		0.0	0.0	0.7

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Smoltification

Potential exposure of Chinook salmon and steelhead smolts to suboptimal water temperatures under baseline and alternative operational conditions was evaluated based on modeled water temperatures at the mouths of the Stanislaus, Tuolumne, and Merced Rivers and in the SJR at Vernalis during the spring outmigration period (April–June). These stations were selected because of the importance of suitable water temperatures for smolt development and health prior to their transition from fresh to saltwater. The following analysis examines differences in exposure of salmon and steelhead smolts to suboptimal water temperatures based on the frequency of modeled 7DADM temperatures that exceed the recommended USEPA criterion of 57.2°F for steelhead smoltification. Steelhead smolts are considered the most temperature-sensitive species and life stage during the spring outmigration period.

Under modeled baseline conditions, spring water temperatures frequently exceed the USEPA criterion for smoltification at the mouths of the Stanislaus, Tuolumne, and Merced Rivers and in the LSJR. Modeled 7DADM water temperatures exceeding the USEPA criterion are predicted to occur 60–90 percent of the time in April, 90 percent of the time in May, and nearly 100 percent of the time in June (Tables 7-24a, 7-24b, and 7-24c). Average 7DADM temperatures ranged from 58.5°F–64.0°F in April, 61.5°F–68.2°F in May, and 66.8°F–72.3°F in June.

Table 7-24a. Distribution of April–~~May~~ June 7DADM Water Temperatures in Relation to USEPA Criteria for Steelhead Smoltification (57.2˚F) at the Confluence of the Stanislaus River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May				June			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	51.2	51.2	51.2	51.1	54.3	54.3	54.3	53.7	57.1	57.2	56.3	54.9
10	54.7	54.9	54.9	54.2	57.6	57.9	57.4	56.2	61.2	61.0	59.9	58.2
20	55.7	55.9	55.8	55.1	58.7	59.1	58.4	57.1	62.6	62.8	61.9	59.9
30	56.6	56.7	56.5	55.9	59.5	59.8	59.0	57.6	63.4	63.6	62.9	61.0
40	57.3	57.4	57.2	56.7	60.0	60.4	59.5	58.1	64.7	65.0	64.3	62.1
50	58.1	58.1	57.9	57.3	60.7	60.9	60.1	59.0	65.8	66.5	65.5	63.4
60	58.9	59.1	58.7	58.1	61.5	61.6	60.9	59.7	68.2	68.6	66.5	64.8
70	59.9	60.0	59.6	58.9	62.7	62.7	61.8	60.6	70.0	70.0	68.3	66.7
80	61.2	61.6	60.7	59.6	64.7	64.0	62.9	61.8	71.5	71.3	70.7	69.5
90	63.1	63.2	61.7	60.7	66.4	66.2	65.0	64.2	73.3	73.2	73.0	72.3
Max	67.1	66.9	66.3	66.2	72.9	71.7	70.8	67.8	77.3	77.4	78.3	78.1
Avg	58.5	58.6	58.2	57.4	61.5	61.5	60.7	59.5	66.8	66.9	66.0	64.4
Change		0.1	-0.3	-1.1		0.0	-0.8	-2.1		0.1	-0.8	-2.4

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-24b. Distribution of April–~~May~~ June 7DADM Water Temperatures in Relation to USEPA Criteria for Steelhead Smoltification (57.2˚F) at the Confluence of the Tuolumne River under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May				June			
Percentile	Baseline	LSJR Alt 2	LSJR Alt3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	52.7	52.7	52.7	52.7	55.7	55.7	55.6	55.6	59.2	59.4	58.3	58.1
10	55.5	55.6	55.3	54.9	59.4	59.2	58.1	57.8	61.8	62.1	60.8	60.6
20	56.9	56.9	56.6	55.9	61.0	60.8	58.9	58.8	63.0	63.1	61.8	61.5
30	58.0	58.0	57.5	56.8	62.3	61.7	59.6	59.3	64.4	64.3	62.6	62.1
40	59.3	59.4	58.3	57.4	63.6	62.5	60.2	59.8	70.9	66.5	63.3	62.8
50	60.7	60.8	59.2	57.7	65.4	63.6	60.7	60.4	74.3	68.7	64.1	63.4
60	62.6	62.3	59.8	58.2	67.3	64.7	61.1	61.1	76.9	70.1	65.2	64.0
70	65.1	63.5	60.7	58.8	69.4	66.3	61.9	61.7	78.1	73.2	67.1	65.0
80	66.9	64.9	61.5	59.4	71.1	67.9	63.1	62.3	79.2	75.5	71.6	68.3
90	69.0	66.5	62.9	60.5	73.2	70.2	65.2	63.2	81.2	78.8	75.5	71.8
Max	74.0	73.5	71.4	67.7	77.6	75.1	69.1	66.0	86.1	85.1	85.1	83.8
Avg	61.7	61.0	59.2	57.9	65.9	64.2	61.1	60.5	72.2	69.4	66.2	64.9
Change		-0.7	-2.5	-3.8		-1.7	-4.8	-5.4		-2.8	-6.0	-7.3

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-24c. Distribution of April–~~May~~ June 7DADM Water Temperatures in Relation to USEPA Criteria for Steelhead Smoltification (57.2˚F) at the Confluence of the Merced River Under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May				June			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	52.1	52.1	52.2	52.2	55.9	55.8	55.8	55.1	57.1	57.3	57.4	57.3
10	58.2	58.3	57.6	55.9	61.2	61.3	60.0	58.5	62.4	62.4	62.4	62.2
20	60.5	60.7	59.5	57.5	63.7	63.0	61.1	59.9	65.4	65.0	64.8	63.6
30	62.0	62.2	60.6	58.9	65.3	64.0	62.1	60.6	69.8	68.0	66.3	64.6
40	63.0	63.2	61.3	59.7	67.0	65.0	62.9	61.4	72.8	70.4	67.7	66.1
50	64.0	63.9	61.9	60.4	68.8	66.0	63.6	62.1	74.2	71.7	69.1	67.4
60	65.0	64.7	62.5	61.1	70.0	67.0	64.5	62.9	75.4	72.7	70.0	68.4
70	66.4	65.4	63.2	61.7	71.3	68.1	65.5	64.0	76.4	74.0	71.5	69.7
80	67.6	66.3	63.8	62.4	72.6	69.5	66.7	65.2	77.5	75.5	73.4	72.2
90	69.6	67.6	64.9	63.5	74.3	70.6	68.5	67.0	78.9	77.4	75.9	74.7
Max	73.2	73.9	73.4	71.7	78.1	75.2	72.2	71.5	83.5	83.3	81.1	80.8
Avg	64.0	63.5	61.7	60.2	68.2	66.1	63.9	62.5	72.3	70.7	69.0	67.8
Change		-0.5	-2.2	-3.8		-2.1	-4.3	-5.7		-1.6	-3.3	-4.6

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

Table 7-24d. Distribution of April–June 7DADM Water Temperatures in Relation to USEPA Criteria for Steelhead Smoltification (57.2˚F) in the San Joaquin River at Vernalis under Modeled Baseline Conditions and LSJR Alternatives 2, 3, and 4

	April				May				June			
Percentile	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Min	54.7	54.7	54.7	54.6	59.6	59.8	58.8	57.8	62.2	62.1	61.2	59.9
10	58.0	58.1	57.8	57.6	61.7	61.8	60.8	60.2	65.7	65.8	64.4	63.5
20	59.1	59.3	59.1	58.4	63.1	63.1	61.7	61.0	66.9	66.9	65.6	64.4
30	59.9	60.0	59.8	59.0	64.0	63.9	62.4	61.4	67.8	67.8	66.5	65.1
40	60.7	60.8	60.3	59.6	64.6	64.5	63.0	62.0	68.6	68.7	67.2	65.8
50	61.5	61.6	61.0	60.1	65.3	65.1	63.7	62.7	69.9	69.7	68.0	66.5
60	62.2	62.3	61.6	60.6	66.2	65.8	64.2	63.3	71.3	71.1	68.7	67.1
70	63.1	63.1	62.2	61.0	67.1	66.5	65.1	64.0	72.6	72.3	69.8	68.0
80	63.9	63.8	62.8	61.7	68.4	67.5	66.0	64.8	73.8	73.6	72.0	70.4
90	65.5	65.3	63.7	62.6	69.9	69.0	67.4	66.0	75.7	75.6	74.5	73.4
Max	69.9	68.8	69.3	68.3	75.0	74.2	71.3	68.9	80.2	80.1	80.1	80.4
Avg	61.6	61.6	60.9	60.1	65.7	65.3	63.9	62.9	70.3	70.2	68.7	67.3
Change		0.0	-0.7	-1.5		-0.3	-1.8	-2.8		-0.1	-1.7	-3.0

Notes: Table shows the percent of time that a temperature of equal or lower value occurs. Gray shading indicates temperatures that exceed USEPA criteria.

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, exposure of Chinook salmon and steelhead to suboptimal water temperatures on the Stanislaus and LSJR would not substantially change compared to baseline conditions. No substantial changes would occur in the frequency of suboptimal water temperatures for migration, spawning, and incubation life stages in the three eastside tributaries although spring water temperatures would be improved for rearing and outmigrating salmon in the Tuolumne and Merced Rivers. Other native fishes would experience a similar range of seasonal water temperatures and therefore would not be substantially affected by implementation of this alternative. Impacts on Chinook salmon, steelhead, and other native fishes would not be adverse and would be less than significant.

Adult Migration

Under LSJR Alternative 2, the frequency of suboptimal water temperatures for Chinook salmon and steelhead adult migration (as defined by the USEPA criterion of 64.4°F) at the mouths of the Stanislaus, Tuolumne, and Merced Rivers and in the SJR at Vernalis is expected to remain largely unchanged from baseline conditions (Tables 7-20a, 7-20b, 7-20c, and 7-20d). Therefore, water temperature impacts on migrating adult salmon (including adults returning to Merced River Hatchery) and steelhead would be less than significant.

Spawning and Incubation

Under LSJR Alternative 2, the frequency of suboptimal water temperatures for Chinook salmon and steelhead spawning and incubation life stages (as defined by the USEPA criterion of 55.4°F) in the Stanislaus, Tuolumne, and Merced Rivers is not expected to change substantially relative to baseline conditions (Tables 7-21a, 7-21b, and 7-21c). Therefore, water temperature impacts on Chinook salmon and steelhead spawning and incubation life stages (including adult salmon and incubating eggs and fry in the Merced River Hatchery) would not be adverse and would be less than significant.

Juvenile Rearing

Under LSJR Alternative 2, exposure of juvenile salmon to suboptimal rearing temperatures (as defined by the USEPA criterion of 60.8°F) at the mouth of the Stanislaus River during the spring rearing period is not expected to change substantially relative to baseline conditions (Table 7-22a). In the Tuolumne and Merced Rivers, rearing temperatures under LSJR Alternative 2 are expected to improve based on reductions in average temperatures of 1.7°F to 2.1°F in May (Tables 7-22b and 7-22c). In the SJR at Vernalis, spring water temperatures under LSJR Alternative 2 are predicted to be similar to those under baseline conditions (Table 7-22d). Overall, changes in the exposure of juvenile salmon and steelhead during the spring rearing period are not expected to result in significant impacts on natural or hatchery production compared to baseline conditions.

Under LSJR Alternative 2, exposure of juvenile steelhead in the Stanislaus, Tuolumne, and Merced River to suboptimal rearing temperatures (as defined by the USEPA criterion of 64.4°F) in July and August is not expected to change substantially relative to baseline conditions (Tables 7-23a, 7-23b, and 7-23c). Therefore, water temperature impacts on summer rearing conditions for juvenile steelhead would not be adverse and would be less than significant.

Smoltification

Under LSJR Alternative 2, exposure of salmon and steelhead smolts to suboptimal temperatures (as defined by the USEPA criterion of 57.2°F) in the Stanislaus River and SJR at Vernalis is not expected to change substantially relative to baseline conditions (Table 7-24a and 7-24d). However, smolt outmigration conditions in the Tuolumne and Merced Rivers are expected to improve based on reductions in average temperatures of 1.7°F–2.1°F in May and 1.6°F–2.8°F in June over the 34-year modeling period (Tables 7-24b and 7-24c). This represents a beneficial effect on spring outmigration conditions for juvenile salmon and steelhead in the Tuolumne and Merced Rivers (including juvenile salmon reared at the Merced River Hatchery and released in the Merced River). Therefore, adverse impacts would be less than significant.

Other Fish Species

Higher spring flows and associated decreases in spring water temperatures under LSJR Alternative 2 are not expected to substantially affect the structure and composition of native and nonnative fish communities in the three eastside tributaries. The range of seasonal water temperatures predicted to occur under LSJR Alternative 2, including maximum water temperatures occurring in the summer, would remain within the ranges generally experienced by other fishes under baseline conditions. Therefore, adverse impacts would be less than significant.

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers and LSJR would experience improved water temperatures primarily during the spring rearing and outmigration months in response to higher flows in each of the tributaries (Tables 7-20a, 7-20b, 7-20c, and 7-20d through Tables 24a, Table 24b, Table 24c, and Table 7-24d). Water temperatures favoring native fish species over nonnative warmwater species would generally be improved relative to baseline conditions. Impacts on Chinook salmon, steelhead, and other native fishes would not be adverse and would be less than significant.

Adult Migration

Under LSJR Alternative 3, exposure of migrating Chinook salmon and steelhead adults to suboptimal water temperatures (as defined by the USEPA criterion of 64.4°F) in the Stanislaus, Tuolumne, Merced, and LSJR would be similar or slightly reduced relative to baseline conditions (Tables 7-20a, 7-20b, 7-20c, and 7-20d). Changes in water temperatures during the fall migration period ranged from little or no change at most locations to a 10 percent reduction in the frequency of suboptimal water temperatures and a 1.2°F reduction in average temperature in the Stanislaus River in October (Tables 7-20a). Therefore, water temperature impacts on migrating adult salmon (including adults returning to Merced River Hatchery) and steelhead would not be adverse and would be less than significant.

Spawning and Incubation

Under LSJR Alternative 3, the percent of time suboptimal water temperatures occur for Chinook salmon and steelhead spawning and incubation life stages (as defined by the USEPA criterion of 55.4°F) in the Stanislaus, Tuolumne, and Merced Rivers is not expected to change substantially relative to baseline conditions (Tables 7-21a, 7-21b, and 7-21c). Changes in the exposure of Chinook salmon and steelhead spawning and incubation life stages to suboptimal water temperatures (as defined by the USEPA criterion of 55.4°F) were characterized by little or no change at most locations. An exception is the 30 percent reduction in the frequency of suboptimal water temperatures and a 1.6°F reduction in average temperature in the Tuolumne River in March (Table 7-21b). Therefore, water temperature impacts on Chinook salmon and steelhead spawning and incubation conditions (including conditions at Merced River Hatchery) would not be adverse and would be less than significant.

Juvenile Rearing

Under LSJR Alternative 3, exposure of juvenile salmon to suboptimal water temperatures (as defined by the USEPA criterion of 60.8°F) during the spring rearing period is expected to decrease in the Stanislaus, Tuolumne and Merced Rivers and LSJR relative to baseline conditions. The largest changes are expected to occur in the Tuolumne River and Merced Rivers where 7DADM temperatures exceeding the USEPA criterion are predicted to decrease in frequency by 10–20 percent in March, 10–20 percent in April, and 10–30 percent in May, corresponding to reductions in average temperatures of 0.4°F–1.2°F in March, 2.2°F–2.5°F in April, and 4.3°F–4.8°F in May (Tables 7-22b and 7-22c). Therefore, implementation of LSJR Alternative 3 would have a beneficial effect on spring rearing conditions for Chinook salmon in the Stanislaus, Tuolumne, and Merced Rivers (including fish reared at the Merced River Hatchery and released upstream of Vernalis), and the LSJR. Adverse impacts would be less than significant.

Under LSJR Alternative 3, juvenile steelhead would experience lower summer water temperatures in the Stanislaus, Tuolumne, and Merced Rivers relative to baseline conditions (Tables 7-23a, 7-23b, and 7-23c). The largest change is expected to occur in the Tuolumne where 7DADM temperatures exceeding the USEPA criterion (64.4°F) in July are predicted to decrease in frequency by approximately 20 percent, corresponding to a reduction in average temperature of 2.0°F (Table 7-23b). Therefore, some improvement in summer rearing conditions for steelhead is expected in the Stanislaus, Tuolumne, and Merced Rivers. Adverse impacts would be less than significant.

Smoltification

Under LSJR Alternative 3, salmon and steelhead smolts would experience lower water temperatures during their outmigration in the Stanislaus, Tuolumne, and Merced Rivers and LSJR relative to baseline conditions (Tables 7-24a, 7-24b, 7-24c, and 7-24d)**.** The largest changes are expected to occur in the Tuolumne River and Merced Rivers where 7DADM temperatures exceeding the USEPA criterion are predicted to decrease in magnitude by an average of 2.2°F–2.5°F in April, 4.3°F–4.8°F in May, and 3.3°F–6.0°F in June (Tables 7-24b and 7-24c). These changes represent improved conditions for smolt development and migration in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR (including juvenile salmon reared at the Merced River Hatchery and released upstream of Vernalis). Adverse impacts would be less than significant.

Other Fish Species

Under LSJR Alternative 3, higher spring flows and associated reductions in water temperature in the Stanislaus, Tuolumne, and Merced Rivers and LSJR could benefit other native species and adversely affect nonnative species, such as largemouth bass and other warmwater species, which prey on or compete with native fishes. Based on reported changes in the abundance and distribution of native and nonnative resident species in the Tuolumne River and other Central Valley streams, higher spring flows and cooler water temperatures that mimic conditions that occur under the natural flow regime provide more appropriate spawning and rearing conditions for native species (Brown and Ford 2002). Increases in spring flows would also improve migration, spawning, and rearing conditions for splittail, sturgeon, striped bass, and other fishes, as well as improve water quality (e.g., water temperature and salinity) in the Stanislaus, Tuolumne, and Merced Rivers and in the LSJR (see Impact AQUA-4, LSJR Alternative 3). Therefore, LSJR Alternative 3 would have beneficial effects on other native fishes in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR. Impacts on native fish species would not be adverse and would be less than significant.

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers and LSJR would experience improved water temperatures primarily during the spring rearing and outmigration months in response to higher flows in each of the tributaries (Tables 7-20a, 7-20b, 7-20c, and 7-20d through Tables 7-24a, 7-24, 7-24c, and 7-24d). Water temperatures favoring native fish species over nonnative warmwater species would be improved relative to baseline conditions. Impacts on Chinook salmon, steelhead, and other native fishes would not be adverse and would be less than significant.

Adult Migration

LSJR Alternative 4, water temperatures for migrating Chinook salmon and steelhead in the Stanislaus, Tuolumne, Merced, and LSJR would be similar or slightly improved relative to baseline conditions (Tables 7-20a, 7-20b, 7-20c, and 7-20d). Changes in average water temperature during the fall migration period ranged from little or no change at most locations to a 1.0°F reduction in average temperature in the Tuolumne River in September (Table 7-20b). Therefore, water temperature impacts on migrating adult salmon (including adults returning to Merced River Hatchery) and steelhead would not be adverse and would be less than significant.

Spawning and Incubation

Under LSJR Alternative 4, no substantial changes are predicted to occur in the frequency of suboptimal water temperatures for Chinook salmon and steelhead spawning and incubation life stages (as defined by the USEPA criterion of 55.4°F) in the Stanislaus, Tuolumne, and Merced Rivers (Tables 7-21a, 7-21b, and 7-21c). Some improvement in water temperatures would occur in February and March when the frequency of water temperatures exceeding the USEPA criterion are expected to decline by 10–40 percent, and average temperatures are expected to decline by up to 2.2°F. Adverse impacts would be less than significant.

Juvenile Rearing

Implementation of LSJR Alternative 4 would substantially reduce the exposure of juvenile salmon to suboptimal water temperatures during the spring rearing period in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR. Under this alternative, modeled 7DADM temperatures exceeding the USEPA criterion are predicted to decline in frequency by approximately 0–30 percent in March, 20–40 percent in April, and 10–30 percent in May, and to be reduced in magnitude by an average of 0.8°F–2.2°F in March, 1.1°F–3.8°F in April, and 2.1°F–5.7°F in May (Tables 7-22a, 7-22b, 7-22c, and 7-22d). These changes represent substantial increases in the frequency, duration, and longitudinal extent of suitable rearing temperatures for juvenile salmon in the LSJR and tributaries. Thus, implementation of LSJR Alternative 4 would have beneficial effects on spring rearing conditions for

Chinook salmon in the Stanislaus, Tuolumne, and Merced Rivers (including juvenile salmon reared at the Merced River Hatchery), and LSJR. Adverse impacts would be less than significant.

Under LSJR Alternative 4, substantial changes in the frequency of suboptimal water temperatures for juvenile steelhead (as defined by the USEPA criterion of 64.4°F) during the summer rearing months are only expected to occur in the Tuolumne River where 7DADM temperatures exceeding the USEPA criterion are predicted to decrease in frequency by 20 percent, and to decrease in magnitude by an average of 1.7°F (Table 7-23b). Adverse impacts would be less than significant.

Smoltification

Under LSJR Alternative 4, salmon and steelhead smolts would experience substantial reductions in exposure to suboptimal water temperatures (as defined by the USEPA criterion of 57.2°F) during the spring outmigration period in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR relative to baseline conditions (Tables 7-24a, 7-24b, 7-24c, and 7-24d). Modeled 7DADM temperatures exceeding the USEPA criterion at the mouths of the Stanislaus, Tuolumne, and Merced Rivers and in the SJR at Vernalis are predicted to decrease in frequency by 20 percent or less but decrease in magnitude by an average of 1.1°F–3.8°F in April, 2.1°F–5.7°F in May, and 2.4°F–7.3°F in June. These changes represent substantial improvement in conditions for smolt development and migration in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR (including juvenile salmon reared at the Merced River Hatchery and released). Adverse impacts would be less than significant.

Other Fish Species

Under LSJR Alternative 4, further increases in spring flows and associated reductions in water temperature (compared to those occurring under LSJR Alternative 3) are expected to further increase the quantity and quality of habitat for native fish species in the Stanislaus, Tuolumne, Merced, and LSJR. As discussed under LSJR Alternative 3, the predicted changes in flows and water temperatures would be expected to reduce the distribution and abundance of nonnative fishes and their negative impacts (e.g., predation) on native fishes (see Impact AQUA-10, LSJR Alternative 4). Therefore, LSJR Alternative 4 would have beneficial effects on native fishes in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR.

Impact AQUA-5: Changes in exposure to pollutants resulting from changes in flow

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

In general, surface water originating in the three eastside tributary watersheds is good quality and has low salinity concentrations. As increased flow due to precipitation or reservoir operations mobilizes sediment, pollutant levels in the water column have the potential to increase if present in the sediment. Certain land uses, such as abandoned mining operations, in the tributary watersheds have leached different pollutants into the rivers. These pollutants include toxic trace metals (e.g., copper, zinc, and cadmium) (Boles et al. 1988). This has increased known pollutant concentrations in river sediment, which can result in increased fish mortality.

Increased flows under the LSJR alternatives have the potential to increase mobilization and concentration of pollutants in surface waters in the three eastside tributaries and LSJR, potentially increasing exposure of aquatic organisms to toxic substances. While copper, zinc, and cadmium tolerance limits exist for juvenile Chinook salmon (Boles et al. 1988), direct effects on fish cannot be accurately or precisely quantified given the current understanding of the complex processes involved in mobilization and fate of sediment-linked toxins. The volume and concentrations of pollutants that could be mobilized into rivers are generally unknown, and site-specific analyses would be needed to confirm real-time concentrations. However, because pollutants attached to sediment enter the water column, the potential for increased toxins in the system can be linked to a change in suspended sediment and turbidity. An increased concentration of toxins as a result of increased flows could adversely impact indicator species. Alternatively, increased flows can also dilute existing pollutants in the water column and any other pollutants that may be mobilized from the sediment on the riverbed and along the river channel, thereby benefiting indicator species.

Decreased flows could increase concentrations of pollutants, adversely impacting indicator species. Decreased flows could also result in increased temperatures, which generally increase the toxic effects of metals and reduce the survival time of Chinook salmon if lethal levels of metals are present. Warming water temperatures can increase pollutant dose because fish respiration and feeding rates must increase to support the higher metabolic rates that result from warmer water temperatures (Myrick and Cech 2004). Additionally, warming water temperatures can reduce the energy reserves that fish utilize to lessen the effects of pollutants (Brooks et al. 2012). Consequently, lower flows and higher temperatures may exacerbate the effects of pollutants (Heugens et al. 2001).

This assessment is qualitative and based on the dilution effects of proposed changes in flows (see Chapter 5, *Surface Hydrology and Water Quality*, Impact WQ-3) and changes in exposure of fish to thermal stress that could increase their uptake and vulnerability to contaminants under each of the LSJR alternatives (see Impact AQUA-4). Potential water quality impacts under the following analysis assumes that dilution from increased flow would result in long-term reductions in contaminant concentrations and exposure of fish to potentially harmful concentrations in the plan area. However, it should be recognized there is uncertainty regarding the effects of flow in addressing contaminant loads because of concerns related to remobilization of pesticides, trace metals, and other contaminants in the sediment, and the need to implement point- and non-point source reduction actions as part of future restoration efforts (McBain and Trush 2002). For a description of expected changes to sediment and turbidity resulting from increased flows, see Impact AQUA-6.

Impact WQ-3 in Chapter 5 was evaluated based on the changes in the 10th percentile and median values of flow. A concentration ratio of more than 1.5 would represent an increase of 50 percent of the baseline concentration and would be expected to cause a significant increase in pollutants when baseline concentrations are approaching water quality objectives for water resources. As detailed in Chapter 5, a concentration ratio of 1.5 would occur if there was a one-third reduction in flow. Therefore, a reduction in 10th percentile or median flows of more than 33 percent for a particular month is considered to be potentially significant and subject to further evaluation.

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, Chinook salmon, steelhead, and other fish species would not experience an increased exposure or vulnerability to contaminants in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR. Flows were similar in most months and substantially higher in the spring (May and June primarily) compared to baseline conditions (Tables 5-17a, 5-17b, 5-17c, and 5-17d). Reductions in magnitude of the 10th to 90th percentile flows of 10 percent or more occurred in some months but these reductions were associated with the highest flow years (e.g., >50th percentile flows) or flows during the winter and early spring (December–March) when water temperatures are not a concern (see Impact AQUA-4, LSJR Alternative 2). Impacts on Chinook salmon, steelhead, and other fishes would not be adverse and would be less than significant.

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, Chinook salmon, steelhead, and other fish species would not experience an increased exposure or vulnerability to contaminants because of higher spring flows and substantial improvement in water temperatures for juvenile rearing and smolt outmigration in the Tuolumne River, the Merced River, and the LSJR (Tables 5-17a, 5-17b, 5-17c, and 5-17d). Reductions in magnitude of the 10th to 90th percentile flows of 10 percent or more occurred in some months but these reductions were associated with the highest flow years (e.g., upper 50th percentile flows) or flows during the winter and early spring (December–March) when water temperatures are not a concern (see Impact AQUA-4, LSJR Alternative 3). Impacts on Chinook salmon, steelhead, and other fishes would not be adverse and would be less than significant.

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, Chinook salmon, steelhead, and other fish species would not experience an increased exposure or vulnerability to contaminants because of higher spring flows and substantial improvement in water temperatures for juvenile rearing and smolt outmigration in the Tuolumne River, the Merced River, and the LSJR (Tables 5-17a, 5-17b, 5-17c, and 5-17d). Reductions in magnitude of the 10th to 90th percentile flows of 10 percent or more occurred in some months but these reductions were associated with the highest flow years (e.g., upper 50th percentile flows) or flows during the winter and early spring (December–March) when water temperatures are not a concern (see Impact AQUA-4, LSJR Alternative 4). Impacts on Chinook salmon, steelhead, and other fishes would not be adverse and would be less than significant.

Impact AQUA-6: Changes in exposure to suspended sediment and turbidity resulting from changes in flow

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

Higher flows generally have a higher capacity to mobilize and transport sediment in rivers, resulting in higher concentrations of suspended sediment and reduced water clarity (i.e., increased turbidity). Suspended sediments, such as clay, silt, organic matter, plankton, and other microscopic organisms cause turbidity in water that can affect primary productivity, water temperature, DO, and fish feeding. During high-flow events, high concentrations of suspended sediment can settle out and bury stream substrates that provide habitat for aquatic invertebrates and other important food sources for fish. Sediment that settles out of suspension may also reduce the quality of spawning substrates and entomb or suffocate salmonid eggs and alevins in stream gravels. Other effects of suspended sediment on fish include displacement from key habitats, physiological stress, respiratory impairment, damage to gills, reduced tolerance to disease and toxicants, and direct mortality at very high levels (Newcombe and Jensen 1996; Bash et al. 2001).

High turbidity levels generally reduce the efficiency of piscivorous (fish-eating) and planktivorous (plankton-eating) fish in finding and capturing their prey (Henley et al. 2000). Higher turbidity may favor the survival of young fish by protecting them from predators (De Robertis et al. 2003), but can also reduce the feeding rates of young fish that depend on sight to detect prey (Newcombe and Jensen 1996). Typically, when waters are turbid, predator success rate is less. Juvenile salmon losses to predators may be reduced by at least 45 percent in turbid stream reaches relative to clearer water reaches (Gregory and Levings 1998). Turbid water may also stimulate faster migration rates, which reduces the time young fish are exposed to freshwater mortality risks (USBR 2008). In the southern Delta, low turbidity contributes to poor feeding conditions and potentially higher predation rates on delta smelt and other pelagic species. For delta smelt, it appears that turbidity enhances visual contrast and detection of prey (Baskerville-Bridges et al. 2004). Feeding of other planktivorous species, such as longfin smelt, may also be similarly affected by turbidity (Nobriga et al. 2008; USBR 2011).

Potential effects of the LSJR alternatives on the frequency and magnitude of flow events capable of inducing sediment transport in the upper and lower reaches of the Stanislaus, Tuolumne, and Merced Rivers were evaluated to determine the potential for changes in exposure of fish to increases in suspended sediment concentrations and turbidity (Impact AQUA-6), and changes in channel complexity (habitat diversity) and spawning gravel quality resulting from gravel mobilization (Impact AQUA-8). Under baseline conditions, gravel transport is estimated to occur at flows between 5,000 and 8,000 cfs in the Stanislaus River (Kondolf et al. 2001), flows between 7,000 and 9,800 cfs in the upper reaches of the Tuolumne River (McBain and Trush 2000), and flows greater than 4,800 cfs in the upper reaches of the Merced River (Stillwater Sciences 2001; Kondolf et al. 1996). Flows below these levels (above approximately 2,000–3,000 cfs) can mobilize finer sediment in the mid- to lower sand-bedded portions of these tributaries, potentially increasing suspended sediment and turbidity in the lower reaches of these tributaries and the LSJR. These flows were used as thresholds to evaluate potential impacts on the indicator fish species and aquatic habitat resulting from changes in the frequency and magnitude of bed-mobilizing flows in the Stanislaus, Tuolumne, and Merced Rivers. This analysis is based on modeled peak monthly flows in the wettest years of the 1922–2003 modeling period (Chapter 6, *Flooding, Sediment, and Erosion*, Tables 6-10 through 6-12).

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, the modeling of peak flows during the wettest years of the 1922–2003 modeling period indicates that the frequency and magnitude of flows exceeding the thresholds associated with gravel mobilization in the upper reaches of the Stanislaus, Tuolumne, and Merced Rivers would be similar to that occurring under baseline conditions (Tables 6-9 through 6-12; Chapter 6, *Flooding, Sediment, and Erosion*, Impact FLO-1) In addition, no substantial changes would occur in the frequency of peak flows capable of inducing increased turbidity and suspended sediment in the lower portions of Stanislaus, Tuolumne, and Merced Rivers (>2,000 cfs). Therefore, no long-term changes in suspended sediment and turbidity affecting aquatic resources would occur. Adverse impacts would be less than significant**.**

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, peak flows associated with gravel mobilization in the Stanislaus, Tuolumne, and Merced Rivers would remain unchanged or decrease in frequency relative to baseline conditions (Tables 6-10 through 6-12; Chapter 6, *Flooding, Sediment, and Erosion*, Impact FLO-1). Peak flow events capable of transporting fine sediment in the lower sand-bedded reaches of these tributaries are predicted to increase in frequency in the Stanislaus River during the 82-year modeling period (15 years under LSJR Alternative 3 compared to 11 years under baseline conditions; see Table 6-10) but the magnitude of these events is expected to remain within the range of historical levels experienced by native fishes and other aquatic species. Furthermore, sediment carried into the southern Delta is generally considered beneficial to delta smelt and other pelagic fish species because of reductions in turbidity that have contributed to habitat degradation for pelagic fishes in the Bay-Delta estuary (Ferrari et al. 2013). Therefore, no long-term changes in suspended sediment and turbidity affecting aquatic resources would occur. Adverse impacts would be less than significant**.**

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, peak flows associated with gravel mobilization would increase in frequency in the Stanislaus River and decrease in frequency in the Tuolumne and Merced River (Tables 6-10 through 6-12; Chapter 6, *Flooding, Sediment, and Erosion*, Impact FLO-1). However, increases in the frequency of gravel-mobilization events are not expected to substantially affect native fish communities or aquatic habitat because of the low frequency of these events over the 82-year modeling period. Furthermore, such events are generally recognized as beneficial for aquatic habitat maintenance (McBain and Trush 2000; Kondolf et al. 2001; Stillwater Sciences 2001, 2004). Similar to LSJR Alternative 3, peak flow events capable of transporting fine sediment in the lower sand-bedded reaches of these tributaries could increase in frequency in the Stanislaus River (16 years under LSJR Alternative 4 compared to 11 years under baseline conditions; see Table 6-10) but the magnitude of these events is expected to remain within the range of historical levels experienced by native fishes and other aquatic species. Furthermore, sediment carried into the southern Delta is generally considered beneficial to delta smelt and other pelagic fish species because of reductions in turbidity that have contributed to habitat degradation for pelagic fishes in the Bay-Delta estuary. Therefore, no long-term changes in suspended sediment and turbidity affecting aquatic resources would occur. Adverse impacts would be less than significant**.**

Impact AQUA-7: Changes in redd dewatering resulting from flow fluctuations

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

Reservoir operations can result in fluctuations in river flows that can dewater Chinook salmon and steelhead redds. In general, redd dewatering depends on site conditions selected by females for spawning, the magnitude and duration of subsequent flow reductions during the incubation period, and the developmental stage of the embryos or fry at the time of the flow reductions. Spawning site selection depends on the presence of suitable water depths, velocities, and substrate sizes for adult spawning activities and redd construction. Suitable spawning sites are also characterized by bed topography that facilitates flow exchange through the gravel, as occurs in the transitional areas between pools and riffles (Shapovalov and Taft 1954) or where other channel features induce upwelling or downwelling (Geist et al. 2001). Following egg deposition and completion of redd construction, the survival of eggs and alevins (yolk-sac fry) depends on the maintenance of suitable hyporheic flow[17], water temperatures, and DO levels. Salmonid eggs can tolerate temporary (1–5 weeks) dewatering provided that the temperature remains suitable and the eggs remain moist (Becker et al. 1982; Reiser and White 1983; McMichael et al. 2005). Alevins are less tolerant of dewatering because of their dependence on hyporheic flow and relatively high concentrations of DO in the surrounding water (Becker et al. 1982).

Potential redd dewatering impacts were evaluated based on habitat suitability criteria (HSC) for Chinook salmon and steelhead spawning (water depths) and published data on egg burial depths. Depth HSCs and redd measurements for Chinook salmon and steelhead in the three eastside tributaries and other Central Valley rivers indicate that the shallowest depth utilized by spawning Chinook salmon and steelhead adults is approximately 0.5 ft (USFWS1993, 1997, 2010; MID 2013; Stillwater Sciences 2013). Redds become fully dewatered when the surface of the hyporheic zone drops below the elevation of the egg pocket. However, impacts may occur with reductions in surface flow depending on site conditions (e.g., intragravel permeability) and developmental stage of the embryos or fry (Reiser and White 1983). Published measurements of egg burial depths (excavation depth to top of main egg pocket) average 0.5–1.4 ft for Chinook salmon and 0.4–0.8 inches for steelhead (DeVries 1997). Because of variability in potential effects related to site conditions and developmental stage, the following analysis includes the assumption that embryos and fry in the shallowest redds begin to experience adverse intragravel conditions with flow reductions exceeding the minimum spawning depth (0.5 ft). Additionally, based on the range of egg burial depths cited above, complete dewatering of the shallowest redds is assumed to occur with flow reductions of approximately 1 foot. Therefore, significant adverse impacts could occur if the frequency of flow reduction of 1 foot or more increases by 10 percent or more under the alternatives.

[17] The *hyporheic zone* is the zone below and adjacent to the streambed where surface and subsurface water mix and are readily exchanged.

Table 7-25 summarizes the flow-depth relationships that were used to calculate average monthly changes in water depth over redds during the Chinook salmon and steelhead incubation periods. These relationships describe the average change in water depth as a function of flow based on a series of channel cross sections and flow-stage relationships within the principal spawning reaches of the Stanislaus, Tuolumne, and Merced Rivers.[18] Polynomial equations were fit to the average flow-depth relationships for each tributary and used to calculate the average monthly change in water depth during the Chinook salmon and steelhead incubation period based on monthly modeled reservoir releases at Goodwin Dam, La Grange Dam, and Crocker-Huffman Dam for the years 1922–2003. It should be recognized that monthly flow modeling provides only a coarse approximation of potential impacts associated with redd dewatering because such impacts are highly sensitive to daily variation in flows, spawning timings, and daily reservoir operational decisions and rules that govern the magnitude and rate of flow reductions during the Chinook salmon spawning and incubation season. Under current operations, redd dewatering has not been identified as a significant stressor on Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers.

Table 7-25. Flow-Depth Relationships for the Principal Chinook Salmon and Steelhead Spawning Reaches in the Stanislaus, Tuolumne, and Merced Rivers

Stanislaus at Goodwin		Tuolumne at La Grange		Merced at Crocker Huffman	
flow (cfs)	depth (feet)	flow (cfs)	depth (feet)	flow (cfs)	depth (feet)
250	3.03	250	3.40	250	2.46
500	3.64	500	3.88	500	2.98
1,000	4.60	1,000	4.61	1,000	3.30
1,500	5.59	1,500	5.13	1,500	3.69
2,000	6.24	2,000	5.52	2,000	4.03
2,500	6.81	2,500	5.85	2,500	4.35
3,000	7.29	3,000	6.04	3,000	4.64
4,000	8.22	4,000	6.28	4,000	5.09
5,000	9.01	5,000	5.95	5,000	5.62

cfs = cubic feet per second

Tables 7-26a, 7-26b, and 7-26c summarize the frequency and magnitude of monthly changes in water depth during the primary Chinook salmon and steelhead incubation months (October–May) under baseline conditions and LSJR Alternatives 2, 3, and 4. The results are shown for 10th, 50th, 90th percentiles and averages for the years 1922–2003. A positive value for a given month indicates an increase in water depth from the previous month, while a negative value indicates a decrease in water depth from the previous month.

[18] These relationships were developed from 36 cross sections on the Stanislaus River between RM 33.3 and 58.5, 37 cross sections on the Tuolumne River between RM 29.2 and 53.1, and 45 cross sections on the Merced River between RM 27.4 and 52.2 (see AD Consultants et al. 2009).

Table 7-26a. Average Monthly Changes in Water Depth (Feet) in the Principal Chinook Salmon and Steelhead Spawning Reach of the Stanislaus River

Percentile	Oct–Nov	Nov–Dec	Dec–Jan	Jan–Feb	Feb–Mar	Mar–Apr	Apr–May
Baseline							
10	-4.2	0.0	0.0	-0.1	-3.2	-0.2	-0.4
50	-4.0	0.0	0.0	0.0	0.0	0.7	0.0
90	-3.8	0.0	0.7	3.8	5.4	5.5	0.5
LSJR Alt 2							
10	-4.2	0.0	0.0	0.0	-3.1	-0.2	-0.4
50	-4.1	0.0	0.0	0.0	0.0	0.9	0.0
90	-3.8	0.0	1.3	3.7	3.7	5.4	0.5
LSJR Alt 3							
10	-4.8	0.0	0.0	0.0	-1.2	-0.1	-0.4
50	-4.3	0.0	0.0	3.3	0.3	0.9	0.3
90	-3.9	0.1	0.1	4.8	3.6	3.7	1.5
LSJR Alt 4							
10	-4.8	0.0	0.0	0.0	-0.9	-0.1	-0.5
50	-4.3	0.0	0.0	3.6	0.5	1.0	0.8
90	-3.9	0.0	0.1	5.7	3.3	2.2	2.0

Table 7-26b. Average Monthly Changes in Water Depth (Feet) in the Principal Chinook Salmon and Steelhead Spawning Reach of the Tuolumne River

Percentile	Oct–Nov	Nov–Dec	Dec–Jan	Jan–Feb	Feb–Mar	Mar–Apr	Apr–May
Baseline							
10	-0.2	0.0	0.0	0.0	-0.2	-1.1	-1.7
50	0.0	0.0	0.0	0.0	0.0	0.2	0.0
90	0.0	0.8	1.5	2.1	1.6	4.5	0.3
LSJR Alt 2							
10	-0.2	0.0	0.0	0.0	-0.6	-1.1	-1.2
50	0.0	0.0	0.0	0.0	0.0	0.2	0.0
90	0.0	0.5	1.6	3.8	3.4	4.2	0.7
LSJR Alt 3							
10	-0.2	-0.7	0.0	0.0	-0.6	-0.7	-0.5
50	0.0	0.0	0.0	0.9	0.2	0.6	0.4
90	0.2	0.0	1.2	4.9	1.9	2.1	1.5
LSJR Alt 4							
10	-0.2	-0.7	0.0	0.0	-0.7	-0.5	-0.5
50	0.0	0.0	0.0	1.8	0.4	0.8	0.4
90	0.1	0.0	0.0	5.4	1.9	1.9	1.4

Table 7-26c. Average Monthly Changes in Water Depth (Feet) in the Principal Chinook Salmon and Steelhead Spawning Reach of the Merced River

Percentile	Oct–Nov	Nov–Dec	Dec–Jan	Jan–Feb	Feb–Mar	Mar–Apr	Apr–May
Baseline							
10	-2.7	0.0	0.0	0.0	-0.9	-2.7	-2.5
50	-2.7	0.0	0.0	0.0	0.4	0.0	0.0
90	-2.6	1.0	1.5	3.3	2.7	0.3	2.9
LSJR Alt 2							
10	-2.7	0.0	0.0	-0.1	-0.9	-2.7	0.0
50	-2.7	0.0	0.0	0.0	0.6	0.0	0.3
90	-0.6	1.0	1.2	2.9	2.7	0.4	2.9
LSJR Alt 3							
10	-2.7	-3.0	0.0	0.0	-0.7	-0.6	0.0
50	-2.7	0.0	0.0	0.0	0.4	0.3	0.5
90	0.0	0.0	0.8	3.4	2.8	0.6	1.2
LSJR Alt 4							
10	-2.7	-3.0	0.0	0.0	-0.8	-0.1	0.0
50	-2.7	0.0	0.0	2.7	0.2	0.4	0.6
90	0.0	0.0	0.5	3.8	2.9	0.8	1.3

Baseline

Seasonal flow fluctuations in the Stanislaus, Tuolumne, and Merced Rivers during the Chinook salmon and steelhead spawning and incubation seasons are generally characterized by flow reductions in the fall (following pulse flows typically in late October to attract Chinook salmon into the tributaries), relatively stable base flows through the winter (punctuated by storm-driven flow pulses), sustained higher flows in the late winter and spring, and a flow reduction to summer base flows in late spring or summer. Under modeled baseline conditions, reductions in monthly flows below Goodwin, La Grange, and Crocker-Huffman Dams typically occur between October and November, resulting in average changes in water depth of 3.7 ft in the Stanislaus River, 0.1 ft in the Tuolumne River, and 2.4 ft in the Merced River (Tables 7-26a, 7-26b, and 7-26c). Although the potential exists for redd dewatering in the Stanislaus and Merced Rivers, the incidence of redd dewatering is likely low because most adults do not spawn until after the fall attraction flow. Beginning in November, modeled baseline flows generally remain stable or increase during the Chinook salmon and steelhead spawning and incubation season.

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, no substantial changes would occur in the frequency and magnitude of flow reductions associated with potential Chinook salmon and steelhead redd dewatering impacts (decreases in water depth of greater than ~~0.5~~ 1 ft or more) relative to baseline conditions (Tables 7-26a, 7-26b, and 7-26c). Therefore, redd dewatering impacts on Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers would be less than significant.

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, no substantial changes would occur in the frequency and magnitude of flow reductions associated with potential Chinook salmon and steelhead redd dewatering impacts (decreases in water depth of greater than 0.5 ft) relative to baseline conditions (Tables 7-26a, 7-26b, and 7-26c). Therefore, redd dewatering impacts on Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers would be less than significant.

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, no substantial changes would occur in the frequency and magnitude of flow reductions associated with potential Chinook salmon and steelhead redd dewatering impacts (decreases in water depth of greater than 1~~0.5~~ ft or more) relative to baseline conditions (Tables 7-26a, 7-26b, and 7-26c). Therefore, redd dewatering impacts on Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers would be less than significant.

Impact AQUA-8: Changes in spawning and rearing habitat quality resulting from changes in peak flows

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

In general, historical dam operations and mining operations in the Stanislaus, Tuolumne, and Merced Rivers have eliminated natural gravel sources and channel forming flows that maintain the geomorphic processes needed to maintain high-quality spawning and rearing habitat for native salmonids and other fishes (McBain and Trush 2002). As discussed for Impact AQUA-6, gravel transport is estimated to occur at flows between 5,000 and 8,000 cfs in the Stanislaus River (Kondolf et al. 2001), between 7,050 and 9,800 cfs in the upper reaches of the Tuolumne River (McBain and Trush 2000), and at flows greater than 4,800 cfs in the upper reaches of the Merced River (Stillwater Sciences 2001; Kondolf et al. 1996). These flows served as thresholds for evaluating the potential for changes in the frequency and magnitude of bed-mobilizing flows that could affect the quality of spawning and rearing habitat in the Stanislaus, Tuolumne, and Merced Rivers. This analysis is based on modeled peak monthly flows in the wettest years of the 1922–2003 modeling period (Chapter 6, *Flooding, Sediment, and Erosion*, Tables 6-10 through 6-12).

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, modeling of peak flows during the wettest years of the 1922–2003 modeling period indicates that the frequency and magnitude of flows exceeding the thresholds associated with gravel mobilization would not change substantially in the Stanislaus, Tuolumne, and Merced Rivers relative to baseline conditions (Tables 6-10 through 6-12; Chapter 6, *Flooding, Sediment, and Erosion*, Impact FLO-1). Under baseline conditions and LSJR Alternative 2, peak monthly flows would exceed the minimum threshold flows (5,000 cfs in the Stanislaus River, 7,000 cfs in the Tuolumne River, and 4,800 cfs in the Merced River) in 3 years in the Stanislaus River, 9 years in the Tuolumne River, and 7 years in the Merced River (Tables 6-10, 6-11, and 6-12). Therefore, no long-term changes in geomorphic conditions significantly affecting spawning and rearing habitat quality would occur. Adverse impacts would be less than significant.

LSJR Alternative 3 (Less than significant)

Similar to LSJR Alternative 2, changes in peak flows under LSJR Alternative 3 are not expected to affect the frequency and magnitude of gravel mobilization events in the Stanislaus, Tuolumne, and Merced Rivers (Tables 6-9 through 6-12; Chapter 6, *Flooding, Sediment, and Erosion*, Impact FLO-1). Therefore, no long-term changes in geomorphic conditions significantly affecting spawning and rearing habitat quality would occur. Adverse impacts would be less than significant.

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, peak flows associated with gravel mobilization would increase in frequency in the Stanislaus River and decrease in frequency in the Tuolumne and Merced River (Tables 6-10 through 6-12; Chapter 6, *Flooding, Sediment, and Erosion*, Impact FLO-1). However, no substantial long-term effects on geomorphic conditions affecting spawning and rearing habitat quality are expected to occur because of the low frequency of these events over the 82-year modeling period. Furthermore, such events are generally recognized as beneficial for aquatic habitat maintenance (McBain and Trush 2000; Kondolf et al. 2001; Stillwater Sciences 2001, 2004). Therefore, no long-term changes in geomorphic conditions significantly affecting spawning and rearing habitat quality would occur. Adverse impacts would be less than significant.

Impact AQUA-9: Changes in food availability resulting from changes in flow and floodplain inundation

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

Losses and degradation of riparian and floodplain habitat and reductions in natural hydrologic variability that connect these habitats to the aquatic ecosystem have been identified as a major stressor on native fish populations through direct impacts on spawning and rearing habitat availability (Impact AQUA-3) and indirect impacts on aquatic productivity and food web support provided by seasonal floodplain inundation (see Appendix C, *Technical Report on the Scientific Basis for Alternatives San Joaquin River Flow and Southern Delta Salinity Objectives*).

The impacts of the alternatives on food web support for Chinook salmon, steelhead, and other native fishes are qualitatively evaluated based on the frequency and magnitude of floodplain inundation in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR (see Impact AQUA-3). As discussed in Appendix C, establishing a more natural flow regime is anticipated to enhance the processes supporting food production for native fish species and other organisms. Therefore, higher spring flows that mimic the natural seasonal flow pattern are assumed to provide increased food web support by enhancing primary and secondary production on floodplains and potentially increasing inputs or organic carbon and nutrients from floodplains to downstream waters.

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, no substantial long-term negative changes on food web support are expected based on predicted changes in the frequency and magnitude of floodplain inundation over the 82-year modeling period (see Impact AQUA-3, LSJR Alternative 2; Tables 7-16a, 7-16b, 7-17c, and 7-17d). Therefore, adverse impacts would be less than significant.

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, higher spring flows and associated increases in riparian and floodplain inundation in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR (see Impact AQUA-3, LSJR Alternative 3) would potentially increase the abundance of aquatic and terrestrial invertebrates available to juvenile salmon and other native fishes that use floodplain habitats for spawning and/or early rearing (e.g., Sacramento splittail), and increase inputs of organic matter and nutrients to the riverine and estuarine ecosystem. Potential increases in food abundance and growth opportunities for fish on floodplains as well as downstream food web support would contribute to the benefits associated with increases in physical habitat discussed in Impact AQUA-3. This represents a beneficial effect on aquatic resources in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR. Adverse impacts would be less than significant.

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, further increases in the frequency, magnitude, and duration of floodplain inundation relative to LSJR Alternative 3 would further enhance aquatic productivity and food web support for native fish species and other aquatic resources. This represents a beneficial effect on aquatic resources in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR. Adverse impacts would be less than significant.

Impact AQUA-10: Changes in predation risk resulting from changes in flow and water temperature

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

Predation pressures on indicator species are considerable under baseline conditions (SJRGA 2009, 2010). Predation impact mechanisms include changes in ecosystem structure that increase prey vulnerability or increase predator feeding efficiency. Several impact mechanisms may contribute to increased predation, including altered flow regimes, removal of riparian cover, changes in turbidity, and reduced habitat heterogeneity (Moyle 2002; Ferrari et al. 2013). These mechanisms generally alter predator-prey relationships by disrupting or reducing cover, space, and refuge. Increased prey vulnerability is also associated with other environmental conditions, including increased water temperature, water diversions, pollutants, and fishing (Spence et al. 1996; Moyle 2002).

Predation by numerous native and nonnative species is exacerbated by water management, channel modifications, and artificial structures (e.g., dams) within the plan area. Fish, avian, and wildlife species that prey on steelhead and fall-run Chinook salmon in the plan area include striped bass, Sacramento pikeminnow, smallmouth bass, trout, largemouth bass, gulls, mergansers, cormorants, river otters, herons, sea lions, and seals (USBR 2008). Infrastructure or operational elements of the water conveyance system may lead to behavioral changes, metabolic disruption, or other biological and ecological outcomes that increase prey vulnerability to predators (BPA 2010). Increased water temperatures or other environmental conditions may place increased metabolic demands on susceptible groups of fish and hinder their flight response or capability to take refuge from threats by predation (Spence et al. 1996). Specifically, warm water temperatures may impact the performance of young salmon or enhance habitat conditions favorable to predatory fishes, thereby increasing losses of young Chinook salmon to predators (Boles et al. 1988). Reductions in shaded riverine aquatic cover can expose fish to increased risk of capture by avian or terrestrial predators (Li et al. 1994; BPA 2010).

As discussed in Appendix C, *Technical Report on the Scientific Basis for Alternatives San Joaquin River Flow and Southern Delta Salinity Objectives*, predation has been identified a significant factor limiting Chinook salmon outmigrant survival in the SJR Basin and southern Delta and a major impediment to Central Valley salmon recovery efforts (EA 1992; TID and MID 1992; FishBio 2013; NMFS 2009c; Dauble et al. 2010). The specific mechanisms by which flow, water temperature, and other flow-related variables affect the success of predator populations and their impact on Chinook salmon and other native fishes are not clearly understood. The relative importance of predation in limiting survival of outmigrating salmon also appears to be strongly influenced by reach-specific factors, such as deepening and simplification of natural channels, as well as dams, diversions, and other artificial structures that concentrate predators, enhance prey vulnerability, or direct outmigrants away from preferred migration routes (Brown et al. 1996; Tucker et al. 1998; Kimmer and Brown 2006; SJRGA 2011). Nevertheless, consistent with broadly recommended restoration strategies in the literature (see Appendix C), a number of studies in Central Valley streams have shown that higher, more variable flows that mimic the natural flow regime to which native fish communities are adapted can effectively limit the success of nonnative fish species, including a number of warmwater species that are predators of juvenile salmonids (EA 1992; McBain & Trush 2000; Brown and Ford 2002; Kiernan et al. 2012).

Predation-related impacts are qualitatively evaluated based on the potential for the LSJR alternatives to modify environmental conditions in the three eastside tributaries that influence predator success or the vulnerability of prey species such as Chinook salmon as steelhead.
This assessment is based on potential changes in predator-prey interactions that could result

from altered flow and temperature conditions. Thus, results from Impact AQUA-3 and Impact AQUA-4 are incorporated in the evaluation, where appropriate.

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, changes in habitat availability and water temperatures (described in the Impact AQUA-3 and Impact AQUA-4 discussions) during the Chinook salmon and steelhead rearing and outmigration periods in the Stanislaus, Tuolumne, and Merced Rivers would not result in significant impacts on these species. Therefore, no negative substantial changes are likely to occur in predator populations or the habitat conditions affecting vulnerability of Chinook salmon and steelhead juveniles to predation in the three eastside tributaries. Adverse impacts would be less than significant.

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, increases in spring flows and decreases in water temperature in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR are expected to improve rearing and outmigration conditions for juvenile salmon and steelhead. These conditions are expected to potentially enhance the growth and development of the juveniles and reduce the severity of temperature-related stresses that could increase their vulnerability to predators. Higher flows and cooler water temperatures are also expected to benefit juvenile salmon and steelhead by limiting the distribution and abundance of largemouth bass and other nonnative species, which typically favor lower flows and warmer temperatures, and currently contribute to high mortality rates of juvenile salmon in the lower reaches of these tributaries (see Impact AQUA-3, LSJR Alternative 3). Flows and temperatures in the three eastside tributaries are not expected to decrease substantially in the summer and, therefore, would not affect summer habitat conditions that support predator populations under baseline conditions. Adverse impacts would be less than significant.

LSJR Alternative 4 (Less than significant)

LSJR Alternative 4 is expected to further improve spring habitat conditions supporting juvenile Chinook salmon and steelhead rearing and outmigration (relative to LSJR Alternative 3), and reduce predation impacts by warmwater fishes as described above. Flows and temperatures in the three eastside tributaries are not expected to decrease substantially in the summer and, therefore, would not change summer habitat conditions that support predator populations under baseline conditions. Adverse impacts would be less than significant.

Impact AQUA-11: Changes in disease risk resulting from changes in water temperature

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative technical analysis.

LSJR Alternatives

Disease impacts fish populations by directly increasing mortality or indirectly increasing mortality by adversely affecting the ability of fish to evade predators or perform other essential behaviors such as feeding, swimming, and defending territories (McCullough 1999). Chinook salmon are susceptible to a variety of diseases, many of which have specific temperature requirements. Certain freshwater diseases are known to be more prevalent in cold water. The mycobacterium *Cytophaga psychrophila* produces disease in salmonids at temperatures of 41°F–50°F, and infectious hematopoietic necrosis (IHN) is a viral disease that is most common at 46.4°F–50°F. BKD has been shown to have optimum temperatures for infection below 59°F (McCullough 1999).

While certain diseases are more prevalent in cold water, most of the more significant diseases afflicting LSJR Chinook salmon increase in virulence as temperature increases. For example, water temperatures greater than 56°F favor the bacterial diseases columnaris and furunculosis, while temperatures greater than 65°F favor the protozoan *Ichthyophthirosis* (Boles et al. 1988). Vibrio is caused by the marine bacterium *Vibrio anguillarum* and produces a hemorrhagic septicemia that has optimum growth conditions in waters above 59°F (McCullough 1999). Most warmwater diseases begin to become serious threats above 59°F, and temperatures in the range of 55°F–59°F appear to be least problematic for salmonids in resisting both cold- and warmwater diseases (McCullough 1999). Steelhead are assumed to be susceptible to the same diseases as Chinook salmon. Although very little information exists to quantify changes in infection levels and mortality rates attributable to these diseases, steelhead are probably more susceptible to diseases in freshwater habitats than Chinook salmon. Because steelhead rear in riverine and estuarine habitats for 1–3 years, compared to the 3- to 7-month rearing period of fall-run Chinook salmon, the exposure to disease or disease carrying organisms in these habitats is increased. This is especially true during summer months when flows are lower and temperatures are higher for steelhead. For this impact assessment, the effects of disease on Chinook salmon are assumed to have similar effects on steelhead and to be generally representative of effects on aquatic resources.

Impacts of disease on Chinook salmon and steelhead are assessed by evaluating potential changes in exposure of juvenile salmonids to water temperatures and that could increase physiological stress and susceptibility to disease. To address temperature-related effects, this assessment focuses on daily water temperatures during the warmest months of the year (March–October) at the mouth of each eastside tributary and in the SJR at Vernalis to determine changes in the percent of time that water temperatures could exceed 59°F under baseline conditions and LSJR Alternatives 2, 3, and 4 (Tables 7-27a, 7-27b, 7-27c, and 7-27d). A 10 percent change in the frequency of modeled average daily water temperatures exceeding this threshold was used to determine the potential for increased disease risk.

Table 7-27a. Percent of Time that the 59°F Threshold in the Stanislaus River at the Confluence is Exceeded

Stanislaus – Confluence	March	April	May	June	July	August	September	October
Baseline	16	28	60	95	97	99	93	55
LSJR Alternative 2	17	30	64	94	97	98	92	51
LSJR Alternative 3	10	26	51	91	97	99	96	44
LSJR Alternative 4	4	15	36	79	99	100	97	47

Table 7-27b. Percent Time that the 59°F Threshold in the Tuolumne River at the Confluence is Exceeded

Tuolumne – Confluence	March	April	May	June	July	August	September	October
Baseline	37	55	84	95	100	100	99	92
LSJR Alternative 2	32	55	81	96	100	100	99	93
LSJR Alternative 3	23	35	56	93	100	100	99	91
LSJR Alternative 4	11	15	44	88	100	100	99	91

Table 7-27c. Percent Time the 59°F Threshold in the Merced River at the Confluence is Exceeded

Merced – Confluence	March	April	May	June	July	August	September	October
Baseline	40	84	91	95	100	100	100	95
LSJR Alternative 2	41	84	91	96	100	100	100	95
LSJR Alternative 3	36	74	85	96	100	100	100	94
LSJR Alternative 4	24	56	72	96	100	100	100	94

Table 7-27d. Percent Time that the 59°F Threshold in the SJR at Vernalis is Exceeded

SJR – Vernalis	March	April	May	June	July	August	September	October
Baseline	31	73	98	100	100	100	100	89
LSJR Alternative 2	32	74	98	100	100	100	100	88
LSJR Alternative 3	27	70	95	100	100	100	100	87
LSJR Alternative 4	17	55	88	100	100	100	100	88

LSJR Alternative 2 (Less than significant)

Under LSJR Alternative 2, no substantial changes are predicted to occur in the frequency of average daily water temperatures exceeding the 59°F threshold at the confluences of the Stanislaus, Tuolumne, and Merced Rivers and in the LSJR relative to baseline conditions (Tables 7-27a, 7-27b, 7-27c, and 7-27d). Therefore, the risk of disease associated with exposure of juveniles to water temperatures exceeding 59°F would be similar to that under baseline conditions. Adverse impacts would be less than significant.

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, the frequency of spring water temperatures exceeding the 59°F threshold would decrease in all three tributaries and in the LSJR, ranging from less than 5 percent decrease in the SJR at Vernalis to nearly a 30 percent decrease in the Tuolumne River (Table 7-27a, 7-27b, 7-27c, and 7-27d). No substantial changes are predicted to occur in the frequency of water temperatures exceeding 59°F during the summer and fall (July–October) although some improvement (-11 percent) is expected in the Stanislaus River in October. Therefore, the risk of disease associated with exposure of juveniles to water temperatures exceeding 59°F during the spring rearing and outmigration would be reduced compared to baseline conditions. Adverse impacts would be less than significant.

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, the frequency of water temperatures exceeding the 59°F threshold would decrease by approximately 10–40 percent in March, April, and May at the mouths of the three tributaries and in the SJR at Vernalis relative to baseline conditions (Tables 7-27a, 7-27b, 7-27c, and 7-27d). Reduced exposure of juvenile salmonids to these water temperatures could extend into June in the Stanislaus and Tuolumne Rivers. Little or no change is predicted to occur in the frequency of water temperatures exceeding 59°F during summer and fall (June–October). Therefore, exposure of juvenile salmonids to water temperatures associated with increased disease risk in the Stanislaus, Tuolumne, and Merced Rivers, and LSJR would be substantially reduced during the spring rearing and outmigration period. Adverse impacts would be less than significant.

Impact AQUA-12: Changes in southern Delta and estuarine habitat resulting from changes in SJR inflows and export effects

No Project Alternative (LSJR/SDWQ Alternative 1)

The No Project Alternative would result in implementation of flow objectives identified in the 2006 Bay-Delta Plan. See Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1),* for the No Project Alternative impact discussion and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1)*, for the No Project Alternative technical analysis.

LSJR Alternatives

Alteration of timing and magnitude of freshwater inflows in combination with export pumping has substantially altered flow patterns in the Delta, resulting in both direct losses of fish through entrainment at the CVP and SWP export facilities, and indirect losses through changes in survival associated with altered migration patterns and habitat quality. Estuarine fishes such as delta smelt are particularly sensitive to these alterations, especially in years when spawning takes place in the southern and central Delta where a large proportion of the population (adults, larvae, and juveniles) may be subject to entrainment. Although capable of directed swimming, juvenile salmonids may also be adversely affected by altered hydrodynamics associated with low flows and relatively high rates of export pumping that result in net flows toward the pumps. These changes can also affect the magnitude of Delta outflow and the position of the low salinity zone (measured by X2), which have been shown to be correlated with the distribution and abundance of a number of estuarine fishes and their food resources.

This assessment examines potential changes in fish entrainment risk and estuarine habitat conditions resulting from changes in SJR inflows and export pumping under LSJR Alternatives 2, 3, and 4, as compared to baseline conditions. As described in Appendix F.1, *Hydrologic and Water Quality Modeling,* Section F.1.2, *Water Supply Effects Modeling—Methods*, the WSE model does not include the Delta. Therefore, potential changes in export pumping and outflow were approximated based on changes in modeled monthly flows in the SJR at Vernalis and application of a number of federal and state rules or objectives currently governing Delta operations (Table F.1.7-1 in Appendix F.1). These rules or objectives include monthly restrictions on export pumping rates, export to inflow ratios, and negative flows in Old and Middle River (OMR) to minimize the risk of entrainment and improve net downstream flows during the primary spawning and early rearing period of delta smelt (December–June) and the primary smolt migration period for SJR Chinook salmon and steelhead (April–May). Although this approach does not fully represent the complexities of Delta water management operations, it was considered a reasonable approach for assessing the relative magnitude of potential changes in fish entrainment and estuarine habitat conditions associated with the LSJR alternatives.

LSJR Alternative 2 (Less than significant)

Based on the WSE modeling results and application of several rules and objectives currently governing Delta operations (see Appendix F.1, *Hydrologic and Water Quality Modeling*), LSJR Alternative 2 is not expected to substantially change export pumping rates relative to baseline conditions. Average pumping rates in December–June when juvenile salmonids and other Delta fish species are most likely to be exposed to potential entrainment effects would be similar to baseline levels in December–May and increase by 216 cfs in June (Table F.1.7-3E). These changes represent less than 5 percent of average SJR flows and therefore would have very small effects on Delta outflow and the position of X2. Although increased export pumping in June represents a potential increase in entrainment risk for larval and juvenile fish, concurrent increases in spring SJR flows (averaging +468 cfs in May and +431 cfs in June) and Delta outflow (averaging +433 cfs in May and +216 cfs in June) (Table F.1-.7-3D and Table F.1.7-3F) represent positive effects on larval/juvenile transport and estuarine habitat conditions. In addition, continued compliance with current restrictions on export pumping rates, export to inflow ratios, and OMR flows would be expected to minimize potential impacts on juvenile salmonids and other Delta fish species during these months. Therefore, potential adverse impacts resulting from changes in Delta operations on fish entrainment and estuarine habitat conditions under LSJR Alternative 2 would be less than significant.

LSJR Alternative 3 (Less than significant)

Under LSJR Alternative 3, average pumping rates in December–June when juvenile salmonids and other Delta fish species are most likely to be exposed to potential entrainment effects would be expected to decrease in December–March (-8 to -147 cfs) and increase in April–June (+50 to +801 cfs) relative to baseline conditions (Table F.1.7-4B). Although increased export pumping in April–June represents a potential increase in entrainment risk for larval and juvenile fish, concurrent increases in spring SJR flows (averaging +810 to +2,400 cfs) and Delta outflow (averaging +761 to +2,102 cfs) (Table F.1.7-4A and Table F.1.7-4C) represent positive effects on larval/juvenile transport and estuarine habitat conditions. In addition, continued compliance with current restrictions on export pumping rates, inflow/export ratios, and OMR flows would be expected to minimize potential impacts on juvenile salmonids and other Delta fish species during these months. Therefore, potential adverse impacts resulting from changes in Delta operations on fish entrainment and estuarine habitat conditions under LSJR Alternative 3 would be less than significant.

LSJR Alternative 4 (Less than significant)

Under LSJR Alternative 4, average pumping rates in December–June when juvenile salmonids and other Delta fish species are most likely to be exposed to potential entrainment effects would be expected to decrease in December and January (-135 cfs and -217 cfs) and increase in February–June (+252 to +1,766 cfs) relative to baseline conditions (Table F.1.7-5B). Although increased export pumping in February–June represents a potential increase in entrainment risk for larval and juvenile fish, concurrent increases in spring SJR flows (averaging +586 to 5,149 cfs) and Delta outflow (averaging +293 to 4,260 cfs) (Table F.1.7-5A and Table F.1.7-5C) represent positive effects on larval/juvenile transport and estuarine habitat conditions. In addition, continued compliance with current restrictions on export pumping rates, inflow/export ratios, and OMR flows would be expected to minimize potential impacts on juvenile salmonids and other Delta fish species during these months. Therefore, impacts resulting from changes in Delta operations on fish entrainment and estuarine habitat conditions under LSJR Alternative 4 would not be adverse and would be less than significant.

7.4.4 Impacts and Mitigation Measures: Extended Plan Area

Bypassing flows in the extended plan area, as described in Chapter 5, *Surface Hydrology and Water Quality*, could potentially impact aquatic biological resources in upstream reservoirs on the Stanislaus and Tuolumne Rivers differently in the extended plan area than described in the plan area. The upstream reservoirs on the Stanislaus and Tuolumne Rivers may experience substantial changes in reservoir volume, which are not experienced by the rim reservoirs in the plan area, especially under drought conditions under LSJR Alternative 3 and LSJR Alternative 4 with or without adaptive implementation. This different potential impact occurs because reservoirs in the extended plan area reservoirs are smaller than the downstream rim reservoirs, which could magnify individual changes. Furthermore, required bypass flows may reduce opportunity for these reservoirs to refill once they are drawn down. Reservoir drawdown could reduce the area and volume of water available for in-reservoir aquatic habitat affecting aquatic species including fish. In addition, water temperature in the upstream reservoirs could increase due to lower storage. As a result, the temperature of the water entering the rim dam reservoirs could increase, although an increase in volume of the rim reservoirs resulting from bypassed upstream flows could help maintain cool temperatures in these reservoirs.

Under LSJR Alternative 2 with adaptive implementation or LSJR Alternative 3 with or without adaptive implementation, the type and scale of impacts on aquatic species during individual reservoir drawdown events would be similar to what is experienced during baseline reservoir operations (USGS Reservoir Gage Data). Additionally, these reservoirs might refill during the subsequent wet season, limiting the duration of reduced reservoir elevations if no water supply shortage is forecast for the upcoming year. In the most extreme cases, during drought years and years with substantial increases in bypass flows in the extended plan area particularly under LSJR Alternative 3 and LSJR Alternative 4 with or without adaptive implementation, some reservoirs might be drawn down more quickly, to lower levels, and for longer periods of time than under baseline conditions. If these conditions occurred there would be an adverse impact on aquatic species because the reservoir habitat would be greatly reduced when compared to baseline conditions.

Changes in river flows on the Stanislaus, Tuolumne, and Merced Rivers as described in Chapter 5, *Surface Hydrology and Water Quality*, would result in similar impacts on aquatic resources described for the plan area. An increase in flow would not result in adverse impacts on aquatic species. However, flows in the extended plan area could decrease in the fall relative to baseline under the LSJR alternatives with or without adaptive implementation; such an outcome is not anticipated in the plan area. This could result in reduced habitat for aquatic species. In addition, during drought conditions, particularlyunder LSJR Alternative 3 and LSJR Alternative 4 with or without adaptive implementation, substantial reservoir volume reductions could occur. Under these conditions there is potential for warmer water to be released from reservoirs, which would adversely impact downstream water temperature and aquatic resources. Furthermore, if low reservoir volumes result in low reservoir carryover volumes, these temperature impacts could be increased.

The increased frequency of lower reservoir levels and potential reduction in river flow in the fall resulting from the LSJR alternatives, however, would be limited by the program of implementation under each of the LSJR alternatives. The program of implementation requires minimum reservoir carryover storage targets or other requirements to help ensure that providing flows to meet the flow objectives will not have adverse temperature or other impacts on fish and wildlife or, if feasible, on other beneficial uses. Other requirements, for example, include, but are not limited to, limits on required bypass flows for reservoirs that store water only for nonconsumptive use so that some water can be temporarily stored upstream. The program of implementation also states that the State Water Board will take actions as necessary to ensure that implementation of the flow objectives does not impact supplies of water for minimum health and safety needs, particularly during drought periods. Accordingly, when the State Water Board implements the flow objectives in a water right proceeding, it will consider impacts on fish, wildlife, and other beneficial uses and health and safety needs, along with water right priority. Until the State Water Board assigns responsibility to meet the flow objectives in the Bay-Delta Plan, it is speculative to identify the exact extent, scope, and frequency of reduced diversions, reduced reservoir levels and their effects on fish, in the extended plan area. When implementing the flow objectives, the State Water Board would identify project-specific impacts and avoid or mitigate, to the extent feasible, significant impacts of lower reservoir levels on aquatic species habitat and temperatures in accordance with CEQA.

At the time of preparation of this programmatic analysis, it is unclear to what extent any significant impacts could be fully mitigated to aquatic species due to a reduction in reservoir storage. Thus, the potential exists for significant impacts. Therefore, this analysis conservatively concludes that impacts associated with lower reservoir levels under LSJR Alternative 2 with adaptive implementation and LSJR Alternatives 3 and 4 with or without adaptive implementation are significant. The following mitigation measure is proposed: when considering carryover storage and other requirements to implement the flow water quality objectives in a water right proceeding, the State Water Board shall ensure that reservoir levels upstream of the rim dams do not cause significant fish and wildlife impacts, unless doing so would be inconsistent with applicable laws. The impact is considered significant, even with mitigation, because the mitigation may not fully mitigate the impact in all situations.

7.5 Cumulative Impacts

For the cumulative impact analysis, refer to Chapter 17, *Cumulative Impacts, Growth-Inducing Effects, and Irreversible Commitment of Resources.*

7.6 References Cited

Adams, P. B., C. B. Grimes, J. E. Hightower, S. T. Lindley, and M. L. Moser. 2002. *2002 Status Review for North American Green Sturgeon (*Acipenser medirostris*).* National Marine Fisheries Service. 58 pp.

Ahearn, D. S., J. H. Viers, J. F. Mount, and R. A. Dahlgren. 2006. Priming the productivity pump: flood pulse driven trends in suspended algal biomass distribution across a restored floodplain. *Freshwater Biology* 51(8):1417–1433.

Allen, P. J., J. J. Cech Jr., and D. Kültz. 2009. Mechanisms of seawater acclimation in a primitive, anadromous fish, the green sturgeon. *Journal of Comparative Physiology* 179(7):903–920.

Alley, D. W., and H. W. Li. 1977. Significance of Microhabitat Selection for Fishes in a Sierra Foothill Stream. *California-Nevada Wildlife Transactions* 13:2–33.

Bash, J., C. Berman, and S. Bolton. 2001. *Effects of turbidity and suspended solids on salmonids*. Center for Streamside Studies, University of Washington, Seattle.

Baskerville-Bridges, B., J. C. Lindberg, and S. I. Doroshov. 2004. The Effect of Light Intensity, Alga Concentration, and Prey Density on the Feeding Behavior of Delta Smelt Larvae. *American Fisheries Society Symposium* 39:219–227.

Baxter, R. 1999a. Chapter 9: Osmeridae. In Orsi, J. J. 1999. *Report on the 1980–1995 Fish, Shrimp, and Crab Sampling in the San Francisco Estuary, California*.

Baxter, R. 1999b. *California Fish and Game: Status of Splittail in California*. 85(1):28-30.

Baxter, R. 2000. *IEP Newsletter: Splittail Investigations*. 13(2):5-6.

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. *Pelagic Organism Decline Progress Report: 2007 Synthesis of Results.*

Baxter, R., M. L. Nobriga, S. B. Slater, and R. W. Fujimura. 2009. *2009 Effects Analysis: State Water Project Effects on Longfin Smelt*.

Beamesderfer, R. C. P., M. Simpson, G. Kopp, J. Inman, A. Fuller, and D. Demko. 2004. *Historical and Current Information on Green Sturgeon Occurrence in the Sacramento and San Joaquin Rivers and Tributaries.* Oakdale, CA. Prepared for State Water Contractors, Sacramento, CA. 46 pp.

Beamesderfer, R. C. P., G. Kopp, and D. Demko. 2005. *Review of the Distribution, Life History and Population Dynamics of Green Sturgeon with Reference to California's Central Valley*. Gresham, OR and Oakdale, CA. 39 pp.

Becker C. D., D. A. Neitzel, and D. H. Fickeisen. 1982. Effects of Dewatering on Chinook Salmon Redds: Tolerance of Four Developmental Phases to Daily Dewaterings. *Transactions of the American Fisheries Society* 111:624–637.

Beer, K. E. 1981. *Embryonic and Larval Development of White Sturgeon (*Acipenser transmontanus*).* Davis, CA. 96 pp.

Bennett, W. A., W. J. Kimmerer, and J. R. Burau. 2002. Plasticity in vertical migration by native and exotic estuarine fishes in a dynamic Low-Salinity Zone. *Limnology and Oceanography* 47(5):1496–1507.

Bennett, W. A. 2005. Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California. *San Francisco Estuary and Watershed Science* 3(2):1–71.

Boles, G. L., S. M. Turek, C. D. Maxwell, and D. M. McGill. 1988. *Water temperature effects on Chinook salmon (*Oncorhynchus tshawytscha*) with emphasis on the Sacramento River: a literature review*. Report to the California Department of Water Resources, Northern District. 43 pp.

Bonneville Power Administration (BPA). 2010. *Predator control helps salmon*. Available: https://www.bpa.gov/news/pubs/GeneralPublications/fish-Predator%20control%20helps%20salmon.pdf.

Bovee, K. D., L. L. Lamb, J. M. Bartholow, C. B. Stalnaker, J. Taylor, and J. Henriksen. 1998. *Stream Habitat Analysis Using the Instream Flow Incremental Methodology.* U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD-1998-0004. viii: 131 pp.

Bowen, M. D., M. Gard, R. Hilldale, K. Zehfuss, and R. Sutton. 2012. *Stanislaus River Discharge-Habitat Relationships for Rearing Salmonids*. Prepared for Central California Area Office, Bureau of Reclamation, Folsom, California. Pgs.

Brooks, M. L., E. Fleishman, L. R. Brown, P. W. Lehman, I. Werner, N. Scholz, C. Michelmore, J. R. Lovvorn, M. L. Johnson, D. Schlenk, S. van Drunick, J. I. Drever, D. M. Stoms, A. E. Parker, and R. Dugdale. 2012. Life Histories, Salinity Zones, and Sublethal Contributions of Contaminants to Pelagic Fish Declines Illustrated with a Case Study of San Francisco Estuary, California, USA. *Estuaries and Coasts* 35(2):603–621.

Brown, L. R. and P. B. Moyle. 1993. Distribution, Ecology, and Status of the Fishes of the San Joaquin River Drainage, California. *California Fish and Game* 79(3):96–114.

Brown, L. R., S. Greene, P. Coulston, and S. Barrow. 1996. *An evaluation of the effectiveness of fish salvage operations at the intake to the California Aqueduct, 1979–1993.* As cited in: J. T. Hollibaugh, editor. 1996. *San Francisco Bay: the Ecosystem*. American Association for the Advancement of Science, Pacific Division. San Francisco, CA. 497–518 pp.

Brown, L. R. 2000. Fish communities and their associations with environmental variables, lower San Joaquin River drainage, California. *Environmental Biology of Fishes* 57(3):251–269.

Brown, L. R., and T. Ford. 2002. Effect of Flow on the Fish Communities of a Regulated California River: Implications for Managing Native Fishes. *River Research and Applications* 18(4):331–342.

Brown, L. R., and J. T. May. 2006. Variation in Spring Nearshore Resident Fish Species Composition and Life Histories in the Lower Sacramento–San Joaquin Watershed and Delta. *San Francisco Estuary and Watershed Science* 4(2):1–15.

Calaveras County General Plan. 1996. *Conservation Element*. Calaveras, CA. 28 pp.

CALFED. 2009. *San Joaquin River Basin Water Temperature Modeling and Analysis.* Prepared for CALFED ERP-06D-S20. Prepared by AD Consultants, Resource Management Associates, Inc. and

Watercourse Engineering, Inc. Available: http://www.rmanet.com/CalFed_Sep09/%20SJRTempModelReport_09.pdf.

California Department of Fish and Game (CDFG). 1992a. *Impact of water management on splittail in the Sacramento–San Joaquin Estuary.* State Water Resources Control Board Hearing for setting interim standards for the Delta. WRINT-DFG-Exhibit 5. 7 pp.

———. 1998. *A Status Review of the Spring-Run Chinook Salmon* (Oncorhyncus tshawytscha) *in the Sacramento River Drainage*.

———. 2001. *California's Living Marine Resources: A Status Report*. Prepared by The Resources Agency of The California Department of Fish and Game.

———. 2002. *Status Review of California Coho Salmon North of San Francisco*. Candidate Species Status Review Report. Prepared by California Department of Fish and Game. 336 pp.

———. 2005. *San Joaquin River Fall-Run Chinook Salmon Population Model.* San Joaquin Valley Southern Sierra Region. November 28. 87 pp.

———. 2007. *Evaluation of Petition: Request by Bay Institute, Center for Biological Diversity, and Natural Resources Defense Council to list the longfin smelt (*Spirinchus thaleichthys*) as threatened or endangered under the California Endangered Species Act*. November 16.

———. 2010. *California Department of Fish and Game Flows Needed in the Delta to Restore Anadromous Salmonid Passage from the San Joaquin River at Vernalis to Chipps Island*. Available: http://www.waterboards.ca.gov/waterrights/water_issues/ programs/bay_delta/deltaflow/docs/exhibits/dfg/dfg_exh3.pdf.

———. 2011a. *A Report to the California Fish and Game Commission on Stressors Impacting Delta Related Organisms*.

———. 2011b. *GrandTab: Fisheries Branch Anadromous Assessment. California Central Valley Sacramento and San Joaquin River Systems Chinook Salmon Escapement: Hatcheries and Natural Areas*. ~~GrandTab~~Available: http://www.dfg.ca.gov/fish/Resources/Chinook/CValleyAssessment.asp.

California Department of Fish and Wildlife (CDFW). ~~———.~~2015.~~Unpublished data.~~ *GrandTab:*~~California Central Valley Chinook Population Database Report. Compiled April 15, 2015.~~ *Fisheries Branch Anadromous Resources Assessment~~,~~ California Central Valley~~,~~ Sacramento and San Joaquin River Systems~~,~~ Chinook Salmon Escapement: Hatcheries and Natural Areas*. ~~Compiled by Jason Azat.~~ April. Available: http://www.dfg.ca.gov/fish/Resources/Chinook/CValleyAssessment.asp.

———2016a. *GrandTab: Fisheries Branch Anadromous Resources Assessment California Central Valley Sacramento and San Joaquin River Systems Chinook Salmon Escapement Hatcheries and Natural Areas.* ~~Unpublished data. GrandTab.~~April. Available: http://www.dfg.ca.gov/fish/Resources/Chinook/CValleyAssessment.asp.~~http://www.calfish.org/tabid/104/Default.aspx.~~

———. 2016b. *Fish Species Information and Conservation Efforts*. Available: https://www.wildlife.ca.gov/Conservation/Fishes. Accessed: July 26, 2016.

California Fish and Game Commission. 2009. *California fish and game commission notice of findings: longfin smelt* (Spirinchus Thaleichthys). Meeting: Woodland California, May 29.

California Sportfishing Protection Alliance (CSPA) and California Water Impact Network (CWIN). 2010. *Comments on the Presentation and Discussion of Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*.

Cbec, Inc. 2010. *Floodplain Inundation Mapping, Appendix 4. San Joaquin River Technical Support*. Prepared for FishBio. 25 pp.

Cech, J. J. Jr., S. J. Mitchell, D. T. Castleberry, and M. McEnroe. 1990. Distribution of California stream fishes: influence of environmental temperature and hypoxia. *Environmental Biology of Fishes* 29(2):95–105.

Cech, J. J. Jr., S. L. Doroshov, G. P. Moberg, B. P. May, R. G. Schaffter, and D. M. Kohlhorst. 2000. *Biological Assessment of Green Sturgeon in the Sacramento-San Joaquin Watershed (Phase 1). Temperature Effects on Green Sturgeon Bioenergetics*. Final Report to the CALFED Bay-Delta Program, Davis, CA. 74 pp.

Coloway, C., and D. E. Stevenson. 2007. Confirmed Record of Two Green Sturgeon from the Bering Sea and Gulf of Alaska. *Northwestern Naturalist* 88(3):188–192.

County of San Joaquin. 2000. *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan*. Available: http://www.sjcog.org/programs-projects/Habitat_files/The-Plan.htm. Accessed: August 28, 2012.

———. 2012. *San Joaquin County General Plan Update*. Last revised: October 9, 2013. Available: http://sjcgpu.com/docs.html#Policy. Accessed: June 2, 2016.

Cramer Fish Sciences (CFS). 2007a. *Upstream Fish Passage at a Resistance Board Weir Using Infrared and Digital Technology in the Lower Stanislaus River, California: 2006-2007 Annual Data Report.* Auburn, CA. Prepared for U.S. Fish and Wildlife Service.

Dauble, D., D. Hankin, J. J. Pizzimenti, and P. Smith. 2010. *The Vernalis Management Program (VAMP): Report of the 2010 Review Panel*. Prepared for the Delta Science Program.

De Robertis, A., C. H. Ryer, A. Veloza, R. D. Brodeur. 2003. Differential Effects of Turbidity on Prey Consumption of Piscivorous and Planktivorous Fish. *Canadian Journal of Fisheries and Aquatic Science* 60(12):1517–1526.

DeVries, P. 1997. Riverine Salmonid Egg Burial Depths: Review of Published Data and Implications for Scour Studies. *Canadian Journal of Fisheries and Aquatic Sciences* 54(8):1685–1698.

Dill, W. A., and A. J. Cordone. 1997. *CDFG Fish Bulletin 178 – History and Status of Introduced Fishes in California, 1871-1996.* 414 pp.

Don Pedro Lake. 2012. *Fishing*. Available: http://donpedrolake.com/RecreationArea/Fishing/index.htm. Accessed: November 13.

DuBois, J., M. Gingras, and R. Mayfield. 2009. *2008 Sturgeon Fishing Report Card: Preliminary Data Report*. Draft. Stockton, CA. Prepared by the California Department of Fish and Game.

DuBois, J., T. Matt, and B. Beckett. 2010. *2009 Sturgeon Fishing Report Card: Preliminary Data Report*. Stockton, CA. Prepared by the California Department of Fish and Game.

DuBois, J., T. Matt, and T. MacColl. 2011. *2010 Sturgeon Fishing Report Card: Preliminary Data Report*. Stockton, CA. Prepared by the California Department of Fish and Game.

DuBois, J., T. MacColl, and E. Haydt. 2012. *2011 Sturgeon Fishing Report Card: Preliminary Data Report*. Stockton, CA. Prepared by the California Department of Fish and Game.

EA Engineering, Science, and Technology, Inc. (EA EST). 1992. *Lower Tuolumne River Predation Study Report, Appendix 22*. Lafayette, CA. Prepared for Turlock Irrigation District, Turlock, CA and Modesto Irrigation District, Modesto, CA.

———. 1999. *Meeting Flow Objectives for the San Joaquin River Agreement 1999-2010. Environmental Impact Statement and Environmental Impact Report*. Available: http://www.sjrg.org/EIR/contents.htm.

Emmett, R. L., S. A. Hinton, S. L., Stone, and M. E. Monaco. 1991. *Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries, Volume 2: Species Life History Summaries*. Rockville, MD. NOAA/NOS Strategic Environmental Assessments Division Estuarine Living Marine Resources Program Report 8. 329 pp.

Farley, T. C. 1966. Striped Bass, Roccus saxatilis, Spawning in the Sacramento-San Joaquin River Systems during 1963 and 1964. Pages 28–43 in J. L. Turner and D. W. Kelley (editors). 2011. *Fish Bulletin 136 – Ecological Studies of the Sacramento–San Joaquin Delta, part II*. Available: http://content.cdlib.org/view?docId=kt8h4nb2t8;NAAN=13030&doc.view=frames&chunk.id=d0e646&toc.depth=1&toc.id=d0e646&brand=calisphere.

Ferrari, M. C. O., L. Ranaker, K. L. Weinersmith, M. J. Young, A. Sih, and J. L. Conrad. 2013. Effects of turbidity and an invasive waterweed on predation by introduced largemouth bass. *Environmental Biology of Fishes* 97(1):79–90.

Feyrer, F., and M. P. Healey. 2003. Fish Community Structure and Environmental Correlates in the Highly Altered Southern Sacramento–San Joaquin Delta. *Environmental Biology of Fishes* 66(2):123–132.

Feyrer, F. 2004. Ecological Segregation of Native and Alien Larval Fish Assemblages in the Southern Sacramento–San Joaquin Delta. *American Fisheries Society* 39:67–79.

Feyrer, F., M. L. Nobriga, and T. R. Sommer. 2007. Multidecadal Trends for Three Declining Fish Species: Habitat Patterns and Mechanisms in the San Francisco Estuary, California, USA. *Canadian Journal of Fisheries and Aquatic Sciences* 64(4):723–734.

———. 2011. Modeling the effects of future outflow on the abiotic habitat of an imperiled estuarine fish. *Estuaries and Coasts* 34(1):120–128.

FishBio. 2013. *Pilot study: the feasibility of using fyke traps in the lower San Joaquin River to capture adult striped bass*. Prepared by S. Ainsley, J. Pombo, T. Wright, and E. Loury, Oakdale, CA.

———. 2017. Learning from carcasses and final fish counts. The Fish Report. Monday, January 23, 2017. Available: http://fishbio.com/field-notes/the-fish-report/learning-carcasses-final-fish-counts. Accessed: August 23, 2017.

Foott, J. S. and R. Fogerty. 2011. *FY 2011 Technical Report: juvenile Stanisalus River Chinook salmon pathogen and physiology assessemtn: January-May 2011*. U. S. Fish & Wildlife Service California – Nevada Fish Helath Center, Anderson, CA. Available:

https://www.fws.gov/lodi/anadromous_fish_restoration/documents/STAN11%20REPORT%207-14%20final.pdf. Accessed: August 28, 2017.

Foott, J. S., R. Stone, and K. Nichols. 2007. Proliferative Kidney Disease (*Tetracapsuloides bryosalmonae*) in Merced River Hatchery Juvenile Chinook Salmon: Mortality and Performance Impairment in 2005 Smolts*. California Fish and Game* 93(2):57–76.

Geist, D. R., T. P. Hanrahan, E. V. Arntzen, G.A. McMichael, C. J. Murray, and Y. J. Chien. 2001. *Pacific Northwest National Laboratory, Physicochemical characteristics of the hyporheic zone affect redd site selection of chum and fall Chinook salmon, Columbia River, 2001*. BPA Report DOE/BP-00000652-5. 26 pp.

Gleason, E., M. Gingras, and J. DuBois. 2008. *2007 Sturgeon Fishing Report Card: Preliminary Data Report*. Prepared by California Department of Fish and Game, Stockton, CA.

Good, T. P., R. S. Waples, and P. Adams. 2005. *Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead*. June. NOAA Technical Memorandum NMFS-NWFSC-66.

Grant, G. C., and P. E. Maslin. 1999. Movements and Reproduction of Hardhead and Sacramento Squawfish in a Small California Stream. *Southwest Association of Naturalists* 44(3):296–310.

Greene, S. 2009. Central Valley Chinook Salmon Catch and Escapement. *IEP Newsletter* 22(3):9–12.

Gregory, R. S., and C. D. Levings. 1998. Turbidity Reduces Predation on Migrating Juvenile Pacific Salmon. *Transactions of the American Fisheries Society* 127(2):275–285.

Grossman, G. D., T. Essington, B. Johnson, J. Miller, N. E. Monsen, and T. N. Pearsons. 2013. *Effects of Predation on Salmonids in the Sacramento River-San Joaquin Delta and Associated Ecosystems*. Report to establish conclusions regarding the importance of predation on salmonids in the Delta. 71 pp.

Hallock, R. J. 1989. *Upper Sacramento River Steelhead (*Oncorhynchus mykiss*), 1952–1988*. Report to the U.S. Fish and Wildlife Service. 85 pp.

Henley, W. F., M. A. Patterson, R. J. Neves, and A. D. Lemly. 2000. Effects of Sedimentation and Turbidity on Lotic Food Webs: A Concise Review for Natural Resource Managers. *Reviews in Fisheries Science* 8(2):125–139.

Herren, J. R., and S. S. Kawasaki. 2001. Inventory of Water Diversions in Four Geographic Areas in California's Central Valley. Pages 343–354 in R. L. Brown. *Fish Bulletin 179 – Contributions to the Biology of Central Valley Salmonids, Volume 2 of 2*.

Heublein, J. C., J. T. Kelly, C. E. Crocker, A. P. Klimley, and S. T. Lindley. 2006. Migration of green sturgeon, *Acipenser medirostris*, in the Sacramento River. *Environmental Biology of Fishes* 84(3):245–258.

Heugens, E., J. Hendriks, T. Dekker, N. M. van Straalen, and W. Admiraal. 2001. A Review of the Effects of Multiple Stressors on Aquatic Organisms and Analysis of Uncertainty Factors for Use in Risk Assessment. *Critical Reviews in Toxicology* 31(3):247–284.

Hicks, M. 2002. *Evaluating Standards for Protecting Aquatic Life in Washington's Surface Water Quality Standards*. *Temperature Criteria*. Draft discussion paper and literature summary. Washington State Department of Ecology. Publ. No. 00-10-070. Olympia, WA.

Hobbs, J. A., L. S. Lewis, N. Ikemiyagi, T. Sommer, and R. D. Baxter. 2010. The use of otolith strontium isotopes ($^{87}Sr/^{86}Sr$) to identify nursery habitat for a threatened estuarine fish. *Environmental Biology of Fishes* 89(3):557–569.

Hobbs, J. A., W. A. Bennett, and J. Burton. 2007. Classification of larval and adult Delta Smelt to nursery areas by use of trace elemental fingerprinting. *Transactions of the American Fisheries Society* 136(2):518–527.

ICF International. 2012. *Administrative Draft Environmental Impact Report/Environmental Impact Statement for the Bay Delta Conservation Plan (BDCP)*. Chapter 11. Prepared for California Department of Water Resources, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. Available: http://baydeltaconservationplan.com/ Library/DocumentsLandingPage/EIREISDocuments.aspx.

Israel, J. A. and A. P. Klimley. 2008. *Life History Conceptual Model for North American Green Sturgeon (*Acipenser medirostris*)*. Davis, CA.

Israel, J. A., and B. May. 2010. Indirect genetic estimates of breeding population size in the polyploid green sturgeon (*Acipenser medirostris*). *Molecular Ecology* 19(5):1058–1070.

Jackson, Z. J., and J. P. Van Eenennaam. 2013. *2012 San Joaquin River Sturgeon Spawning Survey*. Final Annual Report. Stockton, CA. Prepared by the U.S. Fish and Wildlife Service, Lodi, CA.

Jackson Z.J., J.J. Gruber, and J.P. Van Eenennaam. 2016. White sturgeon spawning in the San Joaquin River, California and effects of water management. *Journal of Fish and Wildlife Management* 7(1):171-180.

Jassby, A. D., W. J. Kimmerer, S. G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J. R. Schubel, and T. J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. *Ecological Applications* 5(1):272–289.

Kelley, J. T., A. P. Klimley, and C. E. Crocker. 2007. Movements of Green Sturgeon, *Acipenser medirostris*, in the San Francisco Bay Estuary, California. *Environmental Biology of Fishes* 79(3):281–295.

Kiernan, J. D., P. B. Moyle, and P. K. Crain. 2012. Restoring native fish assemblages to a regulated California stream using the natural flow regime concept. *Ecological Applications* 22(5):1472–1482.

Kimmerer, W. J. 2002. Physical, Biological, and Management Responses to Variable Freshwater Flow into the San Francisco Estuary. *Estuaries* 25(6):1275–1290.

———. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento–San Joaquin Delta. *San Francisco Estuary and Watershed Science* 6(2):1–27.

Kimmerer, W. J., and R. Brown. 2006. *A Summary of the June 22-23, 2005 Predation Workshop, Including the Expert Panel Final Report*. Prepared for Johnnie Moore, CALFED Lead Scientist.

Kimmerer, W. J., and M. L. Nobriga. 2008. Investigating Particle Transport and Fate in the Sacramento–San Joaquin Delta Using a Particle Tracking Model. *San Francisco Estuary and Watershed Science* 6(1).

Kohlhorst, D. W. 1976. Sturgeon Spawning in the Sacramento River in 1973, as Determined by Distribution of Larvae. *California Fish and Game* 62(1):32–40.

Kondolf, G. M., J. C. Vick, and T. M. Ramirez. 1996. Salmon Spawning Habitat and Rehabilitation on the Merced River, California: An Evaluation of Project Planning and Performance. *Transactions of the American Fisheries Society* 125(6):899–912.

Kondolf, G. M., A. Falzone, and K. S. Schneider. 2001. *Reconnaissance-Level Assessment of Channel Change and Spawning Habitat on the Stanislaus River below Goodwin Dam*. Report to the U.S. Fish and Wildlife Service. 52 pp.

Kurth, R., and M. Nobriga. 2001. Food habits of larval splittail. *IEP Newsletter* 14(3):40–42.

Kynard, B., E. Parker, and T. Parker. 2005. Behavior of early life intervals of Klamath River green sturgeon, *Acipenser medirostris*, with a note on body color. *Environmental Biology of Fishes* 72(1):85–97.

Lehman, P. W., S. J. Teh, G. L. Boyer, M. L. Nobriga, E. Bass, and C. Hogle. 2010. Initial impacts of *Microcystis aeruginosa* blooms on the aquatic food web in the San Francisco Estuary. *Hydrobiologia* 637(1):229–248.

Li, H. W., G. A. Lamberti, T. N. Pearsons, C. K. Tait, J. L. Li, and J. C. Buckhouse. 1994. Cumulative Effects of Riparian Disturbances along High Trout Streams of the John Day Basin, Oregon. *Transactions of the American Fisheries Society* 123(4):627–640.

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L. W. Botsford, D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy, R. Webb, B. K. Wells, and T. H. Williams. 2009. *What caused the Sacramento River fall Chinook stock collapse?* March 18. Pre-publication report to the Pacific Fishery Management Council.

Loboschefsky, E., G. Benigno, T. Sommer, K. A. Rose, T. Ginn, A. Massoudieh, and F. Loge. 2012. Individual-level and population-level historical prey demand of San Francisco Estuary striped bass using a bioenergetics model. *San Francisco Estuary and Water Sciences* 10(1).

Mager, R., S. I. Doroshov, and J. P. Van Eenennaam. 2004. Early Life Stages of ~~Delta smelt~~Delta Smelt. *American Fisheries Society Symposium* 39:169–180.

Mariposa County. 2010. *Volume I – Mariposa County Wide General Plan*. Available: http://ca-mariposacounty.civicplus.com/index.aspx?NID=1142. Accessed: June 2, 2016.

Matella, M. K., and A. M. Merenlender. 2014. Scenarios for Restoring Floodplain Ecology Given Changes to River Flows Under Climate Change: Case from the San Joaquin River, California. *River Research and Applications* 31(3):280–290.

McBain and Trush. 1999. *Habitat Restoration Plan for the Lower Tuolumne River Corridor.* Final Report. Prepared for the Tuolumne River Technical Advisory Committee. 217 pp.

———. 2000. *Habitat Restroation Plan for the Lower Tuolumne River Corridor*. Final Report. Arcata, CA. Prepared for the Tuolumne River Technical Advisory Committee.

———. 2002. *San Joaquin River Restoration Study Background Report*. December. Available: http://www.restoresjr.net/program_library/05-Pre-Settlement/index.html.

McCullough, D. A. 1999. *A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon*. Prepared for the U.S. Environmental Protection Agency. 279 pp.

McCullough, D. A., S. Spaulding, D. Sturdevant, and M. Hicks. 2001. *Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids*. EPA-910-D-01-005. Prepared for the U.S. Environmental Protection Agency.

McEwan, D. 2001. Central Valley Steelhead. In Brown, R. L. *Fish Bulletin 179 – Contributions to the Biology of Central Valley Salmonids, Volume 1 of 2*.

McEwan, D., and T. Jackson. 1996. *Steelhead Restoration and Management Plan for California*.

McMichael G. A., C. L. Rakowski, B. B. James, and J. A. Lukas. 2005. Estimated Fall Chinook Salmon Survival to Emergence in Dewatered Redds in a Shallow Side Channel of the Columbia River. *North American Journal of Fisheries Management* 25:876–884.

Meng, L., and S. A. Mattern. 2001. Native and introduced larval fishes of Suisin Marsh, California: the effects of freshwater flow. *Transactions of American Fisheries Society* 130:750–765.

Meng, L., and P. B. Moyle. 1995. Status of splittail in the Sacramento-San Joaquin estuary. *Transactions of American Fisheries Society* 124:538–549.

Merced Irrigation District (Merced ID). 2011. *Technical Memorandum 3-1. Reservoir fish populations. Merced River hydroelectric project.* March. FERC Project No. 2179.

Merz, J. E., P. S. Bergman, J. F. Melgo, and S. Hamilton. 2013. Longfin smelt: spatial dynamics and ontogeny in the San Francisco Estuary, California. Auburn and Sacramento, CA. *California Fish and Game* 99(3):122–148.

Mesick, C. F. 2001. Unpublished. *Factors that Potentially Limit the Populations of Fall-Run Chinook Salmon in the San Joaquin River Tributaries*.

———2009. *The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases*. U.S. Fish and Wildlife Service, Energy and Instream Flow Branch, Sacramento, CA. September. Exhibit No. FWS-50.

———. 2010a. *The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Merced River due to Insufficient Instream Flow Releases.* November 30. Prepared for California Sportfishing Protection Alliance, El Dorado, CA.

———. 2010b. *Testimony of Carl Mesick regarding Statement of Key Issues on the Volume, Quality, and Timing of Delta Outflows Necessary for the Delta Ecosystem to Protect Public Trust Resources with Particular Reference to Fall-Run Chinook Salmon in the San Joaquin River Basin.* Available: http://www.waterboards.ca.gov/waterrights/water_issues/programs/ bay_delta/deltaflow/docs/exhibits/cspa/cspa_exh7_mesick_test.pdf.

Mesick, C. F., and D. Marston. 2007. *Provisional Draft: Relationships Between Fall-Run Chinook Salmon Recruitment to the Major San Joaquin River Tributaries and Stream Flow, Delta Exports, the Head of the Old River Barrier, and Tributary Restoration Projects from the Early 1980s to 2003*.

Mesick, C. F, J. McLain, D. Marston, and T. Heyne. 2007. *Limiting Factor Analyses & Recommended Studies for Fall-run Chinook Salmon and Rainbow Trout in the Tuolumne River*. Draft. Sacramento, CA and Fresno, CA.

Modesto Irrigation District (MID). 2013. *Technical Memorandum 3-1: Reservoir Fish Populations. Merced River Hydroelectric Project*. FERC Project No. 2179.

Monsen, N. E., J. E. Cloern, and J. R. Bureau. 2007. Effects of Flow Diversions on Water and Habitat Quality: Examples from California's Highly Manipulated Sacramento–San Joaquin Delta*. San Francisco Estuary and Watershed Science* 5(3):16.

Moyle, P. B. 2002. *Inland Fishes of California Revised and Expanded*. University of California Press. 502 pp.

Moyle, P. B., R. D. Baxter, T. R. Sommer, T. C. Foin, and S. A. Matern. 2004. Biology and Population Dynamics of Sacramento Splittail (*Pogonichthys Macrolepidotus*) in the San Francisco Estuary: A Review*. San Francisco Estuary and Watershed Science* 2(2):1–47.

Moyle, P. B., P. K. Crain, and K. Whitener. 2007. Patterns in the Use of a Restored California Floodplain by Native and Alien fishes. *San Francisco Estuary and Watershed Science* 5:1–27. Available: http://repositories.cdlib.org/jmie/sfews/vol5/iss3/art1

Moyle, P. B., J. A. Israel, and S. B. Purdy. 2008. *Salmon, Steelhead, and Trout in California: Status of an Emblematic Fauna*. Davis, CA.

Moyle, P. B., J. R. Lund, W. A. Bennett, and W. E. Fleenor. 2010. Habitat Variability and Complexity in the Upper San Francisco Estuary. *San Francisco Estuary and Watershed Science* 8(3).

Moyle, P.B., R.M. Yoshiyama, and R.A. Knapp. 1996. *Status of Fish and Fisheries*. Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis, CA.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D., Wikramanayake. 1995. *Fish Species of Special Concern in California*. Second Edition. Prepared for the State of California Resources Agency, California Department of Fish and Game, Inland Fisheries Division. 277 pp.

Musick J. A., M. M. Harbin, S. A. Berkeley, G. H. Burgess, A. M. Eklund, L. Findley, R. G. Gilmore, J. T. Golden, D. S. Ha, G. R. Huntsman, J. C. McGovern, S. J. Parker, S. G. Poss, E. Sala, T. W. Schmidt, G. R. Sedberry, H. Weeks, and S. G. Wright. 2000. Marine, Estuarine, and Diadromous Fish Stocks at Risk of Extinction in North America (Exclusive of Pacific Salmonids). *Fisheries* 25(11).

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grand, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998*. ~~Status~~ Review of the Status of Chinook Salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce., NOAA Tech*. Memo. NMFS-NWFSC-35. 443 pp.

Myrick, C. A., and J. J. Cech Jr. 2001. *Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations*. Bay-Delta Modeling Forum Technical Publication. 57 pp.

———. 2004. Temperature effects on juvenile anadromous salmonids in California's central valley: what don't we know? Davis, CA. *Reviews in Fish Biology and Fisheries* 14:113–123.

Nakamoto, R. J., T. T. Kisanuki, and G. H. Goldsmith. 1995*. Age and Growth of Klamath River Green Sturgeon (*Acipenser medirostris*).* Arcata, CA.

National Marine Fisheries Services (NMFS). 2005. *Green Sturgeon (*Acipenser medirostris*) Status Review Update.*

———. 2009a*. Endangered Species Act Section 7 Consultation. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project*. June.

———. 2009b. *Endangered Species Act Section 7 Consultation. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project, Appendix 5: Technical Memorandum for the San Joquin Actions*. June.

———. 2009c. *Public Draft Recovery Plan for the Evolutionary Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead*. October. Sacramento Protected Resources Division.

———. 2010. *Federal Recovery Outline: North American Green Sturgeon Southern District Population Segment*. Prepared by National Marine Fisheries Service, Southwest Region.

———. 2011. *ESA Salmon Critical Habitat*. Last revised: September 6. Available: http://www.nwr.noaa.gov/Salmon-Habitat/Critical-Habitat/Index.cfm.

———. 2014. *Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead*. July. California Central Valley Area Office.

———. 2017. Technical Memorandum to account for reintroduced San Joaquin River Spring-run Chinook salmon per CFR 233.301(b)(5)(ii):7. Available: http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/San%20Joaquin/fy2017_sjr_spring-run_tech_memo_final.pdf. Accessed: June 3.

National Wild and Scenic River Systems. 2016. Available: https://www.rivers.gov/rivers/tuolumne.php and https://www.rivers.gov/rivers/merced.php. Accessed: June 1.

Newcombe, C. P., and J. O. T. Jensen. 1996. Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact. *North American Journal of Fisheries Management* 16(4):693–727.

Newman, K. B., and P. L. Brandes. 2010. Hierarchical Modeling of Juvenile Chinook Salmon Survival as a Function of Sacramento–San Joaquin Delta Water Exports. *North American Journal of Fisheries Management* 30(1):157–169.

Nichols, K., and J. S. Foott. 2002. *Health Monitoring of Hatchery and Natural Fall-Run Chinook Salmon Juveniles in the San Joaquin River and Tributaries, April–June 2001*.

Nobriga, M. L. 1998. *Evidence of Food Limitation in Larval Delta Smelt*. Prepared by the California Department of Water Resources.

———. 2002. Larval Delta Smelt Diet Composition and Feeding Incidence: Environmental and Ontogenetic Influences. *California Fish and Game* 88(4):149–164.

Nobriga, M. L., and F. Feyrer. 2007. Shallow-Water Piscivore-Prey Dynamics in California's Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science* 5(2).

Nobriga, M. L., T. R. Sommer, F. Feyrer, and K. Fleming. 2008. Long-Term Trends in Summertime Habitat Suitability for Delta Smelt (*Hypomesus Transpacificus*). *San Francisco Estuary and Watershed Science* 6(1):1–13.

Pacific Gas and Electric Company (PG&E). 2000. *Hydrodivestiture Draft Environmental Impact Report*. *Chapter 4.4, Fisheries and Aquatic Biology*.

Palmer-Zwahlen, M., and B. Kormos. 2013*. Recovery of Coded-Wire Tags form Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2011*. Santa Rosa, CA.

Poytress, W. R., J. J. Gruber, J. P. Van Eenennaam, M. Gard. 2015. Spatial and Temporal Distribution of Spawning events and Habitat Characteristics of Sacrmanto River Green Sturgeon. *Transactions of the American Fisheries Society* 144:1129–1142. Available: https://www.fws.gov/redbluff/MSJM%20Reports/GST/Poytress_et_al_0002-8487.2015.pdf. Accessed: December 1, 2017.

Pyper, B., and C. Justice. 2006. *Analyses of rotary screw sampling of migrating juvenile Chinook salmon in the Stanislaus River, 1996–2005*. August. Cramer Fish ScienceKohs. Gresham, OR.

Radtke, L. D. 1966. Distribution of Smelt, Juvenile Sturgeon and Starry Flounder in the Sacramento–San Joaquin Delta. Pages 115–119 in S. A. L. Turner and D. W. Kelley (editors). *Fish Bulletin 136 – Ecological Studies of the Sacramento–San Joaquin Delta, Part II*. Available: http://content.cdlib.org/view?docId=kt8h4nb2t8&chunk.id=d0e3269&brand=calisphere&doc.view=entire_text.

Reynolds F. L., T. J. Mills, and R. Benthin. 1993. *Restoring Central Valley Streams: A Plan for Action*. California Department of Fish and Game. 217 pp.

Rosenfield, J. A., and R. D. Baxter. 2007. Population Dynamics and Distribution Patterns of Longfin Smelt in the San Francisco Estuary. *Transactions of the American Fisheries Society* 136(36):1577–1592.

San Joaquin County. 2005. *San Joaquin County: Community Development Department*. Last revised: 2013. Available: http://www.sjgov.org/commdev/cgi-bin/cdyn.exe/planning_generalplan?grp=planning&htm=generalplan&sid=&typ=generalplan. Accessed: June 2, 2016.

San Joaquin River Group Authority (SJRGA). 2009. *2008 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan.*

———. 2010. *2009 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan.*

———. 2011. *2010 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan*. Available: http://www.sjrg.org/technicalreport/2010/2010_01.pdf. Accessed: November 28, 2012.

San Joaquin River Technical Committee (SJRTC). 2008. *Draft Summary Report of the Vernalis Adaptive Management Plan (VAMP) for 2000-2008*. Prepared for the Advisory Panel Review Conducted by the Delta Science Program. 84 pp.

Schindler, D. E., J. R. Hodgson, and J. F. Kitchell. 1997. Density-Dependent Changes in Individual Foraging Specialization of Largemouth Bass. *Oecologia* 110(4):592–600.

Seesholtz, A. M., M. J. Manuel, and J. P. Van Eenennaam. 2014. First documented spawning and associated habitat conditions for green sturgeon in the Feather river, California. *Environmental Bioliology of Fishes* 98:905.

Shapovalov, L., and A. C. Taft. 1954. *The Life Histories of the Steelhead Rainbow Trout (*Salmo gairdneri gairdneri*) and Silver Salmon (*Oncorhynchus kisutch*) with Special Reference to Waddell Creek, California, and Recommendations Regarding their Management.* California Department of Fish and Game Fish Bulletin. Vol. 98. Available: http://escholarship.org/uc/item/2v45f61k#page-1.

Sommer, T. R., R. D. Baxter, and B. Herbold. 1997. Resilience of Splittail in the Sacramento–San Joaquin Estuary. *Transactions of the American Fisheries Society* 126(6):961–976.

Sommer, T. R., W. C. Harrell, A. M. Solger, B. Tom, and W. Kimmerer. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. *Aquatic Conservation: Marine and Freshwater Ecosystems* 14(3):247–261.

Sommer, T. R., C. Armor, R. D. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, and B. Herbold. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. *Fisheries* 32(6):270–277.

Sommer, T. R., F. H. Mejia, M. L. Nobriga, F. Feyrer, and L. Grimaldo. 2011. The Spawning Migration of Delta Smelt in the Upper San Francisco Estuary. *San Francisco Estuary and Watershed Science* 9(2).

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58(2):325–333.

S.P. Cramer & Associates, Inc. 2000. *Outmigrant trapping of juvenile salmonids in the lower Stanislaus River Caswell State Park Site 1999.* Report submitted to U.S. Fish and Wildlife Services under subcontract to CH2Mhill. Appendices and 146 pp.

———. 2001. *Outmigrant trapping of juvenile salmonids in the lower Stanislaus River Caswell State Park site 2000*. Final report. Prepared for U.S. Fish and Wildlife Service, Gresham, OR.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. *An ecosystem approach to salmonid conservation*. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. Available from the National Marine Fisheries Service, Portland, OR.

Stanislaus River Fish Group. 2003. *A summary of fisheries research in the lower Stanislaus River*. Working draft. June. Prepared by Carl Messick Consultants, S. P. Cramer & Associates, and California Rivers Restoration Fund.

State Water Resources Control Board (State Water Board). 1999. *Final Environmental Impact Report for Implementation of the 1995 Bay/Delta Water Quality Control Plan*.

———. 2006. *San Francisco Bay/Sacramento–San Joaquin Delta Estuary (Bay-Delta) Water Quality Control Plan*. Sacramento, CA. Available: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/.

Stevens, D. E., and L. W. Miller. 1983. Effects of River Flow on Abundance of Young Chinook Salmon, American Shad, Longfin Smelt, and Delta Smelt in the Sacramento-San Joaquin River System. *North American Journal of Fisheries Management* 3(4):425–437.

Stevens, D. E., D. W. Kohlhorst, L. W. Miller, and D. W. Kelley. 1985. The Decline of Striped Bass in the Sacramento-San Joaquin Estuary, California. *Transactions of the American Fisheries Society* 114(1):12–30.

Stier, D. J., and J. H. Crance. 1985. *Habitat Suitability Index Models and Instream Suitability Curves: American Shad*. USFWS Biology Report 82 (10.88). 34 pp.

Stillwater Sciences. 2001. *2000 Tuolumne River smolt survival and upper screw traps report*. Prepared by Stillwater Sciences, Berkeley, CA with assistance from S. P. Cramer and Associates, Gresham, OR. Prepared for the Tuolumne River Technical Advisory Committee.

———. 2002. *Merced River Corridor Restoration Plan*. Berkeley, CA. 245 pp.

———. 2003. *Draft Restoration Objectives for the San Joaquin River*. Prepared for the Friant Users Water Authority and Natural Resources Defense Council. 613 pp.

———. 2004. *Standard Assessment Methodology for the Sacramento River Bank Protection Project*. Final Report. Davis, CA. Prepared for the U.S. Army Corps of Engineers, Sacramento, CA.

———. 2006. *Lower Tuolumne River Predation Assessment.* Final Report. Berkeley, CA. Prepared by Stillwater Sciences and McBain & Trush, Inc. Prepared for the Tuolumne River Technical Advisory Committee, Turlock and Modesto Irrigation Districts, USFWS Anadromous Fish Restoration Program, and California Bay-Delta Authority.

———. 2013. *Lower Tuolumne River Instream Flow Study*. Final Report. Prepared by Stillwater Sciences, Davis, CA. Prepared for Turlock Irrigation District and Modesto Irrigation District, Turlock, CA and Modesto, CA.

———. n.d.. *AFRP/CALFED Adaptive Management Forum. Tuolumne River restoration program summary report. Summary of studies, conceptual models, restoration projects, and ongoing monitoring*. Prepared by Stillwater Sciences with Tuolumne River Technical Advisory Committee, Berkeley, CA.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982. *Habitat Suitability Index Models: Largemouth Bass*. U.S. Department of Interior, Washington, D.C.

Sullivan, K., D. J. Martin, R. D. Cardwell, J. E. Toll, and S. Dake. 2000. *An Analysis of the Effects of Temperature on Salmonids of the Pacific Northwest with Implications for Selecting Temperature Criteria*. Sustainable Ecosystems Institute. Portland, OR.

Swanson, C., T. Reid, P. S. Young, and J. J. Cech Jr. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced Wakasagi (*H. nipponensis*) in an altered California estuary. *Oecologia* 123:384–390.

The Bay Institute (TBI) and Natural Resources Defense Council (NRDC). 2010. *Exhibit-3. Written Testimony of Christina Swanson, Ph.D., John Cain, Feff Opperman, Ph.D., and Mark Tompkins, Ph.D*. *Regarding Delta Inflows.*

Tucker, M. E., C. M. Williams, and R. R. Johnson. 1998. *Abundance, Food Habits and Life History Aspects of Sacramento Squawfish and Striped Bass at the Red Bluff Diversion Complex, Including the Research Pumping Plant, Sacramento River, California, 1994-1996*. Annual Report. Prepared by the U.S. Fish and Wildlife Service. Prepared for the U.S. Bureau of Reclamation, Red Bluff, CA.

Tuolumne County. 1996. *General Plan*. Adopted by the Tuolumne County Board of Supervisors.

Turlock Irrigation District (TID) and Modesto Irrigation District (MID). 1992*.* Lower Tuolumne River predation study report. Appendix 22 to Don Pedro Project Fisheries Studies Report (FERC Article 39, Project No. 2299). In *Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299. Vol. VII.* Prepared by T. Ford, Turlock and Modesto Irrigation Districts, and EA Engineering, Science, and Technology, Lafayette, CA.

———. 2012. *2011 Lower Tuolumne River annual report.* Available: http://tuolumnerivertac.com/Documents/2012_FERC_Report.pdf. Accessed: November 28.

U. S. Bureau of Reclamation (USBR). 2008. *Biological Assessment on the Continued Long-Term Operations of the Central Valley Project and the State Water Project*. August.

———. 2009. *Final Environmental Impact Statement for the Delta-Mendota Canal/California Aqueduct Intertie. Chapter 4, Biological Environment*. November.

———. 2011. *Draft Program Environmental Impact Statement/Environmental Impact Report*. Prepared for the San Joaquin River Restoration Program. SCH #2007081125. 1,706 pp.

U.S. Bureau of Reclamation (USBR) and California Department of Water Resources (DWR). 2003. *Upper San Joaquin River Basin Storage Investigation. Surface Storage Option Technical Appendix to the Phase 1 Investigation Report*. Prepared by MWH. 56 pp.

~~U.S. Department of the Interior (USDOI). 2008. *Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment*. 1,016 pp.~~

U.S. Environmental Protection Agency (USEPA). 2003. *USEPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards*. April. USEPA 910-B-03-002. 49 pp.

U.S. Fish and Wildlife Service (USFWS). 1995. *Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California. Volume 3*. May 9. Prepared for the U.S. Fish and Wildlife Services under the direction of the Anadromous Fish Restoration Program Core Group, Stockton, CA.

———. 1996. *Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes*. U.S. Fish and Wildlife Service. Portland, OR.

———. 1999. *A summary of the habitat restoration plan for the lower Tuolumne River corridor*. March. Prepared for the Tuolumne River Technical Advisory Committee. Available: http://www.fws.gov/stockton/afrp/documents/tuolplan.pdf. Accessed: May 17, 2012.

———. 2008. *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)*. 396 pp.

———. 2010. *Relationships Between Flow Fluctuations and Redd Dewatering and Juvenile Stranding for Chinook Salmon and Steelhead/Rainbow Trout in the Yuba River*. Prepared by Energy Planning and Instream Flow Branch. 67 pp.

———. 2011. *Identification of the Instream Flow Requirements for Anadromous Fish in the Streams Within the Central Valley of California and Fisheries Investigations*. Annual Progress Report Fiscal Year 2011. Sacramento, CA.

———. 2012. *Identification of the Instream Flow Requirements for Anadromous Fish in the Streams Within the Central Valley of California and Fisheries Investigations*. Annual Progress Report Fiscal Year 2012. Sacramento, CA.

———. 2013. *Identification of the Instream Flow Requirements for Anadromous Fish in the Streams Within the Central Valley of California and Fisheries Investigations*. Annual Progress Report Fiscal Year 2013. Sacramento, CA.

———. 2017. *Into the darkness: imperiled spring-run Chinook salmon released into upper San Joaquin River*. Available: https://www.fws.gov/cno/newsroom/featured/2017/2017_spring-run_chinook_release/. Accessed: August 4, 2017.

U.S. Geological Survey (USGS). 2016. *11292800 Beardsley Lake Near Strawberry CA*. Reservoir Gage Data. Available: http://waterdata.usgs.gov/ca/nwis/uv?site_no=11292800. Accessed: June 9.

———. 2016. *11277200 Cherry Lake Near Hetch Hetchy CA*. Reservoir Gage Data. Available: http://waterdata.usgs.gov/nwis/uv?site_no=11277200. Accessed: June 9.

———. 2016. *11277500 Lake Eleanor Near Hetch Hetchy CA*. Reservoir Gage Data. Available: http://waterdata.usgs.gov/nwis/uv?site_no=11277500. Accessed: June 9.

———. 2016. *11297700 Lyons Reservoir Near Long Barn CA*. Reservoir Gage Data. Available: http://waterdata.usgs.gov/ca/nwis/wys_rpt/?site_no=11297700&agency_cd=USGS. Accessed: June 9.

———. 2016. *11293770 New Spicer Meadow Reservoir Near Big Meadow CA*. Reservoir Gage Data. Available: http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11293770. Accessed: June 9.

Wang, J. C. S. 1986. *Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories*. Technical Report 9. Prepared for the Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary.

Wang, J. C. S., and R. L. Brown. 1993. *Observations of Early Life Stages of Delta Smelt,* Hypomesus transpacificus*, in the Sacramento-San Joaquin Estuary in 1991, with a Review of its Ecological Status in 1988 to 1990.* Technical Report 35. Prepared for the Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary.

Wang, J. C. S. 2007. *Spawning, Early Life Stages, and Early Life Histories of the Osmerids Found in the Sacramento–San Joaquin Delta of California*.

Welch, D. W., S. Turo, and S. D. Batten. 2006. Large-Scale Marine and Freshwater Movements of White Sturgeon. *Transactions of the American Fisheries Society* (135)2:386–389.

Williams, J. G. 2006. Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. *Estuary and Watershed Science* 4(3): Article 2.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 1996. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. In Brown, R.L. 2001. *Fish Bulletin 179 – Contributions to the Biology of Central Valley Salmonids, Volume 1 of 2*.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical abundance and decline of Chinook salmon in the Central Valley region of California. *North American Journal of Fisheries Management* 18:487–521.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2000. Chinook salmon in the California Central Valley: An Assessment. *Fisheries* 25(2):6–20.

Young, P. S., and J. J. Cech, Jr. 1996. Environmental Tolerances and Requirements of Splittail. *Transactions of the American Fisheries Society* 125(5):664–678.

Zimmerman, C. E., G. W. Edwards, and K. Perry. 2008. *Final Report Maternal Origin and Migratory History of* Oncorhynchus mykiss *captured in rivers of the Central Valley, California*. 25 pp.

Zydlewski, J., and S. D. McCormick. 1997. The Ontogeny of Salinity Tolerance in the American Shad, *Alosa sapidissima*. *Canadian Journal of Fishery and Aquatic Science* 54:182–189.