Public Comment
2016 Bay-Delta Plan Amendment & SED
Deadline: 3/17/17 12:00 noon

RECEIVED
3-16-17
SWRCB Clerk

March 16, 2017

Jeanine Townsend, Clerk
State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814-0100

RE: Comments on the Revised Draft Substitute Environmental Document for Phase I of the Update of the Bay-Delta Water Quality Control Plan

Sent via email to: commentletters@waterboards.ca.gov

Dear Ms. Townsend:

On behalf of the Natural Resources Defense Council, The Bay Institute, Defenders of Wildlife, and San Francisco Baykeeper, we are writing to provide comments on the revised draft Substitute Environmental Document for Phase I of the Update of the Bay-Delta Water Quality Control Plan ("SED"). As you know, our organizations are dedicated to helping to protect and restore the health of the Bay-Delta estuary and watershed, including its native fish and wildlife populations. We have participated in this proceeding since the State Water Resources Control Board issued its initial notice of preparation in 2009, and in many cases our involvement goes back decades. Whether for fishermen whose livelihoods depend on healthy salmon runs, or members of the public who recreate in and value these rivers that are held in Public Trust for all of us, the health and abundance of our native salmon runs, the health of these three rivers – the Stanislaus, Tuolumne, and Merced – and the health of the Bay-Delta estuary is of paramount importance.

The State Water Resources Control Board ("SWRCB") last meaningfully updated the Plan more than 20 years ago, and since that time, salmon populations have continued to decline, jeopardizing the state's salmon fishery and demonstrating the inadequacy of existing flow conditions to achieve the narrative salmon protection objective. While the SED proposes to increase flows, the available scientific evidence demonstrates that the proposal fails to provide the flow conditions necessary to achieve the Bay-Delta Plan's existing salmon protection objective, the proposed San Joaquin migratory fish viability objective, maintain fish in good condition, and protect the Public Trust. We therefore urge the SWRCB to adopt a flow range of 40-60% of unimpaired flow, and a starting point of 50%, consistent with the best available science and the requirements of State law.

In 2013, several of our organizations provided written comments demonstrating flaws with the 2012 proposal and analyses, emphasizing that the proposed flows were inadequate and higher flows were necessary. Those prior comments (TBI et al. 2013) are hereby incorporated by reference. Other state and federal agencies, including the California Department of Fish and Wildlife, likewise concluded that higher flow levels were necessary to achieve the existing narrative salmon protection objective and to protect the Public Trust. While the SWRCB has addressed several of those prior flaws, its revised proposal still fails to provide adequate flow conditions to protect and restore salmon and the health of these rivers. On the pages that follow, we emphasize that:

I. The Narrative Objective Must Be Revised to Be Consistent with the Existing Narrative Salmon Protection Objective, and the SED Must Demonstrate that the Program of Implementation is Likely to Achieve that Objective;
II. The SED and Existing Scientific Information Demonstrates that Current Flows Violate Section 5937 of the Fish and Game Code, and the SWRCB Must Ensure that Instream Flows Below Reservoirs Are Sufficient to Maintain Fish in Good Condition;
III. The SED Fails to Utilize Scientifically Sound Analyses Regarding the Effects of Flow Alternatives on Fisheries and Ecosystems, the SED fails to demonstrate that the Program of Implementation is Likely to Achieve the Narrative Salmon Protection Objective and the San Joaquin Migratory Fish Viability Objective, and the Preferred Alternative Fails to Provide Flows that are Likely Adequate to Achieve the Narrative Salmon Protection Objective or Maintain Fish in Good Condition;
IV. The SED Fails to Analyze Potential Adverse Environmental Impacts of Waiving Instream Flow Requirements in Future Drought Emergencies, as Authorized in the Program of Implementation;
V. The Program of Implementation Fails to Ensure that Discretion in Flow Shaping and Volume will Achieve Water Quality Control Plan Objectives and the SMART Biological and Environmental Targets Used To Track Compliance And Effectiveness;
VI. The Program of Implementation Must Include Enforceable Carryover Storage Requirements in Upstream Reservoirs to Mitigate and Avoid Impacts, Consistent with the Substitute Environmental Document;
VII. The SED Fails to Consider the SWRCB's Legal Authority to Require Water Rights Holders to Invest in Habitat Restoration and Other Non-Flow Measures;

VIII. The SED's Analysis of Changes in CVP/SWP Water Exports is Flawed Because it Fails to Consider the Right of Upstream Water Users to Dedicate these Flows Under Section 1707;

IX. The SED Fails to Adequately Consider the Feasibility of Protecting Public Trust Resources Because it Fails to Consider Improvements in Water Use Efficiency and Alternative Water Supplies; and,

X. The SED's Analysis of Water Supply Impacts is Flawed and Overestimates Likely Impacts.

We urge the SWRCB to revise the SED and adopt higher instream flows, consistent with the best available science and the recommendations below and in TBI et al. 2013.

I. The Narrative Objective Must Be Revised to Be Consistent with the Existing Narrative Salmon Protection Objective, and the SED Must Demonstrate that the Program of Implementation is Likely to Achieve that Objective.

Our 2013 comments on the draft SED provided detailed explanation why the language of the proposed San Joaquin River inflow narrative objective must be revised to be consistent with the existing salmon protection objective (also known as the salmon doubling objective), and we provided proposed changes to the San Joaquin River inflow narrative objective to accomplish this requirement. *See* TBI et al. 2013 at 3-6. Our 2013 comments also addressed the legal requirement that the Board demonstrate that the program of implementation is likely to achieve the salmon doubling objective. *Id*. at 3; *id.*, Exhibit 2, at 10-11. In addition, our 2013 comments discussed at length how the SWRCB cannot balance away the achievement of the salmon doubling objective or the California Endangered Species Act ("CESA"), how the SWRCB must protect Public Trust resources to the extent feasible, and how the SWRCB must consider alternative water supplies in any balancing. *Id*. at 4, 42-46; *id*., Exhibit 2. Our 2013 comments regarding these points are hereby incorporated by reference; these comments apply to the narrative objective in the 2016 draft SED, to the SWRCB's duty to ensure that the flows are likely to achieve the narrative salmon protection objective and protect the Public Trust to the extent feasible, and to the limits on the SWRCB's authority to balance beneficial uses.

Unfortunately, in Appendix K of the draft 2016 SED, the SWRCB failed to change the language of the San Joaquin River inflow narrative migratory fish viability objective to be consistent with the narrative salmon protection objective, even though the draft San Joaquin River inflow narrative objective included in the 2011 Revised Notice of Preparation for this proceeding explicitly included the salmon doubling objective. *See* Revised Notice of Preparation, April 1, 2011, Attachment 2.[1] We have therefore enclosed with these comments an updated redline of

[1] Similarly, the conclusion of the 2012 Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives, which is included in the 2016 Draft SED, explicitly references the

Table 3 (Appendix A), which includes proposed changes to the San Joaquin River inflow narrative flow objective to ensure it is consistent with the existing salmon protection objective.

On the other hand, in Appendix K of the revised 2016 SED, the SWRCB appropriately included San Joaquin River inflow as a numeric objective, not just a narrative objective as in the 2013 draft SED. We strongly support this change to include flows as a numeric objective. However, the draft language in Table 3 does not appear to allow for deviations from the running average to allow for adaptive implementation (flow shifting and flow shaping) to attain the plan objectives. We have therefore also enclosed with these comments a redline of Table 3 that provides appropriately limited discretion for adaptive implementation of the running average of flows.

In addition to our prior comments, on the pages that follow we provide additional detail regarding the Board's legal obligation to ensure that the measures included in this update of the Water Quality Control Plan are sufficient to provide the instream conditions that are necessary to achieve the existing narrative salmon protection objective.

More than 20 years ago, the SWRCB adopted the narrative salmon protection objective in the 1995 Bay Delta Water Quality Control Plan. And it has been nearly 30 years since California enacted the Salmon, Steelhead Trout, and Anadromous Fisheries Act into law in 1988, which first identified the State's salmon doubling program. Cal. Fish and Game Code §§6900 *et seq*. Yet as the SWRCB is well aware, salmon populations in the Stanislaus, Tuolumne, and Merced Rivers have not only failed to achieve the doubling objectives; rather, instead of increasing in abundance, on average salmon escapement has declined since the 1995 Plan was adopted.

The 1995 Plan stated that there was scientific uncertainty whether the numeric flow objectives would achieve the narrative salmon protection objective. 1995 Bay-Delta Water Quality Control Plan at 28; *State Water Resources Control Board Cases*, 136 Cal.App.4th 674, 775-76 (2006). The SWRCB made a similar argument in Decision 1641. *See* Revised Decision 1641, at 61 ("Implementing the narrative objective for salmon protection requires a long-term process. A period of actual operation meeting the numerical objectives in the 1995 Bay-Delta Plan or the measures under the SJRA/VAMP, coupled with adequate monitoring, is required before the SWRCB can determine whether additional implementation measures are needed to meet this objective."). In the 2006 plan, it is clear that the San Joaquin River inflow objectives were intended to achieve the narrative salmon protection objective. *See* 2006 Bay Delta Water

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salmon doubling objective in its draft narrative objective for San Joaquin River flow. *See* SED, Appendix C, at 3-56. This provides additional evidence that the proceeding is intended to provide the flows necessary to achieve the salmon doubling objective. Inexplicably, this language was not included in the draft narrative objective included in either the 2012 or 2016 draft SED. In addition, Appendix K to the 2016 revised SED references the doubling objective in identifying the biological goals and objectives for the program of implementation. SED, Appendix K, at 33 ("The salmonid biological goals for this program of implementation will be specific to the LSJR and its tributaries and will contribute to meeting the overall goals for each population, including the salmon doubling objective established in state and federal law."); *see* Hearing Transcript, Nov. 29, 2016, at 128-129.

Quality Control Plan, at 33 ("D-1641 did not require separate actions to implement the narrative objective for salmon because the State Water Board expects that implementation of the numeric flow-dependent objectives and other non-flow measures will implement this objective.").

However, there is now overwhelming scientific evidence that the flows required in the 1995 Plan for the Stanislaus, Tuolumne, Merced, and lower San Joaquin River are wholly inadequate to provide in-river survival of salmon necessary to achieve the objective. In fact, such scientific evidence has been available for more than a decade. For instance, the California Department of Fish and Game concluded more than a decade ago that:

> We noted, and the Draft Plan acknowledges, that salmon populations in the basin are below State and Federal "population doubling objectives" and, rather than increasing, are in fact declining. Further, the "equivalent fishery protection" standard, assumed to be achieved by the VAMP agreement and the State Water Board's adoption, remains unsatisfied. In your workshop, we and others presented substantial science-based evidence that these tributary salmon population long-term declines are directly related to magnitude, frequency, and duration of flow in the San Joaquin River during the spring.

Letter from Ryan Broddrick to Tam Dudoc, Nov. 8, 2006 at 2. In 2013, the California Department of Fish and Wildlife concluded that higher instream flows in the winter-spring period, in the range of 50-60% of unimpaired flow, were necessary to achieve the narrative salmon protection objective. CDFW 2013 (comments on 2012 SED). The SWRCB has acknowledged this scientific information regarding the decline of salmon populations in these tributaries and the primary importance that spring instream flows play in determining survival and abundance of salmonids. *See, e.g.,* SWRCB 2010; 2012 SED; 2016 SED.

As a result of this overwhelming scientific evidence regarding the inadequacy of existing flows in the 1995 Plan to achieve the narrative salmon protection objective, the SWRCB's obligation in this proceeding is to establish new instream flows necessary to achieve the narrative salmon protection objective. As we noted in our prior comments, the Court of Appeals emphasized in 2006 that:

> [d]etermining what actions were required to achieve the narrative salmon protection objective was part of the Board's obligation in formulating the 1995 Bay–Delta Plan in the first place. (See §§ 13050, subd. (j)(3) [a water quality control plan must include "[a] program of implementation needed for achieving water quality objectives"], 13242, subd. (a) [a "program of implementation for achieving water quality objectives" must include "[a] description of the nature of actions which are necessary to achieve the objectives"].)

> …
> If the Audubon Society parties are correct in their contention that scientific evidence shows the flows needed to achieve the narrative salmon protection objective must be greater than the Vernalis flow objectives of the 1995 Bay–Delta Plan, then that evidence may provide a basis for changing the Vernalis flow objectives in the next regulatory proceeding to review and revise the water quality control plan for the Bay–Delta.

State Water Resources Control Board Cases, 136 Cal.App.4th at 776-77. The court of appeals 1986 decision in *U.S. v. SWRCB* reached a similar conclusion, holding that, "Once the Board establishes water quality objectives which ensure reasonable protection of beneficial uses (§ 13241), the Board has the added responsibility to complete the water quality control plan by preparing an implementation program to achieve the water quality objectives." 182 Cal.App.3d 82, 119 (1986). Because the scientific evidence is available and overwhelming, now is the time to adopt flow standards to achieve the narrative salmon protection objective. Commercial and recreational fishermen, businesses, communities and conservation groups have waited – and suffered – decades for adequate flows to restore and sustain salmon populations on these rivers.

Moreover, the decision by the Court of Appeals in the *State Water Resources Control Board Cases* provides a strong rebuttal to argument that the Board could now approve flows less than those necessary to achieve the narrative salmon protection objective, or could approve a plan that substantially delays implementation of flows that are scientifically demonstrated to be likely to achieve the narrative salmon protection objective.[2] Although some water users argued that the SWRCB could substitute the Vernalis Adaptive Management Plan for the full San Joaquin River inflows called for under the 1995 Plan as part of a staged implementation of the San Joaquin River inflow objectives or as an interim, experimental stage of those objectives, the Court disagreed and concluded this would constitute an unlawful, de facto amendment of the 1995 Plan. 136 Cal.App.4th at 726-736. The court emphasized that nothing in the Plan itself expressly authorized a staged or delayed implementation of the Plan, notwithstanding the language of section 13242(b) of the Water Code, and that "regardless of the timing issue, the Board has failed to identify anything in the plan that authorized it to implement a flow objective other than the Vernalis pulse flow objective, even temporarily." *Id*. at 726-27. Moreover, as the Court noted, section 13247 of the Water Code requires that a water quality plan be implemented, preventing the Board from implementing measures less than those required by the plan without changing the plan itself. *Id*. at 730. And as noted above, there has been widespread scientific understanding, for more than a decade, that current flows are inadequate to achieve the narrative salmon protection objective, undermining any argument for further delay in achieving the objective.

[2] In addition, the Board does not have discretion to delay implementation of statutory obligations, including the statutory obligation under sections 5937 or 5946 of the Fish and Game Code that requires the owner of any dam to release sufficient flows from dams and reservoirs to maintain fish downstream in good condition. *See California Trout v. Superior Court*, 218 Cal.App.3d 187, 201, 203-211 (1990).

Finally, we note that the SWRCB's Notice of Preparation for Phase I did not notify the public of any potential changes to the narrative salmon protection objective, and instead limited the notice to changes to the San Joaquin River inflow objective and South Delta salinity objective. *See* Fourth Revised Notice, December 22, 2016. Indeed, as noted above, the 2011 revised notice explicitly included salmon doubling as part of the narrative flow objective for the San Joaquin River, *see* Revised Notice of Preparation, April 1, 2011, Attachment 2, and language in the SED references the salmon doubling objective in identifying the biological goals and objectives for the program of implementation for the San Joaquin River inflow objectives. SED, Appendix K, at 33. This proceeding is not proposing any changes to the narrative salmon protection objective, nor could the SWRCB do so. As we emphasized in our 2013 comments,

> …the salmon doubling requirements of state and federal law is an expression of the Board's responsibilities under the Public Trust. The Board must abide by the Legislature's determination that the doubling of natural production of salmon is a statewide policy (Cal. Fish & Game Code § 6902(a)) and the water quality control plan should be consistent with that policy. The salmon doubling policy is intended to ensure that the State does more than meet the absolute minimum requirements of the state and federal Endangered Species Acts. As with section 5937 of the Fish and Game Code, section 6900 et seq is a legislative expression of the Public Trust, and the Board lacks authority to balance away achievement of this state policy. (*See California Trout, Inc. v. State Water Resources Control Bd*., 207 Cal.App.3d 585, 622-625, 631 (1989); SWRCB Decision 1631 at 172; SWRCB Decision 1644 at 27; Exhibit 1).

TBI et al. 2013 at 3-4; *see also* TBI et al. 2013, Exhibit 2.

After more than 20 years of waiting, it is time for the SWRCB to adopt flow requirements for the Stanislaus, Tuolumne, Merced, and lower San Joaquin River that are likely to provide the instream flow conditions necessary to achieve the narrative salmon protection objective in the existing Plan. However, as discussed below, the proposal fails to provide flow and water quality conditions that are reasonably likely achieve the narrative salmon protection objective in the Plan.

II. The SED and Existing Scientific Information Demonstrates that Current Flows Violate Section 5937 of the Fish and Game Code, and the SWRCB Must Ensure that Instream Flows Below Reservoirs Are Sufficient to Maintain Fish in Good Condition.

For more than a century, California law has required the owner of any dam to release sufficient flows to maintain fish in good condition below the dam. Cal. Fish and Game Code § 5937. The requirements of section 5937 evolved from a series of statutory protections for instream flows and fisheries, dating from California's earliest days of statehood. *See* Karrigan Bork et al., The Rebirth of California Fish and Game Code § 5937: Water for Fish, 45 U.C. Davis L. Rev. 809 (2012). The protections required by section 5937 or its predecessors have been in place since dams were constructed on the Stanislaus,[3] Tuolumne, and Merced Rivers, particularly the more recent and larger reservoirs.

Despite these legal protections, the scientific evidence in the SED and in other sources unambiguously demonstrates that salmon and other native fish below the dams on these three tributaries have not been maintained in good condition. For instance, despite historically being the largest run on many of these rivers, spring run Chinook salmon have largely been extirpated from these rivers (although remnant populations have been discovered on the Tuolumne and Stanislaus Rivers in recent years). *See, e.g.*, SED at 7-16 to 7-17; NMFS, 5-Year Review: Summary and Evaluation of Central Valley Spring-run Chinook Salmon Evolutionary Significant Unit, April 2016.[4] Similarly, despite historically large populations, Central Valley Steelhead currently is listed as a threatened species under the federal Endangered Species Act, with only remnant populations remaining on these rivers. SED at 7-17 to 7-18, 7-32. In 2016, NMFS concluded that this distinct population segment remained at risk of extinction, and observed that only small numbers of wild steelhead (as opposed to hatchery produced steelhead) were observed in recent years in most of the Central Valley monitoring programs. NMFS, 5-Year Review: Summary and Evaluation of Central Valley Steelhead Salmon Evolutionary Significant Unit, May 2016.[5] Populations of fall run Chinook salmon, the backbone of the State's salmon fishery, have remained low in most years on these rivers. SED at 7-15, 7-32 to 7-33, 7-36 to 7-38, 7-40 to 7-41. According to data from CDFW, the abundance of fall run Chinook salmon on the Tuolumne and Merced Rivers have declined substantially since the 1980s, and on all three rivers have exhibited clear boom and bust cycles with extremely low abundance in dry years and droughts. TBI et al. 2013 at 4-5; Cal. Dept. of Fish and Wildlife, California Central Valley Chinook Population Database Report, GrandTab 2016.04.11.[6] Moreover, the majority of fall run

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[3] The Ninth Circuit Court of Appeals has recently reaffirmed the legal duty of the Bureau of Reclamation to comply with section 5937, holding that, "This code section not only allows, but requires BOR to allow sufficient water to pass the Lewiston Dam to maintain the fish below the Dam. The use of the unconditional "shall" indicates that such required releases are not dependent on having a proper water permit." *San Luis & Delta Mendota Water Authority v. Haugrud*, __ F.3d ___, 2017 WL 677537 at *12 (Feb. 21, 2017).

[4] This report from NMFS is available online at: http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_cv-spring-run-chinook.pdf and is hereby incorporated by reference.

[5] This report from NMFS is available online at: http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_cv-steelhead.pdf and is hereby incorporated by reference.

[6] This report is available online at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381&inline=1 and is hereby incorporated by reference.

Chinook salmon that return to spawn on these rivers are hatchery fish, demonstrating that natural production of fall run Chinook salmon is even worse than absolute abundance and escapement numbers indicate. *See* Melodie Palmer-Zwahlen and Brett Kormos, Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement, Inland Harvest, and Ocean Harvest in 2012, California Department of Fish and Wildlife Administrative Report 2015-4, November 2015;[7] Melodie Palmer-Zwahlen and Brett Kormos, Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement, Inland Harvest, and Ocean Harvest in 2011, California Department of Fish and Wildlife Administrative Report 2013-2, December 2013;[8] Brett Kormos, Melodie Palmer-Zwahlen, and Alice Low, Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2010, California Department of Fish and Wildlife Administrative Report 2012-2, March 2012.[9]

Moreover, the overwhelming scientific evidence in the SED, our prior comments on the SED and these comments on the revised SED, and comments of other state and federal fishery agencies in this proceeding demonstrate that the failure to maintain fish in good condition below dams on the Stanislaus, Tuolumne and Merced Rivers is a result of the failure to release sufficient flow downstream. *See, e.g.*, SWRCB 2010; TBI et al. 2013; CDFW 2013; NMFS 2013; SED, Appendix C. As a result, there can be no question that these dam owners are and have been in violation of section 5937 of the Fish and Game Code.

The SWRCB has an obligation in this proceeding to ensure that instream flows are sufficient to maintain fish in good condition below these reservoirs, and cannot seek to balance away achievement of these statutorily mandated expressions of the Public Trust. *See California Trout v. State Water Resources Control Board*, 207 Cal.App.3d 585 (1989); TBI et al. 2013 at 45. Moreover, the Board cannot unreasonably delay the imposition of adequate permit terms and conditions to protect these Public Trust values. *California Trout v. Superior Court*, 218 Cal.App.3d 187 (1990). Chapter 1 of the SED should be revised to acknowledge the Board's authority and obligations under section 5937 of the Fish and Game Code.

For decades, water rights holders on the Stanislaus, Tuolumne, and Merced Rivers have reaped the water supply and other benefits of reservoirs and dams on these rivers, while failing to meet their responsibilities to maintain fish in good condition. There is no time for further delay. The SWRCB must take timely action to impose terms and conditions that require the release of

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[7] This report is available online at: http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=112524 and is incorporated by reference.
[8] This report is available online at: http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=75609 and is incorporated by reference.
[9] This report is available online at: http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=44306 and is incorporated by reference.

sufficient flow to maintain fish in good condition below the dams and reservoirs on these three rivers.

III. The SED Fails to Utilize Scientifically Sound Analyses Regarding the Effects of Flow Alternatives on Fisheries and Ecosystems, the SED fails to demonstrate that the Program of Implementation is Likely to Achieve the Narrative Salmon Protection Objective and the San Joaquin Migratory Fish Viability objective, and the Preferred Alternative Fails to Provide Flows that are Likely Adequate to Achieve the Narrative Salmon Protection Objective or Maintain Fish in Good Condition.

As discussed above, the Board must demonstrate that its water quality control plan is reasonably likely to attain plan objectives. Regarding the existing narrative salmon protection objective, that means that the plan must provide for levels of fresh water flow that are consistent with attaining natural production of Chinook salmon that is double the 1967-1991 average production[10] for each of the three San Joaquin tributaries. With regard to the SED's focus on maintenance of "viable" populations, the Board needs to demonstrate that its plan supports appropriate levels of all attributes that define a viable population, including abundance (e.g., production), productivity (e.g., survival rates), life history diversity, genetic diversity, and spatial distribution of populations (McElhaney *et al*. 2000; Lindley *et al.* 2007).

A variety of tools and data sets exist that permit analysis of the potential for plan alternatives to meet plan objectives; however, the SED does not employ these tools and data sets to demonstrate the adequacy of its preferred alternative. In addition, the SED does not address the need to restore self-sustaining populations of spring-run Chinook salmon to the lower San Joaquin River's three main tributaries (NMFS 2014; Franks 2012). As a result, the SED does not employ the best available science regarding the effect of flow levels on attainment of plan objectives.

a. The SED fails to adequately analyze the environmental impacts of alternatives because it fails to consider the best available scientific information showing the strong relationships between flow rates, volume, and variability with salmon survival

In our comments on the draft 2012 SED, we presented evidence of strong positive relationships between Chinook salmon escapement (and production) and several flow metrics. However, although the SWRCB has acknowledged these relationships and confirmed the likely causal connection between freshwater flow rates in the winter-spring and subsequent salmon abundance, *see, e.g.*, SWRCB 2010, the SED fails to analyze the effect of its flow alternatives in

[10] Production is the number of Age 2+ salmon in the ocean that emanate from a given watershed. The number is currently estimated based on subsequent escapement (return of adults to each watershed) and assumptions about survival of migrating adults and hatchery contributions to escapement.

light of these relationships in a scientifically credible manner. As we discuss below, there is strong scientific support for these prior analyses, and more recent scientific information that was not available in 2012. The SED must be revised to include analyses of the alternatives that accounts for the effect of these relationships on production / subsequent escapement.

1. *Production and escapement of San Joaquin salmon is strongly correlated with river flow rates during the months of egg incubation and juvenile migration; no other variable explains the pattern of salmon escapement to the San Joaquin River's main tributaries through time.*

In our previous comments (TBI et al. 2010, Ex. 3; TBI et al. 2013), we demonstrated that winter-spring flows at Vernalis are correlated with salmon production in the ocean. Similar analyses of the relationships between instream flows and subsequent escapement (or production) of Chinook salmon were included in the SWRCB's 2010 Flow Criteria Report, which the SWRCB concluded was based on the best available science. SWRCB 2010 at 56-60, 119-121; *see also* Figure 1. These and similar analyses were included in the SED, as a technical appendix on the scientific basis for San Joaquin River flow objectives. SED Appendix C.

Recently, we explored the flow-abundance analysis by investigating whether factors in addition to seasonal flow levels (as measured at Vernalis) were significantly correlated with historical San Joaquin salmon escapement. Although it has been suggested that density of predators on juvenile salmon, such as Striped Bass, plays a role in the decline of San Joaquin salmon population, *see, e.g.*, draft SED at 7-35 and 7-46, a recent analysis of the effect of predator density on Central Valley Chinook salmon productivity and abundance (Grossman 2016) concluded:

> … it has recently been proposed that Striped Bass populations be significantly reduced to facilitate recovery of endangered Central Valley Chinook Salmon …[however] the most likely outcome of Striped Bass removal is that a competing predator will increase in abundance and there will be little reduction in predation mortality for Chinook Salmon. It is likely that the most productive management strategy for decreasing predation on Chinook Salmon and other Delta fishes is to restore natural habitat and flows, especially in predation hot spots.

Grossman 2016 at 16. Moyle and Bennett 2010 raised similar concerns and noted that, "reducing the striped bass population may or may not have a desirable effect. In our opinion, it is most likely to have a negative effect. … We stress that attempting to reduce striped bass and other predator populations is unlikely to make a difference in saving endangered fishes, and will serve only to distract attention from some of the real problems." Moyle and Bennett 2010 at 3.

We analyzed whether a statistically significant relationship exists between adult Striped Bass abundance in the Delta and salmon escapement, and we found no significant negative correlation between annual indices of adult Striped Bass abundance in the Delta (Peterson Index; Stevens et al. 1985) in the year when salmon migrate to the ocean and San Joaquin River basin Chinook salmon abundance 2 or 3 years later when those same salmon return as adults (Figure 2).

Similarly, ocean conditions also have been posited as potential drivers of Central Valley Chinook salmon populations. That relationship is complex and likely results from an interaction between conditions that juvenile salmon experience in their freshwater habitat and those that they find when they enter the marine environment. For instance, Satterthwaite et al. 2014 found strong evidence of an interaction between ocean conditions and ocean entry timing of Central Valley Chinook salmon. Similarly, while documenting the potential linkage between ocean conditions in the mid-2000s and the subsequent fall-run Chinook salmon stock collapse and ocean fishery closure, Lindley et al. 2009 noted that: "…long-term declines in the condition of freshwater habitats are expected to result in increasingly severe downturns in abundance during episodes of poor ocean survival." Lindley et al. 2009 at 38. These authors also identified constrained life-history diversity among juvenile Central Valley Chinook salmon as a factor that magnifies the effect of ocean conditions on subsequent ocean production and escapement.

Both Pacific Decadal Oscillation (PDO; Mantua *et al*. 1997) and North Pacific Gyre Oscillation (NPGO; De Lorenzo *et al*. 2008) characterize variation in Pacific Ocean temperatures and have been linked to marine ecosystem productivity and salmon escapement; however, we found no statistically significant correlation between these two metrics and escapement of San Joaquin River salmon through time (Figure 3). The lack of significant linear statistical relationships between the historic pattern of San Joaquin River Chinook salmon production and ocean conditions does not mean that ocean conditions have no effect on salmon production, but it does suggest that ocean conditions are not responsible for the overall pattern in year-to-year salmon returns.

Finally, although year-to-year variation in hatchery production of Chinook salmon (both on the Merced River in the San Joaquin basin and on the nearby Mokelumne River) could potentially influence total San Joaquin River Chinook salmon escapement, we found no statistical correlation between San Joaquin River adult escapement and prior releases of fish from the Merced hatchery or total annual Merced hatchery plus Mokelumne hatchery releases (Figure 4).

These statistical analyses provide additional scientific evidence that flow is the strongest determinant of San Joaquin Chinook salmon escapement 2.5 years later. The SED should be modified to evaluate the likely effect of its flow alternatives on future abundance of San Joaquin salmon using the empirical relationship between Chinook salmon abundance in the San Joaquin's tributaries and flow levels as measured at Vernalis. Under current landscape conditions (e.g., geometry of the tributaries and lower San Joaquin River) and reservoir operations, the persistent and significant relationship between flow levels (measured at Vernalis during winter-spring in year x+1) and subsequent escapement (measured in year x+3) is a reasonable tool for predicting future abundance of salmon in response to changes in flow levels. This relationship could be further refined by incorporating spawning stock into the flow-abundance relationship (e.g., to account for the apparently strong, flow-dependent carrying capacity limitation on production of juvenile Chinook salmon from some San Joaquin River tributaries. Sturrock and Johnson 2016 presentation to the SWRCB; *see infra*).

2. *The SED fails to acknowledge or analyze recurrence frequency of flow levels that the Board and CDFW acknowledge are associated with viable populations or the attainment of population abundance levels required by state and federal law.*

Productivity (survival rate) in fresh water that supports rapid population growth, up to system carrying capacity, is an essential feature of Chinook population viability (McElhany et al. 2000; Lindley et al. 2007). As a result, both the SED's proposed narrative objective ("viable" populations of Chinook salmon on the San Joaquin tributaries) and the requirement of state law that reservoirs release flows sufficient to maintain populations of fish below dams in good condition (Cal. Fish and Game Code § 5937) require that flow rates and other environmental conditions support the potential for rapid population growth in most years. High fecundity and typical egg and juvenile survival rates make Chinook salmon populations capable of explosive growth (Healy 1991; Quinn 2005; SEP 2016[11]). For example, Quinn 2005 (Table 15-1) reports average survival rates from a range of managed Chinook salmon populations of 17.5 adults per spawning female. The health and viability of salmon populations rely on intense competition on the spawning grounds, which result from high survival rates throughout earlier stages of the life cycle. Indeed, the ecology, behavior, and even morphology of Chinook salmon are shaped by intense competition for mates and spawning territories in populations where abundance is most often limited by constrained carrying capacity for spawning salmon (e.g., Healy 1991; Quinn 2005).

Numerous studies presented to the SWRCB (e.g., CDFG 2010; TBI et al. 2010, exhibit 3; TBI et al. 2013) demonstrate the relationship between average winter-spring flow levels in the San Joaquin River at Vernalis >5,000 cfs and subsequent increases in Chinook salmon escapement. In our analyses of the effect of the flow alternatives in the 2012 SED, we found that achieving the necessary recurrence frequency of years with ≥5,000 cfs seasonal average flow (the threshold associated with potential population growth) would require a flow regime of between 50-60% of the San Joaquin's unimpaired winter-spring flow (TBI et al. 2013). In the absence of a change in the San Joaquin flow-population growth relationship, flow prescriptions <50% UIF are likely to result in a low frequency of salmon population growth that is inconsistent with attainment of the

[11] The final report of the Scientific Evaluation Process (SEP 2016) is enclosed as Appendix B.

narrative salmon protection objective or the narrative San Joaquin migratory fish viability objective. The SED fails to analyze the effects of flow alternatives in achieving these flow rates and the likely effects on subsequent escapement based on this relationship. The SED should be revised to do so.

The SED also fails to analyze the recurrence frequency of average winter-spring flow levels that are believed to correspond with attainment of the AFRP doubling target, and thus the existing salmon protection objective. TBI et al. 2010, exhibit 3 found that San Joaquin salmon populations approached target levels when average March-Jun flows were >10,000 cfs. To generate average flows >10,000 cfs during the winter-spring period in ½ of years, a flow prescription between 60-75% of unimpaired flows would be necessary (TBI et al. 2013). Under current conditions, flow prescriptions that require <60% UIF are unlikely to result in adequate habitat space for production of the number of juvenile salmon that are necessary to attain the doubling objective.

Regarding flow levels associated with population growth (>5,000 cfs Mar-Jun average) and target abundance (>10,000cfs Mar-Jun average), the State Board concluded:

> "Available scientific information indicates that average March through June flows of 5,000 cfs on the San Joaquin River at Vernalis represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon and that average flows of 10,000 cfs during this period may provide conditions necessary to achieve doubling of San Joaquin basin fall-run. Both the AFRP and DFG flow recommendations to achieve doubling also seem to support these general levels of flow…."

SWRCB 2010 at 119.

Attainment of these seasonal average flow levels on San Joaquin salmon escapement will not be affected by manipulation of the hydrograph within the winter-spring months ("flow shaping") because they are based on the volume of flow during the season. Of concern, however, is that in some of its alternatives the SED allows water that would otherwise flow during the Feb-Jun period to be retained in storage until later in the year (or subsequent years) in order to manage reservoir storage ("flow shifting"). Any shifting of flow out of the Feb-Jun period will necessarily result in a lower volume of flow during this season, and such flow shifting therefore is very likely to **reduce** the frequency of meeting or exceeding the critical seasonal average flow thresholds described above.

The analyses presented in our prior comments, as updated here, remain valid. These analyses demonstrate that the Preferred Alternative is unlikely to achieve the existing narrative salmon protection objective in the Plan or the proposed San Joaquin migratory fish viability objective in the SED. The SED should be revised to include these and/or similar analyses of the effects of the flow alternatives on subsequent salmon escapement, production, and/or on juvenile survival.

3. *The SED fails to examine the relationships between river flow rates and both juvenile salmon productivity and the life-history diversity that leads to greater population resilience in the face of uncertain conditions in the Delta, Bay, and Pacific Ocean environments.*

The best available science demonstrates that the relationship between freshwater flow rates during egg incubation and juvenile rearing and migration and Chinook salmon escapement back to the San Joaquin Rivers tributaries ~2.5 years later can be explained by increases in (a) juvenile salmon productivity (i.e., the number of juveniles leaving a San Joaquin tributary per adult salmon returning to that tributary the previous fall) and/or (b) survival of juvenile salmon in environments downstream of the tributaries and mainstem San Joaquin River (i.e., in the Delta, Bay, and/or marine environments) as a result of conditions experienced in the freshwater environment.

Zeug et al. 2014 documented a strong positive relationship between both flow volume and flow variance and juvenile salmon outmigration from the Stanislaus River relative to adult escapement the prior fall. Their analysis found that the cumulative volume of flow during the 120 day rearing period in the winter/ spring months was the strongest predictor (R^2=0.68) of juvenile salmon survival between the rotary screw trap ("RST") at Oakdale (near the bottom of the spawning reach) and the RST at Caswell, 9 km upstream from the confluence with the lower San Joaquin River. Similarly, discharge variance (the variability of flow during this period) was a strong predictor of survival between these RSTs on the Stanislaus River (R^2=0.66).[12] Their analysis also concluded that increased cumulative flow volume and flow variance during the rearing period resulted in higher numbers of pre-smolts successfully migrating downstream. The authors concluded that:

> A strong positive response in survival, the proportion of pre-smolt migrants and the size of smolts were observed when cumulative flow and flow variance were greater. Together, these data suggest that periods of high discharge in combination with high discharge variance are important for successful emigration as well as migrant size and the maintenance of diverse migration strategies.

[12] As the U.S. Fish and Wildlife Service demonstrated in its presentation to the SWRCB at the January 2017 hearing date, a longer averaging period for flows (7 days vs 3 days) results in reduced flow variability. In addition, flow shaping is also likely to reduce flow variability.

> Survival of migrating juveniles was higher when both cumulative discharge and discharge variance were greater.

Zeug et al. 2014 at 9. The analysis presented in our 2010 and 2013 comments demonstrated that average flow rates (which is simply a different expression of total volume) during the rearing period result in higher subsequent escapement. Zeug et al. 2014 demonstrates that total flow volume during the winter/spring months explains much of the variability in juvenile survival during the rearing periods, with substantially higher survival resulting from higher flow volumes. The authors suggest that floodplain inundation, reduced exposure to predators, and higher turbidity are potential mechanisms explaining these relationships. The analysis presented in Zeug et al. 2014 could be used in the SED to analyze the likely effects of flow alternatives on survival in the Stanislaus River, and the SED should be revised to include discussion of Zeug et al. 2014.[13]

Similarly, SEP (2016) calculated egg-juvenile survival rates on the Stanislaus by estimating the number of eggs deposited by each annual cohort of adult Chinook salmon returning to the Stanislaus River and comparing that total to estimated juvenile abundance near the river's confluence with the San Joaquin River the following spring. Those data reveal uniformly poor survival (mean = 1.1%) when flows were <~438TAF (53% of the median year unimpaired flow) in the Feb-Jun period (Figure 5). In the six years when Feb-Jun flows were >438 TAF, estimated egg-to-outmigrant survival averaged 9.4%. In every year that flow was greater than this level, estimated survival was higher than the highest survival recorded when flows were below 438 TAF. Thus, for salmon that spawn in the Stanislaus River, juvenile survival rates that are consistent with population growth are very unlikely to occur under current conditions when Feb-Jun flows <53% of the median Feb-Jun unimpaired flow for the Stanislaus River. The frequency of years with flows greater than this threshold must increase substantially in order to encourage positive population growth rates to occur frequently, as they would in a viable salmon populations and one that is being maintained in good condition. Frequent population growth will be needed to attain the narrative salmon protection objective and frequent occurrence of juvenile survival rates that support population growth will be required to maintain the required abundance of salmon after the target is attained. As with our prior analyses, which demonstrated the importance of seasonal flow rates on San Joaquin salmon success, this analysis likewise demonstrates that the Preferred Alternative is unlikely to achieve either the proposed narrative San Joaquin migratory fish viability objective in the SED or the existing narrative salmon protection objective in the Plan, and that greater seasonal volume of flow (a metric that is unaffected by flow shaping) is required.

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[13] The SED's use of a 7 day running average will result in greater variability than the 14 day running average proposed in 2012, although, as discussed *infra*, variability may be reduced or eliminated through flow shaping and shifting and variability would be increased through use of a 3 day running average instead.

SEP (2016) has calculated the spawner-to-juvenile outmigrant productivity levels that are needed to support population doubling (and thus the narrative salmon protection objective) within a reasonable amount of time on the Stanislaus River, and is developing analogous targets for the Tuolumne and Merced Rivers. By making reasonable assumptions regarding improvements to salmon survival in the Delta (an important outcome for Phase II of the SWRCB's Water Quality Control Plan Update), the SWRCB can determine productivity levels that are necessary to achieve the salmon protection and San Joaquin migratory fish viability objectives. A viable population would require survival rates that are typical of Chinook salmon populations in other watersheds throughout their range (e.g., Healy 1991; Quinn 2005). Indeed, survival rates necessary to serve each of these three goals (growth, resilience, species-typical) have been determined for the Stanislaus River population of Chinook salmon (SEP 2016) and analogous targets for the Tuolumne and Merced populations are in process. The SED should adopt these SMART (specific, measurable, attainable, relevant, and time-bound) biological targets in order to guide adaptive management and ensure attainment of the existing narrative doubling objective and proposed viability objectives.

Like productivity (population growth rates), life history diversity (e.g., the range of ages and body size at migration) is considered to be a key attribute of salmonid population viability (McElhany et al. 2000; Lindley et al. 2007). A diverse portfolio of life history types is believed to stabilize population dynamics and lead to greater population resilience (Lindley et al. 2009; Carlson and Satterthwaite 2011) by improving the prospect that at least some fraction of the migrant cohort will encounter favorable conditions in subsequent environments downstream – in other words, improvements in the distribution of life history types among juvenile migrants allows for improved average survival downstream (e.g., Satterthwaite et al. 2014). The importance of providing conditions that support juvenile life history diversity within salmon populations is an emerging theme in research on and management of Pacific salmon populations, including those in the Central Valley (Beechie et al. 2006; Lindley et al. 2009; Miller et al. 2010; Satterthwaite et al. 2014; Zeug et al. 2014; Sturrock et al. 2015). Indeed, Carlson and Satterthwaite (2011) recommended prioritizing restoration of San Joaquin Basin Chinook salmon populations as the most effective means of buffering the larger Central Valley Chinook salmon fishery against catastrophic population collapses.

Whereas much research has focused on smolts, fry and parr life history strategies are critically important to maintaining population viability of Chinook salmon populations on the San Joaquin tributaries (Sturrock et al. 2015; Sturrock and Johnson 2016 presentation to the SWRCB). For instance, Sturrock et al. 2015 wrote that:

> The loss of genetic and life history diversity has been documented across many taxonomic groups, and is considered a leading cause of increased extinction risk. Juvenile salmon leave their natal rivers at different sizes, ages and times of the year, and it is thought that this life history variation contributes to their population sustainability, and is

> thus central to many recovery efforts …. Juvenile [Chinook salmon] abundance and outmigration behavior [on the Stanislaus River in 2000 and 2003] varied with hydroclimatic regime, while downstream survival appeared to be driven by size- and time-selective mortality. Although fry survival is generally assumed to be negligible in this system, >20% of the adult spawners from outmigration year 2000 had outmigrated as fry. In both years, all three phenotypes contributed to the spawning population, however their relative proportions differed...

Sturrock et al. 2015 at 1.

Yet despite the SED's emphasis on "viable" salmonid populations, and the specific mention of genetic and life history diversity as indicators of viability in the proposed narrative San Joaquin migratory fish viability objective, the SED fails to analyze the effect of tributary and mainstem flow levels and flow variance on the production of different Chinook salmon or *O. mykiss* juvenile life history types. In addition to overall greater productivity in the egg-to-juvenile outmigrant segment of the salmon life-cycle, increases in winter-spring flow rates and variability correspond to increased production of fry and parr juvenile salmon life history types that contribute to subsequent adult returns (Figure 6; Sturrock et al. 2015; Zeug et al. 2014; Sturrock et al. *in prep*) and the size of outmigrating smolt (Zeug et al. 2014). The SED should incorporate results from these studies that demonstrate a relationship between flow volume and variability on production of a range of body sizes among juvenile Chinook salmon migrants. For instance, one way that the SED can analyze effects of flow alternatives on the timing of juvenile outmigration and life history diversity is to analyze the effect of flow alternatives on the duration of suitable migration temperatures.

Finally, the SED should adopt SMART targets for life-history diversity among San Joaquin River Chinook salmon juveniles. These targets can and should include a minimum seasonal period in which juvenile Chinook salmon migration is expected to occur and minimum distribution of size classes that should be detected during migrations. Such SMART targets have been developed for the Stanislaus River populations (both spring-run and fall-run) of Chinook salmon (SEP 2016) and are in process for the other two tributaries and lower San Joaquin River; the SED should incorporate these targets in order to ensure attainment of the narrative salmon protection objective, narrative San Joaquin migratory fish viability objective, and requirement that fish populations be maintained in good condition on the San Joaquin tributaries.

4. *The SED fails to analyze the need and potential for re-establishing self-sustaining viable populations of spring-run Chinook salmon in the lower San Joaquin River's three main tributaries and the positive effect that such restoration will have on the persistence of this run across the Central Valley and on the maintenance of the Chinook salmon commercial fishery.*

The number and diversity of somewhat independent units of Chinook salmon populations (their spatial distribution) is another key attribute of population viability (McElhany et al. 2000; Lindley et al. 2007). The San Joaquin River, and in particular, its Stanislaus River, Tuolumne River, and Merced River tributaries, historically supported some of the Central Valley's largest populations of spring-run Chinook salmon (Yoshiyama et al. 1998; Moyle 2002). These populations were extirpated at the end of the 20th century, but spring-run Chinook salmon (or, at least, Chinook salmon displaying behaviors typical of the spring-run evolutionary significant unit) have been observed recently in these waterways (e.g., Franks 2012) and restoration of multiple self-sustaining populations to Central Valley rivers draining the southern Sierra is a prime element in the NMFS' Endangered Species Act recovery plan for this species (NMFS 2014). Restoration of spring-run Chinook salmon populations in the Central Valley and eventual ESA de-listing will have important benefits to recreational and commercial fishing off the California coast (the spring-run's endangered status constrains the public fishery); the Board should analyze the effects of alternative flow levels on the restoration and maintenance of spring-run Chinook salmon populations below the dams on the Stanislaus, Tuolumne, and Merced Rivers.

b. The SED fails to examine how inadequate flows limit carrying capacity and the production of juvenile salmon populations from the three tributaries.

The SED fails to analyze how flow alternatives contribute to the existence of adequate habitat to support juvenile salmon production that is consistent with attainment of the narrative salmon protection objective. The maximum number of individuals of a given species that an area's habitat can sustain over the long term is known as the area's "carrying capacity." The carrying capacity of habitats on the San Joaquin Rivers tributaries and lower San Joaquin River mainstem must be adequate to support salmon doubling– in other words, there must be adequate space of sufficient quality to accommodate the number of spawning adults, eggs and juveniles, respectively, that are necessary to attain the production targets (i.e., after accounting for mortality between the different life stages). There is strong evidence that low flows cause insufficient carrying capacity (spawning/incubation habitat or juvenile rearing habitat or both) that limits production of juvenile salmon from the San Joaquin River's tributaries and on the lower San Joaquin River; at higher flow rates, carrying capacity constraints on juvenile production are reduced. The SED must analyze how flow alternatives affect the ability of the tributaries and lower San Joaquin River mainstem to achieve and maintain the salmon protection objective, and the influence of different flow levels on the potential for and efficacy of other approaches to generating additional habitat space (i.e., increasing carrying capacity). Below, we demonstrate that such analyses are possible using available data and tools.

Evidence suggests that the salmon carrying capacity of San Joaquin tributaries is driven by flow levels and that AFRP production targets cannot be achieved or maintained when low flow conditions occur frequently, as they do currently. The SWRCB's finding that seasonal average flows >10,000 cfs correspond with attainment of AFRP doubling objectives is consistent with the idea that habitat availability limits total population size on the San Joaquin tributaries. Similarly, Zeug et al. 2014 found that prior abundance of spawners is, in general, a poor predictor of juvenile survival/passage on the Stanislaus. In addition, in their 2016 presentation to the SWRCB, Sturrock and Johnson reported that the number of juvenile salmon produced on the Stanislaus River was unresponsive to the adult spawning stock in years with low winter-spring flow rates, but that production of juveniles (in all size classes studied) was well-correlated with the number of spawning adults in years with high flows (Figure 6; Sturrock et al. *in prep.; see also* SEP 2016). These findings indicate that carrying-capacity on the tributaries is limited at low flow conditions and increases at higher flows during winter and spring.

Flow-mediated carrying capacity may result from the effect of flow levels on a number of factors (or combination of factors) that are important determinants of salmon spawning and juvenile rearing and migration success. For example, through their effect on suitable temperatures, flow levels may affect the spatial and temporal availability of potential spawning and incubation habitat. Similarly, flow levels affect river temperature and availability of migration cues in ways that permit or prohibit successful juvenile rearing and migration. Also, river flow levels determine the magnitude and timing of availability of shallow off-channel rearing habitats that affect juvenile salmon growth and survival during their residence in fresh water (Sommer et al. 2001; Jeffres et al. 2008).

We note that the need for improved river flows to increase juvenile salmon survival and carrying capacity for various life history strategies on the San Joaquin River mainstem or its tributaries will not be eliminated (and, in some cases, may not even be reduced) as a result of physical manipulation of the riverbed or floodplain ("habitat restoration"). Indeed, the suitability of salmon habitat is an interaction of water quality (broadly construed) and the landforms that the water flows over and through. The relationship between the success of salmon habitat restoration and river flow rates is evident in the outcomes of restoration projects such as the multiple components of the "Special Run Pool 9 and 7/11" project led, in part, by Turlock Irrigation District and Modesto Irrigation Districts, which were intended to "reduce/eliminate habitat favored by predatory bass species and replace it with high quality Chinook salmon habitat" (TID and MID 2006 at ES-2) and increase juvenile Chinook salmon rearing habitat availability and quality, among other purposes.[14] Consultants to these water districts have admitted that post-project monitoring revealed that these projects largely failed to reduce density of salmon predators, increase Chinook salmon rearing habitat, or increase Chinook salmon survival; these

[14] This multi-part, multi-million dollar project, funded in part by CBDA, was the subject of a presentation to the State Water Board during its December 20, 2016 Modesto hearing on the Phase I SED.

outcomes were each attributed to low flows in the years that followed project implementation. For example, in explaining the "continued high abundance of smallmouth and largemouth bass at the SRP 9," the synthesis report concludes:

> The most important goal of the project was to increase Chinook salmon outmigrant survival. Several studies have identified a positive relationship between spring flows and Chinook salmon outmigrant survival from the Tuolumne River, as well as recruitment to the population in subsequent years (e.g., TID/MID 1992b, 2004a). This restoration project was based on studies conducted in the early 1990s that concluded that predation by largemouth and smallmouth bass was a significant source of density independent mortality for outmigrant salmon (TID/MID 1992a). *It is notable that this study was conducted during low flow years, when bass are expected to be most abundant (Brown and Ford 2002) and predator efficiency is expected to be high. The results may be most applicable to dry year conditions*.

TID and MID 2006 at 133 (emphasis added). The report then hypothesizes that the project may have successfully reduced the rate of river flow needed to provide a "safe velocity corridor" from >2000 cfs pre-project to >300 cfs post-project; discussion of other elements of the project reveal that "the greatest benefits of the project for rearing salmon occur during flows > 1,500 cfs." *Id*. at 135. The success or failure of these particular projects notwithstanding, it is clear that project proponents acknowledge that their benefits are flow-dependent and generally increase as flows increase. Thus, even if the SWRCB is presented with evidence that habitat restoration activities will occur on the tributaries or lower San Joaquin River mainstem, it cannot assume that these restoration activities will be protective of Chinook salmon populations without increases in river flow rates (below we address how the SWRCB should estimate the flow levels needed to provide benefits from one kind of habitat restoration – floodplain inundation).

The SED does not explore the carrying capacity of the San Joaquin River or its three main tributaries or the effect of flow regime alternatives on the imposition or alleviation of carrying capacity constraints on local Chinook salmon populations. Although it is possible that the current relationship between flow levels and carrying capacity for Chinook salmon juveniles (and thus, attainment of the AFRP doubling targets) could be affected by significant and widespread improvement in the quality and availability of off-channel rearing habitats (generically, "floodplains"), precise tailoring of releases to achieve particular environmental services, carryover storage requirements that improve temperature conditions, or a mixture of these approaches, the SED fails to analyze both the potential for this effect and the appropriate level of flow combined with specific levels of non-flow restoration. It is essential to analyze the interaction between the required flow regime and of any of these "alternatives" to flow, because the performance of these "alternatives" depends directly on the amount of water dedicated to environmental purposes. The SED must be modified so that it accounts for the effect of flow on available habitat and the efficacy of physical manipulations to the river (e.g., gravel augmentation or earth-moving on the floodplains) that are intended to expand carrying capacity for juvenile salmon.

c. The SED's analysis of the effect of flow alternatives on the availability of shallow inundated rearing habitat for juvenile salmon is flawed.

The SED acknowledges the importance of periodic inundation of shallow water habitats (loosely "floodplains") to the health and productivity of both aquatic and riparian ecosystems. SED at §19.3. The SED identifies specific benefits (including increased survival and growth) of short-term inundation for salmonid populations of the San Joaquin River valley as well as benefits that accrue to "steelhead, sturgeon, splittail…, bank swallow, western pond turtle, Fremont cottonwood and many other species." SED at 19-54. However, the SED does not describe a specific target for inundated floodplain habitat that is needed to support desired populations of salmon, populations of other organisms, or key ecosystem processes (e.g., food generation and transport; aquifer recharge; seedling germination) that rely on floodplain inundation. Instead, the SED reports a wetted-acre days metric in its assessment of the availability of shallow inundated salmon rearing habitat under different flow prescriptions, and the SED's analysis of changes in this metric boils down to 'more is better.' Because there is no quantified objective for salmon production (or other SMART targets), the SED does not provide a way to evaluate whether incremental changes in habitat availability, as indexed by "wetted acre days," produce meaningfully better outcomes that support viable salmonid populations and/or contribute to meeting salmon doubling targets.

In fact, "wetted acre days" is an inadequate indicator of actual useful habitat available to fish populations. Habitat is defined by numerous physical variables that can be measured in the field (e.g., cover and substrate) and measured or modeled assuming different flow conditions (e.g., depth, velocity, and duration of inundation). Acres that are inundated to a depth that is too shallow, for too short a period, at the wrong time, and/or that lack appropriate cover and substrate, may be included in the calculation of "wetted acre days," but they would provide little ecological value to migrating juvenile salmon and other fish.

In contrast to the approach in the SED, the Central Valley Flood Protection Plan (CVFPP; CDWR 2016a) modeled the habitat needed to support the salmon doubling objective for fall run Chinook salmon, including habitat needs in the San Joaquin Basin. As explained in more detail in the attached appendix to these comments (Appendix C), the CVFPP used estimated mortality rates for Chinook salmon after they exit Central Valley rivers to determine the number of juveniles that would need to exit each Central Valley tributary in order to result in AFRP production targets for that tributary (i.e., [number of juveniles exiting rivers] = [AFRP population natural production target] ÷ [post-riverine survival rate for Central Valley Chinook salmon]) and then used the Emigrating Salmonid Habitat Estimation model (ESHE; SJRRP 2012) to determine the number of acres of suitable rearing habitat required to support that number of juveniles. EHSE employs user-defined inputs (including field and laboratory estimates) of Chinook salmon juvenile growth, migration rate, and territory size, spawning location and timing (where and when fish enter the model), initial abundance, and mortality rates to estimate total habitat need in defined river reaches for each day that juvenile salmon are in the river. After "fish" enter the model, the population need for habitat at any location changes as individuals grow, migrate, and die. For each reach, the maximum habitat area needed on any one day during the migration season represents the total inundated habitat acreage needed in that reach to support the juvenile population that will lead to AFRP doubling targets. The sum of these reach-specific maxima across a river is the total area of inundated habitat needed on that river.

The SED should use the ESHE model to analyze rearing habitat required on the three tributaries and the lower mainstem San Joaquin River to support required salmon populations. The estimate of required rearing habitat for each waterway should be incorporated into the final SED as SMART environmental targets that guide adaptive implementation of plan. Below, we illustrate the proper approach to estimating habitat needs necessary to support the existing narrative salmon protection objective.

We analyzed the potential for different flow regimes (30-60% UIF as a 7-d running average) to produce CVFPP 2016 estimates of habitat need in the Stanislaus, Tuolumne, and Merced Rivers during the median year of inundation (which differs from the median year of volume; *see* Appendix D). The ESHE model estimates acreage of habitat required to support a target population assuming that each of the acres is 100% suitable; however, perfect habitat suitability is never found in the real world, so ESHE habitat estimates must be expanded based on an estimate of habitat suitability (i.e., [total actual rearing acreage required] = [ESHE estimated acreage] ÷ [habitat suitability][15]). We made several liberal assumptions regarding how much suitable rearing habitat would be generated by different flow regimes. For example, we assumed that available floodplain acreage would be relatively high quality when inundated for the proper duration (i.e., mostly appropriate depth, flow velocity, cover, etc.). Floodplain habitat must be inundated for a certain amount of time in order to attain high quality. Specifically, in low gradient areas, habitat must inundate for a minimum of 10 consecutive days before it will begin to generate significant prey items for Chinook salmon (Jeffres *unpublished data*) and reaches high levels after approximately 14 days (Grosholz and Gallo 2006); thus, we assumed that inundated habitat through the lower half of the tributaries and all of the lower San Joaquin mainstem would reach high suitability after 10 days. High gradient floodplains generate a different kind of food supply more quickly (i.e., terrestrial invertebrates that fall into the water

[15] Habitat suitability is expressed as a percentage of perfect suitability.

column; R. Henery, California Science Director for Trout Unlimited, *personal communication*), so we assumed that those reaches of habitat would reach their highest suitability after just 3 days of inundation. We also assumed that the timing of peak habitat need corresponded with the timing of peak flow (i.e., habitat inundation).

Our analysis revealed that, under current conditions, the full acreage of habitat identified in the CVFPP (2016) will not be inundated on any of the tributaries or the lower mainstem San Joaquin River during the median year of inundation, assuming a 7d average of unimpaired hydrograph (Figures D2 through D-5, Appendix D). This is a result of the current geometry (e.g., levees, incised channels) of these rivers; habitat restoration involving significant earth-moving will be necessary to increase the area inundated under future flow regimes. If reservoir releases are timed optimally ("flow shaping"), a flow regime between 50-60% UIF will inundate all of the targeted rearing habitat needed required in the lower San Joaquin in the wettest one-third of years (i.e., the 33% exceedance year for floodplain inundation; Figure D-6, Table D-4, Appendix D). Even in such an above-normal year, flow prescriptions ≤40% will not result in any days of complete inundation of the necessary habitat and will require that more than 5100 ac of habitat to be restored to a condition that will inundate under the 40% UIF hydrograph (and almost 6800 ac under the 30% hydrograph).[16]

Migrating juvenile salmon require rearing habitat throughout the course of their migrations (or, more accurately, individuals require feeding and resting habitat wherever their metabolism demands on their journey – the distribution of those different individual needs creates a need for well-distributed habitat along the migratory corridor). It is worth noting that outputs from the ESHE model can be used to determine the optimal spatial (and temporal) distribution of Chinook salmon rearing habitat. The SWRCB should evaluate habitat distribution results from new ESHE model runs as candidates for environmental objectives to include in the final SED.

Our estimates, based on CVFPP findings, illustrate the approach the SWRCB should take to (a) develop SMART environmental targets for rearing habitat and (b) evaluate how different flow levels contribute to attainment of those habitat targets. However, the model can and should be re-run for the final SED in order to incorporate appropriate assumptions. For example, because

[16] The necessary inundated habitat acreage may be achieved with less physical habitat restoration if habitat is restored to higher suitability than that assumed here or by using more aggressive flow shaping (effectively creating temporary flows that reflect much higher % UIF flow prescriptions). Aggressive flow shaping would require "borrowing" flows from other parts of the Feb-Jun measurement period which could result in negative conditions for juvenile salmon (e.g., increased temperature, poor migration cues, less habitat inundation) during the period from which the needed water was "borrowed" (*see* Temperature Appendix E). For example, flow could be reduced in the early part of the season because the size of the block (i.e., the seasonal volume of unimpaired flow) is highly uncertain until at least April. However, reductions in flows during the early part of the Feb-Jun period will tend to reduce success of the fry outmigrant life history type, which represents an important component of subsequent escapement and overall life history diversity on the tributaries (Zeug et al. 2014; Sturrock et al. 2015; Sturrock et al. *in prep.*). As noted above, flow shaping is also likely to result in reduced flow variability, and Zeug et al. 2014 demonstrates that decreased flow variability is associated with decreased migratory survival.

available habitat is likely to be of lower quality than we assumed, the habitat needs we identified from CVFPP outputs likely underestimate the actual need for inundated habitat acreage on the tributaries and the lower San Joaquin River mainstem to achieve either the existing narrative salmon protection objective.[17] Similarly, because the timing of peak habitat need and the timing of peak flow may not match, the flow-habitat levels identified in our example may underestimate the % UIF required to inundate the requisite habitat. Also, the CVFPP estimates did not cover habitat needs upstream of the CVFPP's geographic purview and so they do not include habitat needs in the upper reaches of the rivers. Furthermore, juvenile salmon survival rates assumed in the CVFPP do not account for likely improved future survival rates in the tributaries and in the Delta that result from improved standards in Phase I and Phase II. Finally, the CVFPP habitat estimates do not account for fish entering the lower San Joaquin River from the SJRRP reaches upstream of the Merced confluence; the SWRCB should account for the flow and habitat related needs of restoration program fish as they migrate through the lower San Joaquin River. The SEP (2016) has developed SMART targets for the extent of rearing and spawning habitat in the Stanislaus River and analogous objectives for the Tuolumne, Merced, and lower San Joaquin Rivers are in process, as are targets that specify the proper distribution of that habitat; the Board should adopt these targets to guide adaptive implementation of the plan and ensure that the tributaries and lower San Joaquin mainstem are a capable of supporting the existing narrative salmon protection objective as well as the survival and life history diversity targets associated with the proposed narrative San Joaquin migratory fish viability objective.

Regardless of specific inputs and outputs, our habitat analyses illustrate relationships between flow and availability of inundated salmonid rearing habitat that have important implications for the feasibility and implied costs of any flow regimes for the San Joaquin tributaries and mainstem. In general, at higher flow levels:

- <u>More habitat acreage will be inundated</u>. For example, our analysis indicates that 3,820 additional acres of habitat would be inundated in the median year for inundation on the tributaries and lower San Joaquin mainstem under a 60% flow alternative than under a 30% UIF flow regime
- <u>Less habitat restoration will be needed</u>. In our example, the increase in inundated habitat produced by differing flow levels alone resulted in a 28% reduction in the amount of habitat that would need to be restored under a 60% UIF versus a 30% UIF flow regime
- <u>Less flow shaping will be necessary</u> to achieve the desired inundated habitat acreage and duration. As a result, the risk of modifying the hydrograph in a way that produces poor conditions for migrating or rearing juvenile salmon is reduced.
- <u>Availability of potential restoration sites increases</u>. A greater range of elevations can be inundated under higher river stages that would accompany flow regimes of 50-60% UIF than would occur under those ≤40% UIF; this translates to a greater acreage of potential restoration sites.

[17] This analysis is focused solely on habitat needs for fall run Chinook salmon, not on spring run Chinook salmon or other species.

- The cost of needed habitat restoration will decrease, as will the time and resources needed to complete the necessary habitat restoration.

In short, habitat restoration will be necessary to reconnect the tributaries and lower mainstem San Joaquin Rivers to an acreage of their floodplains that is sufficient to support target salmon populations; however, the amount of restoration and cost of the required earth-moving decrease at higher flows and the availability of potential restoration sites increases under higher flow prescriptions. The analysis in the SED is flawed because it does not analyze the benefits of different flow prescriptions with respect to a population objective (i.e., the existing doubling targets); such an approach is necessary to generate SMART targets for rearing habitat. As a result, the SED ignores major societal obligations, costs, and obstacles associated with low flow prescriptions; any cost-benefit analysis of the SED's different alternatives is incomplete and biased without accounting for the effect of flow regimes on habitat availability.

Failure to attain the habitat restoration targets identified by the CVFFP (or more refined estimates that should be produced) should not be interpreted to mean that attainment of the existing narrative salmon protection standard is not possible. Rather, challenges in attaining needed rearing habitat for salmon reveal limitations on the potential for this management option to replace the need for flow and its associated in-channel habitat improvements (e.g., attainment of satisfactory temperatures). If inundated rearing habitat needs are not satisfied on the tributaries, additional improvements to in-channel survival upstream will need to be combined with additional rearing habitat downstream (i.e., in the lower San Joaquin River mainstem or the Delta).

d. The SED's analysis of the effect of flow alternatives water temperature conditions in the San Joaquin River and its tributaries is flawed.

Analyzing temperature effects of different flow management alternatives is valuable because temperature dictates many processes and outcomes in the aquatic environment, particularly for ecothermic (cold-blooded) organisms like salmon, their prey, and many of their predators. However, temperatures must be linked to actual biological relationships and thresholds in order to understand the effect of temperature differences among alternatives. The draft SED presents all temperature changes of 1^{o}F as though they have equal benefit, regardless of the absolute temperatures or life stages involved. However, as discussed below, the approach in the SED is scientifically inaccurate.

Temperature tolerances differ among Chinook salmon life stages and are characterized by thresholds and curvilinear effects (Temperature Appendix E, Figure E-2). For example, a 1^{o}F temperature difference between alternatives that both produce lethal results, detrimental results, or optimal results is not a biologically meaningful outcome. For any life stage, temperature changes in the range between "optimal" and "detrimental" (i.e., within the "sub-optimal" range of temperatures; *see* SEP (2016) for a discussion of the terms “optimal”, “sub-optimal”, and “detrimental”) are likely to produce real biological effects that translate to differences in population dynamics; however, within the “sub-optimal” temperature range, a 1^{o}F change between two alternatives will have different population consequences depending on where the absolute temperatures fall in the “sub-optimal” range. As a result of its simplistic rule for identifying meaningful temperature differences among alternatives, the SED fails to identify significant effects of its flow alternatives and implies that there will be different outcomes even when and where none are likely.

We analyzed the potential for different flow alternatives described in the draft SED to produce temperature-related effects that would translate to meaningfully different biological outcomes, including those that may prevent the tributaries from supporting required populations of salmon (Appendix E). We used temperature modeling results presented in Chapter 19 of the draft SED and temperature thresholds reported in USEPA (2003) and SEP (2016). Chapter 19 of the SED employs USEPA (2003) thresholds as a benchmark for effects. SEP (2016) also uses the USEPA values but includes additional temperature levels found in the literature that define “optimal” conditions and biologically significant thresholds that fall in the temperature range between EPA’s beneficial and its lethal thresholds; this latter set of intermediate temperature thresholds allowed us to distinguish between “fair” and “poor” temperature conditions (Appendix E, Figure E-2). The overarching point is that a range of temperature related effects with real biological significance occur between well-defined temperatures that create “optimal” (no temperature stress) conditions and lethal conditions.

The SED’s temperature results reveal that different flow alternatives can be expected to produce very different biological outcomes as a result of the different temperature regimes they generate during the February-June period.[18] On the Stanislaus River, flow regimes between 50% and 60% unimpaired flow (“UIF”) result in optimal incubation conditions (no temperature related mortality) to river mile 28.2 (“1/2 river”) through February of the warmest 10% of years, as opposed to fair conditions (associated with some temperature-related mortality) for alternatives ≤40% UIF (Appendix E, Figure E-3). Fair conditions persist through March at river mile 43.7 (“3/4 river”) under 50% and 60% UIF flow regimes, whereas poor incubation conditions (high temperature-related mortality) or worse are expected at this point in the river under alternatives ≤40% UIF. These are very real and important differences in temperature conditions that will result in significant reduction in the miles of the Stanislaus River that will available for salmon incubation (and a reduction in carrying capacity) under the 40% UIF flow regime during warmer years than would occur under ≥50% UIF conditions.

[18] The carryover storage requirements in the SED resulted in few meaningful temperature differences among alternatives on any of the rivers between September and January.

All flow regimes are expected to produce poor-temperature conditions, on average, on the Stanislaus River during May of the warmest 10% of years (Figure E-3), and this makes successful migration during April of the warmest 10% of years all the more important. Migrating juvenile Chinook salmon will experience some temperature stress, on average, from at least RM 13.3 under the 40% UIF alternative during April, whereas conditions remain optimal or close to optimal to the confluence under the ≥50% UIF flow regimes. As with spawning and incubation conditions, there will be significant temperature benefits to juvenile Chinook salmon migrating from the Stanislaus River under the ≥50% UIF alternatives in the warmest years as compared to alternatives that reserve less water for environmental protection.

Temperature conditions modeled in the draft SED can be expected to produce severe constraints for the Tuolumne River salmon population that impair population viability and the prospect of achieving or maintaining federal and state salmon doubling requirements (Figure E-4). At 40% UIF, both incubation and migration periods for Chinook salmon on the Tuolumne River will be truncated by a month as compared to ≥50% UIF alternatives. Under flow regimes ≥50% UIF, incubating salmon eggs on the Tuolumne River can be expected to experience low levels of temperature-related mortality during February and March of the warmest years down to at least RM 38.29 ("3/4 river"); temperature related mortality at this point in the river would be high under 40% UIF and incubation failure would occur here under alternatives with ≤30% UIF (Figure E-4). Whereas temperature conditions remain optimal-to-fair for migrating and rearing juvenile salmon through May at 60% UIF, and are at worst "fair" through May at 50% UIF, temperature related mortality for migrating juveniles will increase significantly at ≤40% UIF. Temperatures experienced by migrating juvenile salmon at 40% UIF are substantially higher (1.4-1.7^{o}F) under 40% UIF than at 50% UIF in April for at least 13 river miles (between "¼ river" and "confluence") and become "poor" under 40% UIF upstream of the confluence during May. These results clearly indicate that the Tuolumne River's carrying capacity for Chinook salmon will be severely constrained by limited incubation habitat in at least 1 of 10 years (and probably more frequently) at flow levels ≤40% UIF and carrying capacity will increase at flow levels ≥50% UIF.

Major differences in temperature-related stress between alternatives with ≤40%UIF and those with ≥50% UIF can be expected for juvenile Chinook salmon rearing and migrating along the Merced River corridor in April and in May during the warmest 10% of years (Figure E-5). In April, ≥50% UIF leads to conditions that are "fair" (low stress) in the lower 13 miles of the river, whereas 40% UIF flow levels produce "poor" (high stress) temperature conditions. Average temperature conditions in May of the warmest years will be poor under ≥50% UIF, but under ≤40% UIF, temperatures during May are "detrimental" (a level associated with nearly complete failure to complete the life cycle). Thus, flows ≥50% UIF result in 2 additional months, and many additional river miles, of suitable rearing and migration habitat compared to regimes ≤40%

UIF – temperature related impacts at ≤40% UIF represent a severe constraint on the Merced's ability to support a viable and self-sustaining salmon population.

Analysis of 7DADM temperature values in years with average temperature conditions (50% exceedance values) revealed similar patterns to those detected in the analysis of the warmest years (90% exceedance values; Figures E-3 through E-5). Higher % UIF flow prescriptions generally led to lower temperatures during the incubation and/or juvenile rearing and migration life stages. Although monthly mean temperatures of average years were, by definition, lower than those for the 90% exceedance years, temperature limitation on salmon productivity and carrying capacity in the tributaries would still be expected at flows ≤40%UIF.

Finally, temperatures expected in the lower San Joaquin River at Vernalis would prevent juvenile salmon migration during the average day in Mays of the warmest years under flow alternatives with ≤30% UIF; the 60% UIF flow regime produced temperatures that were more than 1^{o}F less than those expected under 40% UIF (Figure E-6) – such a temperature difference is expected to produce real improvement in salmon survival and condition. Under average temperature conditions (i.e., "mean" year temperatures), juvenile rearing and migration in the lower San Joaquin River during June will be more successful (especially during the earlier parts of the month) under flows ≥50% UIF than at lower flows. The truncation of juvenile Chinook salmon migration as a result of high temperatures expected under lower flow alternatives described in the SED represents a severe impact to the tributaries' ability to attain the existing narrative salmon protection objective, both through its impact on population survival rates (productivity) and because the limited time for successful development under low flow alternatives represents a reduction in the rivers' carrying capacity. Furthermore, because the reduction in migration opportunities will affect late migrating, smolt-sized salmon disproportionately, the low flow alternatives are likely to have severe negative effects on the life-history diversity attribute of population viability. The SED must analyze and account for these potential limitation son population viability and condition in evaluating and selecting a flow alternative.

The draft SED's analysis of temperature effects is flawed because it does not discriminate meaningful temperature differences from those which are unlikely to produce detectable biological responses. Substantial benefits to the productivity and resilience (i.e., viability) of San Joaquin valley salmon populations accrue under flow regimes ≥50% UIF that will not occur under flow regimes with ≤40% UIF. Temperatures presented in the draft SED for flow regimes ≤40% UIF would be expected to produce frequent catastrophic declines in fall-run Chinook salmon populations, with concomitant impacts to the ecosystems and fisheries that rely on these fish. Also, because temperature conditions that occur under flow proposals with ≤40% UIF would limit carrying capacity of the San Joaquin River's tributaries, even under average conditions, such flow alternatives would not be expected to support attainment and maintenance of AFRP population targets for these rivers.

Lastly, the analysis of temperature impacts in the SED and that performed above assumes no flow shifting or flow shaping (i.e., "borrowing" water from one part of the Feb-Jun period in order to produce desired effects in another part of the year). However, these adjustments to a 7 day moving average of unimpaired approach are almost certain to result in worse temperature conditions for the time periods from which the flow is borrowed. The draft SED does not anticipate or clearly describe how the water budget (the % UIF) will interact with (and potentially limit) flow-shaping operations and/or the need to restore juvenile rearing habitat for Chinook salmon even though these elements of the Draft SED's proposed management regime are inextricably linked. The draft SED fails to reveal these linkages or to explore how they will affect the implementation or efficacy of future flow standards.

e. The SED fails to analyze the effect of alternatives on dissolved oxygen levels in the lower San Joaquin River or its tributaries.

The SED incorrectly claims "adverse effects associated with low DO levels have not been documented in reaches of the SJR or the three eastside tributaries" (SED at 7-66). This statement is contradicted by the observation that

> "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)."

SED at 7-50.

As described in our previous comments (TBI et al. 2013), low dissolved oxygen levels are a longstanding and persistent problem in the lower San Joaquin River and some of its tributaries (citing CVRWQCB and CBDA 2006). Low DO levels can block migration of adult salmon and such effects have been documented on the lower San Joaquin River (Hallock et al. 1970); sturgeon are even more sensitive to low DO levels than salmon (Cech and Doroshov 2004) and conditions that frequently prevail in the lower San Joaquin River would be expected to block migrations of both green and white sturgeon adults and juveniles (CVRWQCB and CBDA 2006).

A mechanical oxygenation system has been installed in the Stockton Deepwater Ship Channel (SDWSC) to combat low DO levels. We demonstrated in our prior comments (TBI et al. 2013) that violations of the existing DO standard for this area are frequent when flows in the SDWSC are <1,000 cfs. We also demonstrated that when flows are <2,000 cfs at Vernalis flows in the SDWSC are generally <1,000 cfs. The Draft SED's proposed minimum flow levels (1,000 cfs at Vernalis) will result in flows in the SDWSC that are well below 1,000 cfs. Thus, despite the implementation of non-flow measures (the SDWSC aeration system), it is likely that the preferred alternative will result in DO levels that are below the minimum required for migrating salmon, steelhead, green sturgeon, white sturgeon, and other aquatic organisms. When such conditions prevail in the fall, adult fall-run Chinook salmon and steelhead migrations will be affected; when these conditions occur in the spring, migrations of adult spring-run Chinook salmon, adult steelhead, juvenile spring-and fall run Chinook and steelhead, green and white sturgeon, and striped bass are likely to be adversely impacted by low DO in the SDWSC. The SED must adopt flow standards that are reasonably likely to eliminate dissolved oxygen impairment of fish and wildlife beneficial uses in the lower San Joaquin River (including, but not limited to, the Stockton Deepwater Ship Channel); the best available science indicates that flow levels greater than the SED's proposed 1,000 cfs minimum at Vernalis will be required.

f. The SED Fails to Adequately Analyze the Effect of Flow Alternatives on in-Channel Habitat Conditions such as Turbidity and Flow Variability.

The SED's analysis of flow alternatives on in-channel habitat conditions is limited to temperature effects. The effects of increased sediment transport and turbidity in the river channels and the southern Delta as a benefit to fish populations were not analyzed, despite the fact that:

- increased flows will tend to transport additional sediments and increase water column turbidity;
- increased turbidity generally improves habitat quality (i.e., survival) for both migrating and estuarine-resident native fishes that live in the south Delta, including Delta smelt (SED at 7-133); and
- turbidity levels in the lower San Joaquin River and southern Delta are unnaturally low (SED at 7-133) and increases in turbidity can have significant positive effects in limiting known ecological stressors such as invasive aquatic macrophytes (Boyer and Sutula 2015) and threats to water quality, such as toxic algal blooms (Berg and Sutula 2015).

The draft SED (Chapter 6) evaluates only the potentially adverse effects of turbidity and erosion (they are "less than significant"). Because it fails to describe the potential for increased frequency of sediment mobilizing flows and changes in baseline turbidity of the lower San Joaquin River and southern Delta, the draft SED ignores differences in potentially important ecological benefits of the flow alternatives. The SED should be revised to account for these positive effects and analyze, to the extent possible, potential differences in sediment transport and turbidity under hydrographs that track natural runoff timing (e.g., a 7 day moving average of UIF) as compared to fully engineered (shaped) hydrographs.

The SED must integrate evaluations of flow on habitat and water quality conditions. Flows that inundate floodplains but do not produce adequate temperatures for juvenile salmon attempting to rear in those habitats will not lead to attainment of the existing salmon protection objective or proposed San Joaquin migratory fish viability objective. Flow levels that achieve adequate temperature protections throughout the juvenile Chinook salmon migration and rearing season, and inundate adequate habitat area while simultaneously supporting other important habitat characteristics are those that have a reasonable likelihood of attaining plan objectives for salmonids.

We have identified multiple quantitative approaches that the SWRCB should apply to evaluating the likelihood that flow alternatives will attain the narrative salmon protection objective and the San Joaquin migratory fish viability objective. In a system that will not be physically modified (i.e., "restored" by earth-moving activities), the strong and significant empirical relationships between seasonal flow and both abundance and productivity of San Joaquin River salmon populations remain the best predictors of the potential for flow alternatives to meet plan objectives. In addition, the relationship between flow and productivity (survival) and diversity of successful life-history types emigrating from the tributaries provides a strong basis for evaluating the effects of different flow alternatives at a local level. Finally, data and analytical tools are available to analyze some (but not all) of the functional mechanisms by which flow alternatives produce salmon habitat so that the SWRCB can analyze the likely efficacy and relative costs of some "alternatives" to flow – integration of results from temperature and floodplain inundation-habitat creation models is required, at a minimum, to evaluate the potential for widespread restoration of rearing habitat to support the narrative doubling objective and the salmon viability objective.

g. The SED's reliance on outputs of the SALSIM model is not consistent with the best available scientific information, as the SED acknowledges, and the SED should not rely on these results.

Rather than incorporate the wealth of scientific information and robust relationships that link flow levels to San Joaquin Chinook salmon abundance, productivity, life history diversity, and both spatial and temporal habitat availability, the draft SED only analyzes the relative performance of its flow alternatives using the CDFW SALSIM model. The SED itself, as well as comments from SWRCB and CDFW staff in the public hearing, acknowledge that the SALSIM model is flawed and currently does not represent the best available science. As CDFW staff acknowledged, inputs to the model are known to be flawed, and that the modeled estimates of salmon production in the draft SED "are likely substantially lower than they should be." CDFW presentation to the SWRCB on 1/3/2017. CDFW's presentation shows that the current model overestimates egg mortality and underestimates juvenile mortality, and that it fails to adequately account for the effects of flows and water temperatures during the winter/spring period. *Id*. Regarding SalSIM results, the SED admits that the effects of floodplain inundation and water temperature "are not represented by the model in a manner that is consistent with current scientific information." SED at 19-74. In addition, the SED admits that the SALSIM model also understates the effects of improved instream flows on success of migrating and rearing juvenile salmon because salmon returns during the first several years of the model (1994-1997) are not affected by any instream flow improvements in those years, and years 2005-2009 are affected by ocean conditions and the model forces production to decline in those years regardless of the flow conditions. SED at 19-85.

The SalSIM results do not track the historical response of San Joaquin salmon production and escapement with winter-spring flows in the San Joaquin River, as measured at Vernalis. As the SED notes, even were the model inputs valid, model outputs are useful only for relative comparison. SED at 19-76 and 19-85. However, even relative comparisons among model alternatives presented in SED Table 19-32 (also Figure 19-14) do not support the SED's choice of preferred alternative because (a) there is no indication that the preferred alternative is likely to attain the existing narrative salmon protection objective or the proposed San Joaquin migratory fish viability objective (*see analyses below*) and (b) there is no comparison of the relative performance of the specific operational schemes (flow shifting and aggressive flow shaping) that are part of the preferred alternative under any environmental allocation other than 40% UIF.

CDFW explained in its presentation to the SWRCB that they are recalibrating the model after correcting flawed model inputs. However, we recommend that the final SED should not rely on SALSIM results. SALSIM modeling that is included in the Final SED should be accompanied by appropriate caveats regarding reliability of the model results, and any SALSIM model results that are presented in the SED should focus on juvenile production, rather than escapement, since this proceeding is focused on actions during the winter/spring time period that affect juvenile production.

IV. The SED Fails to Analyze Potential Adverse Environmental Impacts of Waiving Instream Flow Requirements in Future Drought Emergencies, as Authorized in the Program of Implementation.

In the Program of Implementation, the SWRCB proposes to authorize waivers of the proposed flow requirements,[19] based upon a determination of a state or local state of emergency. SED, App. K, at 35. Although not specifically stated, we presume that the SWRCB would consider

[19] Notwithstanding this language in the SED, state law requires the SWRCB and all other state agencies to implement water quality standards that are in an adopted water quality control plan. Cal. Water Code § 13247. The SWRCB cannot use an administrative action, such as a petition for temporary urgency change petition, to change water quality standards absent the waiver of section 13247 by the Governor, an action that is wholly inappropriate for drought conditions that are reasonably certain to recur. In addition, any such waivers of water quality standards, such as through adoption of a temporary urgency change petition, would likely violate the Clean Water Act without review and approval of the U.S. Environmental Protection Agency.

extended droughts to constitute a state of emergency under this section. However, droughts should not be considered an unexpected emergency, because they are a fact of life in California. The modern hydrologic record includes several multiyear drought sequences, and hydrologic modeling accounts for these historic droughts. The SED's failure to plan for extended drought conditions is wholly inappropriate and unlawful, and the failure to identify likely adverse environmental impacts that would result from future waivers – and potential mitigation measures for such impacts – violates CEQA.

We recognize that specific off-ramps from the proposed flow requirements may be appropriate during extended multi-year drought periods, provided that the SED: (1) establishes in advance of these periods the hydrologic criteria and triggers to determine when such waivers would be appropriate, rather than ad hoc or arbitrary political criteria; (2) identifies default compliance measures during such waivers, and; (3) analyzes the likely effects of imposing the default compliance measures in order to ensure that these waivers would not result in significant adverse environmental impacts and that the objectives are still achieved over time.[20] However, the SED wholly fails to take these steps: it fails to quantify the frequency, magnitude, and duration of such waivers; it fails to identify potential measures that would be required instead, and; it fails to analyze the environmental impacts of implementing alternative measures. As a result, the SED fails to identify likely adverse impacts of the proposed action, and fails to analyze whether the proposed action is likely to achieve the narrative salmon doubling objective. This is unlawful.

As the SWRCB is well aware, the approval of temporary urgency change petitions to weaken or waive existing water quality standards during the recent drought has had devastating impacts on fish and wildlife. *See, e.g.*, Defenders of Wildlife et al., Request for Emergency Regulations, August 9, 2016;[21] Central Valley Project and State Water Project, 2016 Drought Contingency Plan (January 15, 2016), at 13-15;[22] letter from NMFS to USBR and DWR regarding reinitiation of consultation, August 17, 2016.[23] Waiving the proposed flow requirements during future droughts is also likely to cause significant adverse environmental impacts on salmon and other fish and wildlife. For instance, increased water temperatures are likely to result from reduced instream flow requirements, which would likely cause significant adverse impacts on incubating egg and/or juvenile salmonid survival. Reduced instream flows also would likely increase

[20] Equally important, the SWRCB must evaluate whether more protective measures are needed in non-drought years to ensure population viability and achievement of objectives will be maintained in light of the expected frequency and duration of drought years in the future.

[21] This document is available online at: https://www.defenders.org/publications/dow-nrdc-tbi_request_for_emergency_regulations_final.pdf and is hereby incorporated by reference.

[22] This report is available online at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/plans/2016dcpfebnov.pdf and is hereby incorporated by reference.

[23] This letter is available online at http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/nmfs_response_to_reclamation_s_request_to_reinitiate_the_2009_cvpswp_operations_consultation_-_august_17__2016.pdf and is incorporated by reference.

predation, reduce dissolved oxygen in the river, and ultimately result in lower salmon survival. This conclusion is consistent with the scientific information presented in our comments and in the SED, which demonstrates lower salmon survival at lower flow volumes.

However, the SED completely fails to analyze the potential environmental impacts of waivers of instream flow objectives pursuant to this authority. Moreover, the declaration of a state of emergency resulting from drought conditions is an arbitrary political, not a specifically defined hydrologic, determination; for instance, in recent years, drought declarations have remained in place during the first wet year following a drought sequence (2011, 2017), and this could result in major hydrologic alteration and adverse impacts to fisheries. Instead of relying on an arbitrary political determination of drought, the SED must identify hydrologic conditions that could justify an offramp from the instream flow objectives. We recommend that the Board should not allow such offramp conditions to be implemented unless and until unimpaired flow conditions are critically dry for at least the prior two consecutive years, and have provided similar language in our redline of Appendix K.

V. The Program of Implementation Fails to Ensure that Discretion in Flow Shaping and Volume will Achieve Water Quality Control Plan Objectives and the SMART Biological and Environmental Targets Used to Track Compliance and Effectiveness.

In Appendix K of the SED, the SWRCB proposes a deeply flawed governance scheme, and inappropriate levels of discretion to change flows and flow standards, without analyzing whether such foreseeable changes are likely to achieve the plan objectives and without requiring that the narrative salmon protection objective and all SMART biological and environmental targets will be met with the change. *See* Draft SED, Appendix K, at 29-31. In addition, Table 3 is inconsistent with this language in the Program of Implementation allowing for greater flexibility. We have provided a redline of this language in Appendix K and Table 3 of the SED, consistent with the discussion below.

The draft plan relies on "adaptive implementation" of the preferred alternative (Appendix K). Adaptive implementation is expected to reflect scientific information that emerges from monitoring or studies on the tributaries or from elsewhere. The intent of "adaptive implementation" is thus quite similar to the better-known rubric of "adaptive resource management" ("ARM"), proposing to use adaptive implementation to optimize flows to achieve the objectives. SED, Appendix K at 30. However, the draft plan provides very little specificity regarding what it means to "optimize" flows or what information will be utilized to determine the optimal level of flow in any given year or time period within that year. ARM requires the expression of desired outcomes in terms of targets that are specific, measureable, achievable, relevant to a plan goal, and time bound (SMART); without such targets, it is impossible to know if the plan is successful or when and to what end plan elements should adapt. The draft SED suggests that future adaptive management decisions should be focused towards achieving such targets, but it does not provide examples of the targets or incorporate known SMART targets that are integral to achieving the existing narrative salmon protection objective and proposed San Joaquin migratory fish viability objective.

The SEP (2016) has defined SMART targets that define the biological outcomes (i.e., egg-to-juvenile survival/productivity; life history timing and diversity) necessary to attain the narrative salmon protection objective for San Joaquin River fall-run Chinook salmon, and the requirement that dam operators maintain fish populations in good condition for fall-run, spring-run Chinook salmon, and both resident and anadromous populations of *Oncorhynchus mykiss*. In addition, SEP (2016) identifies the timing and spatial extent of the physical, chemical, and biological conditions that best available science indicates are necessary to achieve those biological targets. Several of these targets are referenced in section III of these comments. The SWRCB should adopt key SMART targets (particularly, egg-to-juvenile survival/productivity, and both timing and size-distribution targets for life history diversity) for fall-run and spring-run Chinook salmon, and both resident and anadromous forms of *O. mykiss* as well as the supporting environmental objectives into its final SED so that these targets can guide adaptive management and the program of implementation.

More generally, the proposed standards for making adaptive changes in Appendix K, and the proposed governance scheme for who would decide to make such changes, are deeply flawed and fail to ensure that the plan objectives are likely to be achieved. With respect to the standards for making changes in implementation, Appendix K would authorize changes in implementation that would change the percent of unimpaired flow, shape flows within the February to June period , shift flows to later in the year, or modify the minimum base flow. SED, Appendix K at 29-31. As currently drafted, the language would allow changes if they would achieve "any" biological goals and would not require the Board to find that with the change, implementation is likely to achieve the Plan's existing salmon protection objective. *Id*. at 30. In addition, the language creates a huge loophole for experiments in implementation, which do not require the changes to be based on meeting SMART targets and/or plan objectives. *Id*. at 31. This is wholly inappropriate, and instead, any changes in implementation must be made solely to achieve all SMART targets and plan objectives, including the narrative salmon protection objective.

With respect to the governance scheme, the SED proposes to establish a working group of water users, fishery agency staff, and other experts who would have a decision-making role. *Id*. at 32. However, the SED does not require any members to represent the public interest, conservation groups, or the fishing industry (let alone roughly equal representation of interests), raising basic issues of fairness. Moreover, the specific decision rules, to the extent identified in the SED, are likely to lead to gridlock and a failure to achieve the Plan objectives and SMART targets.

For instance, the governance proposal requires the concurrence of all members of the working group for the Executive Director to approve any changes to the percent of unimpaired flow within the range, or changes to the minimum flows. *Id*. at 30-31. Given the broad opposition from tributary water users to a percent of unimpaired flow approach and to the specific flow range in this and the prior draft SED, their rejection of the scientific information that justifies flow requirements, and their refusal to participate in the scientific process to establish SMART targets, it is exceedingly unlikely that water users would agree to higher unimpaired flows within the range. At the same time, it is wholly inappropriate to give water users power to veto changes on flows within the range; changes on the percent of unimpaired flow and minimum flow levels must be made, based on the best available science, on the likelihood to achieve the plan objectives and SMART targets. With respect to adaptive implementation decisions that shape flow (instead of relying on the running average) or which shifts flows to later in the year, the SED proposes that the Executive Director can approve the changes if one or more members of the working group agrees. *Id*. As a result, for any of these proposed changes, the likely outcome is gridlock where unanimity is required, and dueling recommendations when it is not. And the process will likely be very resource intensive process, as DWR and USBR's various stakeholder processes have demonstrated, with very little benefit.

Instead of the expensive, unwieldly, and unfair process proposed in the SED, we urge the SWRCB to create a public process for all stakeholders – including water users and the public – to provide input on decisions, but ultimately the SWRCB must require that fishery agencies and SWRCB make final decisions on adaptive implementation. This is consistent with the approach taken in the 2008 and 2009 biological opinions, after the prior consensus based approach to adaptive implementation was an abject failure that jeopardized the continued existence of endangered species and was found to violate the Endangered Species Act. Of course water users and reservoir operators should provide input, but all decisions should be made by the fishery agencies and SWRCB. Absent such changes, the governance scheme is almost certain to fail, jeopardizing achievement of the objectives. Regardless of the structure, the decision-making process and the results should be subject to periodic independent scientific review organized by the Delta Science Program or the SWRCB itself.

In addition to these problems that apply to all of the adaptive implementation measures, the specific adaptive implementation measures (a) through (d) also must be revised.

First, Appendix K proposes to allow the Executive Director to alter the required percent of unimpaired flow within the 30-50% flow range every year.[24] However, given the 3 year life cycle of Chinook salmon, it is very likely that several years of monitoring data from

[24] There is no scientific justification for allowing for 30% of unimpaired flow, as the best available science demonstrates this flow level is not likely to achieve a viable salmon population, let alone achieve the narrative salmon doubling objective required by the Plan.

implementation will be necessary before there is sufficient information to justify a change within the flow range, particularly given the changes in year to year hydrology. In addition, by changing the percentage of unimpaired flow on an annual basis, the scientific information generated by the monitoring program will be of limited utility, because there will be even smaller sample sizes and additional covariates (changes in flow volumes / rates and other operations) against which to evaluate effects. Instead, we recommend that Appendix K explicitly require a review of percentage of flow within the flow range every 5 years, reviewing the monitoring data, progress towards achieving the salmon doubling objective, and independent scientific peer review by the Delta Science Program. This provides greater certainty to stakeholders and ensures a more robust scientific framework for decision-making.

Second, we agree that changes from a 7 day running average[25] can be appropriate in some instances order to achieve SMART targets and the plan objectives, but as discussed above, before making any such change the SWRCB or Executive Director must make a finding that the change is necessary to achieve the plan objectives (including the doubling objective) and all SMART targets. A key benefit of the use of a running average is to mimic the variability of the natural hydrograph, which is critical to juvenile salmonid survival. In addition, the language in the SED may unintentionally result in lesser flow volume than that required by a strict running average, and we have included language to ensure that the full flow volume available on a running average is also available through flow shaping.

Lastly, the SED inappropriately proposes to allow substantial shifting of flow from the spring period to the summer or fall months. Such flow shifting is likely to cause significant adverse effects on achieving the plan objectives, since best available science demonstrates that the actual volume of flow in this period is the strongest statistical predictor of juvenile salmon survival. *See* Zeug et al. 2014. Moreover, the SED largely fails to analyze the potential environmental effects of such flow shifting, particularly at levels below 40% of unimpaired flow (the draft currently would allow for less than 30% of the unimpaired flow during these months). Instead of allowing flow shifting from February through June, we recommend allowing flow shifting only from flows in the month of June; this allows some flexibility to address water temperatures and other concerns, but also ensures that the bulk of flows are released in the spring months when they affect juvenile salmon survival. To the extent there are substantial problems in other months that do not arise from implementation of increased spring flows, the SWRCB should establish water quality objectives for those other months.

[25] As demonstrated by the testimony of the U.S. Fish and Wildlife Service on DATE, using a 7 day running average already loses much of the variability of flow. Given the importance of flow variability, *see* Zeug et al. 2014, a 3 day running average should instead be encouraged.

VI. The Program of Implementation Must Include Enforceable Carryover Storage Requirements in Upstream Reservoirs to Mitigate and Avoid Impacts, Consistent with the Substitute Environmental Document.

The SED appropriately analyzes and discloses that it requires implementation of enforceable carryover storage requirements at upstream reservoirs, in order to mitigate potentially significant adverse impacts that might otherwise result. Such measures are clearly within the SWRCB's authority, and they are appropriate. Moreover, because the SED fails to analyze potential adverse impacts in the absence of carryover storage requirements, it would be unlawful for the SWRCB to fail to implement these requirements. Nonetheless, we recommend that the SWRCB, consistent with the analysis in the SED, should revise the Program of Implementation to more clearly require implementation of enforceable carryover storage requirements at upstream reservoirs.[26]

The SWRCB unquestionably has the legal authority to impose downstream water temperature or carryover storage requirements at upstream reservoirs, in order to prevent harm to Public Trust resources. *See, e.g.,* Water Rights Order 90-5; Water Rights Order 91-03, at 10-11 (explaining that, "[i]f the Bureau failed to meet the temperature control requirements in Order WR 90-5 because it did not retain sufficient cold water in storage, and retention of cold water was within the Bureau's reasonable control, the Bureau would be in violation of Order 90-5."); Water Rights Order 2015-0043 (order denying in part and granting in part petitions for reconsideration and addressing objections, upholding requirements to establish carryover storage requirements for Shasta, New Melones, and Folsom reservoirs); letter from Tom Howard to Ron Milligan, July 8, 2016, at 2 (approving the 2016 Shasta water temperature plan, conditioned upon meeting cold water pool requirements and requiring reductions in reservoir releases if such conditions are not met); Order Approving in Part and Denying in Part a Petition for Temporary Urgency Changes in permit Terms and Conditions Requiring Compliance with San Joaquin River Flows, April 19, 2016, Term and Condition 5 ("Reclamation shall achieve an end of September 2016 carryover storage level of 415 TAF in New Melones Reservoir."); Water Rights Decision 1644, at 177-78 (requiring implementation of temperature management plan and reserving continuing authority to establish water temperature requirements for the lower Yuba River for the protection of fishery resources). Reservoir carryover storage requirements are appropriate mitigation measures under CEQA, intended to avoid significant adverse environmental impacts that might otherwise result.[27]

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[26] Appendix K appropriately includes language in the Program of Implementation requiring the imposition of mitigation measures to avoid unreasonable impacts to groundwater using its existing authorities, including authorities under Article X, Section 2 of the Constitution and the Sustainable Groundwater Management Act. SED, Appendix K at 28.

[27] Similarly, under the physical solution doctrine and section 5937 of the Fish and Game Code, the Board has authority and duty to require reservoir operations to maintain fish in good condition, such as maintaining carryover storage and/or a coldwater pool, when at other times the water rights holder benefits from substantial water

The SED appropriately includes reservoir carryover storage requirements in the modeling and analysis of potential environmental impacts. Implementation of such measures is necessary to avoid the likely adverse impacts that would otherwise result, and because the SED does not analyze these potential adverse impacts in the absence of such requirements. The SWRCB would violate CEQA if it failed to implement carryover storage requirements consistent with those included in the SED, because the SED does not analyze potential impacts if such reasonable carryover storage requirements are not implemented.

VII. The SED Fails to Consider the SWRCB's Legal Authority to Require Water Rights Holders to Invest in Habitat Restoration and Other Non-Flow Measures.

As discussed in our prior comments, the SWRCB has legal authority to require water rights holders to invest in habitat restoration and other non-flow measures under the physical solution doctrine. *See* 2013 Comments, Exhibit 2, at 6-7. For instance, in Decision 1631, the SWRCB ordered the Los Angeles Department of Water and Power to undertake habitat restoration projects in order to reduce flow requirements, stating that, "as part of a physical solution allowing for diversion of water for municipal use, LADWP can be required to undertake waterfowl habitat restoration measures. Waterfowl habitat restoration can serve to restore public trust uses while requiring a smaller commitment of water." Decision 1631 at 118; *see* SWRCB Water Rights Order 98-05 (approving habitat restoration measures implementing Decision 1631). The SWRCB and the courts have discussed the physical solution doctrine in other decisions and orders as well. *See, e.g.*, SWRCB Water Rights Order 90-16 (holding that under the physical solution doctrine and section 5937 of the Fish and Game Code, the Board can require releases from a reservoir greater than unimpaired inflow during certain times of the year, in order to keep fish in good condition); Decision 1630 (discussing the physical solution doctrine in the context of the SWRCB's decision finding waste and unreasonable use and mandating water conservation measures in the Imperial Irrigation District); *City of Barstow v. Mojave Water Agency*, 23 Cal.4th 1224, 1249-51 (2000). The SED ignores the authority of the SWRCB to

diversions from the river. *See also* SWRCB Water Rights Order 90-16. As the California Department of Fish and Wildlife concluded in a recent amicus brief to the Ninth Circuit Court of Appeals,

> As early as 1932, a California Court of Appeal held that a water right holder has no authority to divert and use the waters of the state "regardless of its duty in so doing to protect the fish therein" and that "the grant of the right to erect a dam" must "be construed to be under the implied condition to keep open the fishways." *People v. Glenn-Colusa Irrigation Dist*., 127 Cal. App. 30, 36-37 (1932).

Amicus Curiae Brief of the California Department of Fish and Wildlife in Support of Federal Cross-Appellants/Appellees, San Luis & Delta Mendota Water Authority v. Jewell, Case No. 14-17479, Ninth Circuit Court of Appeals, December 21, 2015.

require water rights holders to invest in habitat restoration and other non-flow measures as part of the program of implementation, and it should be revised accordingly.

VIII. The SED's Analysis of Changes in CVP/SWP Water Exports is Flawed Because it Fails to Consider the Right of Upstream Water Users to Dedicate these Flows Under Section 1707.

As we discussed in our prior comments, tributary water rights holders have the right to temporarily dedicate water to instream flow through the Delta under sections 1707(c) and 1725 of the Water Code, and prevent downstream water users, including the CVP and SWP, from diverting any of this flow absent a transfer agreement between the parties. *See* TBI et al. 2013 at 42. By dedicating flow to instream use under section 1707(c), these flows would not contribute to meeting instream flow requirements such as new Delta outflow requirements adopted in Phase II. Cal. Water Code § 1707(c). As we discussed in our prior comments, this would not cause an injury to downstream water rights holders. TBI et al. 2013 at 42 (citing *State Water Resources Control Board Cases*, 136 Cal.App.4th 674, 798-806 (2006)). However, the SED's analysis of potential changes in water exports by the CVP and SWP fails to consider this legal right, and the draft Program of Implementation likewise ignores this legal right. *See* SED at 5-78 and Appendix K. The SWRCB should revise the SED and Appendix K to explicitly recognize this right, and condition the discussion of changes in Delta exports in the SED accordingly.

IX. The SED Fails to Adequately Consider the Feasibility of Protecting Public Trust Resources Because it Fails to Consider Improvements in Water Use Efficiency and Alternative Water Supplies.

In order to fulfill its mandatory duty to protect the Public Trust to the extent feasible, as well as to balance potential impacts to other beneficial uses of water in setting water quality standards, the SWRCB must consider the availability of water supplies from wastewater recycling, improved water use efficiency, urban stormwater capture, and other sources. Unfortunately, the SED fails to do so. We have discussed the necessity of this analysis of alternative supplies at length in our prior comment letters, and those prior comments are fully incorporated by reference. *See* TBI et al. 2013; TBI et al. 2013 Exhibit 2. We briefly summarize those points again:

- First, the SWRCB has considered the availability of recycled water and other water supplies in determining the feasibility of protecting Public Trust resources in Mono Lake. *See* Decision 1631 at 165-168, 176-177. Similar feasibility analysis was required by the courts in decisions to protect Public Trust resources in Putah Creek and the American River. *See* Brian Gray, Ensuring the Public Trust, 45 U.C. Davis Law Rev. 973 (2012).
- Second, the SWRCB is required to consider the need to develop and use recycled water in establishing water quality objectives, *see* Cal. Water Code § 13241(f), and this

approach of considering alternative water supplies is consistent with the statutory obligation to reduce reliance on the Delta and invest in regional and local water supplies, *see* Cal. Water Code § 85021. The necessity of consideration of alternative water supplies in determining the feasibility of protecting Public Trust resources is essentially an exercise of the physical solution doctrine, where such a physical solution can reasonably accommodate both consumptive uses and protection of the Public Trust. *See* Brian Gray, Ensuring the Public Trust, 45 U.C. Davis Law Rev. 973 (2012). Unlike consumptive users of water, there are no alternative water supplies for salmon and other native fish species in these tributaries.

- Third, the SWRCB lacks the authority to balance away statutory expressions of the Public Trust, such as section 5937 of the Fish and Game Code or the California Endangered Species Act, and likewise lacks the authority to balance away achievement of the narrative salmon doubling objective. *See, e.g., California Trout, Inc. v. State Water Resources Control Bd.*, 218 Cal.App.3d 187, 195 (1990); Decision 1631 at 12, 172; Decision 1644 at 27.
- Fourth, while the SWRCB must consider economic impacts, it must also consider economic benefits of protecting Public Trust resources, including the benefits of improved water quality, recreation, and sport and commercial fishing. In addition, the fact that alternative water supplies would incur some additional costs does not preclude protecting Public Trust resources; instead, the question is whether these costs make protection of the Public Trust infeasible. *See* Decision 1631 at 176-177.

Unfortunately, the revised SED fails to meaningfully analyze the availability of alternative water supplies, including improved agricultural and urban water use efficiency, water recycling, or groundwater banking and recharge projects. As a result, the SED overstates likely water supply impacts and fails to provide the information necessary for the Board to determine the feasibility of fully protecting Public Trust resources consistent with the SWRCB's 2010 report (or any lower flow alternative). The SED must be revised to consider alternative water supply projects, including those discussed *infra*.

X. The SED's Analysis of Water Supply Impacts is Flawed and Overestimates Likely Impacts

The SED also fails to accurately assess likely water supply impacts to both urban and agricultural water users. The analysis of potential water supply impacts in the SED appropriately begins by modelling the potential reduction in total surface water supplies under the alternatives. However, the analysis of total water supply impacts in the SED is inaccurate because it fails to consider the likely effects on water supply from waiving flow requirements during future droughts, as authorized in the Program of Implementation. As the SED demonstrates, potential water supply impacts under the alternatives are minimal in wet and above normal years and higher in dry and critically dry years. *See* SED at ES-26. As a result, the failure to consider the effects of weakening or waiving flow requirements in future droughts – as the SED authorizes – results in substantially overestimating likely water supply impacts, as well as potential impacts to agricultural acreage, economics, and employment. The analyses and text in the SED should be revised to be consistent with the authority in the Program of Implementation to waive or weaken flow standards during future drought emergencies, and with our comments regarding changes to this authority.

a. The analysis of potential agricultural water supply impacts is flawed.

The SED then assumes that the City and County of San Francisco would enter into water transfer agreements with agricultural water users, paying those users to bear the water supply impact. However, while the SED accounts for the economic impact to SFPUC from these water transfers, it fails to account for the economic benefits to agricultural users from such transfer agreements; thus it overstates the economic impacts to agricultural users in its analysis of economic impacts. Some stakeholders have argued that such water transfer agreements are not likely to occur, in which case, the water supply impacts to agricultural users would be lower than the 14% reduction in surface water supplies under the 40% flow alternative demonstrated in the SED (and impacts to urban users would be higher by an equal amount, consistent with the estimates in Appendix I of the SED).[28] The SED should be revised to quantify the reduced water supply impacts to agricultural water users without the assumed water transfers to SFPUC, consistent with the analysis of potential urban water supply impacts in Appendix I.

The SED also assesses potential impacts to groundwater, providing estimates of potential water supply impacts with no increase in groundwater pumping, with 2009 levels of groundwater pumping, and with 2014 levels of groundwater pumping. *See* SED, Appendix G at G-28 to -29.

However, because this is a water quality plan, and not a water rights decision, the specific impacts to any water rights holder or category of user cannot be determined with great specificity. Importantly, while the SWRCB has the general obligation to follow the rule of priority in implementing new flow objectives, the rule of priority is not absolute:

> Although the rule of priority is not absolute, the Board is obligated to protect water right priorities unless doing so will result in the unreasonable use of water, harm to values protected by the public trust doctrine, or the violation of some other equally important principle or interest.

[28] Indeed, San Francisco appears to have waived any legal argument regarding the assessment of economic or water supply impacts as those are apportioned between agricultural and urban water users. *See* City and County of San Francisco 2013 comments on draft SED, at 5 ("the draft SED should not draw conclusions in its current analysis about how water rights issues will be addressed between the SFPUC and the Districts.").

El Dorado Irr. Dist. v. State Water Res. Control Bd., 142 Cal.App.4th 937, 944 (2006). Thus, where application of the rule of priority would result in impacts to drinking water for human health and safety, or would allow the continuation of wasteful irrigation practices, it likely must yield. Similarly, if urban water users offered to pay agricultural water users for improvements in agricultural water use efficiency, which would enable those agricultural water users to conserve water that would be available for transfer, such an offer may constitute a physical solution that the Board could order be implemented. Such an agreement would be substantially similar to the SWRCB's actions regarding the funding of water conservation measures by the Imperial Irrigation District (including lining of the All-American Canal) through water transfer agreements that paid for the conserved water. *See* Decision 1600; Water Rights Order 88-20; Revised Water Rights Order 2002-0013.[29]

Indeed, as we discussed in detail in our 2013 comments and attached analysis by the Pacific Institute, there are substantial opportunities to improve agricultural water use efficiency by water rights holders in this proceeding that could create significant conserved water. TBI et al. 2013; *id*., Exhibit 4. However, the revised SED fails to consider potential improvements in agricultural water use efficiency, and thus fails to accurately assess the likely water supply impacts of the alternatives on agricultural water rights holders. As we also noted in our prior comments, the Board has the authority to require implementation of conservation and efficiency measures to avoid waste and reduce or avoid impacts. *Id*. The SED wholly fails to analyze the potential to reduce or avoid water supply impacts through improvements to irrigation efficiency, including pressurizing water supply systems so water is available on demand and other analyses in our prior comments. The SED also fails to analyze the potential for multi-benefit projects, such as floodplain restoration, to provide ecosystem benefits while also increasing groundwater recharge and supply (particularly on the Merced and Stanislaus Rivers).

b. The analysis of potential water supply impacts to the SFPUC is flawed.

With respect to potential water supply impacts to the San Francisco Public Utility Commission's ("SFPUC) retail and wholesale service area, the SED also inaccurately estimates potential impacts. First, the analysis in the SED assumes urban water demand levels that are dramatically higher than current uses. In assessing urban water supply impacts, the SED assumes a demand level of 260 MGD (290TAF); however, according to SFPUC's 2015 Urban Water Management Plan,[30] urban demand in the wholesale and retail area was reduced to 175 MGD (222TAF) in 2015-2016. Even prior to the imposition of mandatory water conservation measures, SFPUC

[29] By citing this authority, we do not take a position regarding the merits of this transfer agreement, including with respect to impacts to the Salton Sea and its Public Trust resources. The SWRCB would have to carefully analyze any such agreement for transfer of conserved water, either as part of Phase III or in a separate water rights proceeding.

[30] SFPUC's 2015 Urban Water Management Plan is available online at: https://sfwater.org/modules/showdocument.aspx?documentid=9300 and is hereby incorporated by reference.

has estimated total wholesale and retail demand in 2012-2013 was 223 MGD. *See* Appendix F.[31] By using inflated urban demand numbers, the SED overestimates likely water supply impacts, and the SED at a minimum should use the 2012-2013 estimate of 223 MGD. *See infra*. In addition, the substantial reduction in urban water demand in the SFPUC service area occurred with virtually no economic impacts, contrary to the extravagant claims by SFPUC's economist in 2013, demonstrating the absurdity of those prior estimates. Indeed, SFPUC's economist has published research concluding that urban water agencies substantially overestimate future water demand. *See* Steven Buck, Hilary Soldati, and David Sunding, Forecasting Urban Water Demand in California: Rethinking Model Evaluation.[32]

In addition, the analysis in the SED and Appendix I wholly ignores potential for wastewater recycling, improved urban water use efficiency, groundwater banking, urban stormwater capture, and additional local projects to offset or reduce demand for water from the Tuolumne River. Appendix I only considers water transfers, desalination, and Delta water exports, ignoring the substantial potential increases in supply and reductions in demand resulting from other local water supply projects (including several projects that are being planned or actually being implemented).

For instance, the 2014 report by NRDC and the Pacific Institute entitled *Untapped Potential* estimated that the Bay Area region could increase water supply by 980,000 acre feet per year through stormwater capture, improved water use efficiency, agricultural water use efficiency, and wastewater recycling.[33] It is important to keep in mind that the estimates in that report account for the fact that these water supply tools may not always be additive; for instance, increases in urban water use efficiency (particularly indoor water use, and assuming no population growth) will reduce the water supply available from wastewater recycling. In addition, while that 2014 analysis is broader than the SFPUC wholesale area, it demonstrates the great potential for improving sustainable water management in the SFPUC region.

Information from *Untapped Potential*, from the 2015 Urban Water Management Plan for SFPUC, and from other sources[34] provide more detail regarding the potential yield from these

[31] Appendix F includes a PDF file and an Excel spreadsheet prepared by SFPUC, both of which were transmitted by staff from SFPUC to staff from NRDC.

[32] This paper is available online at: http://ageconsearch.umn.edu/bitstream/205737/2/buck%20et%20al_forecasting%20water%20demand_aaea2015.pdf and is hereby incorporated by reference.

[33] This paper is available online at: https://www.nrdc.org/resources/untapped-potential-californias-water-supply and is hereby incorporated by reference.

[34] For instance, SFPUC, BAWSCA, and other Bay Area agencies are collaborating on a Bay Area Regional Reliability effort, which has identified a number of existing projects to improve regional water supply reliability and is evaluating investments in additional projects, including potable reuse projects, groundwater projects, and interties and transfer agreements. A summary is available online at: http://www.bayareareliability.com/wp-content/uploads/2016/04/Bay-Area-Regional-Reliability-2014-Fact-Sheet-5-6-14.pdf?545d25 and is hereby incorporated by reference.

sustainable water supply tools, which should be considered in the SED.[35] Cumulatively, these water supply sources and improvements in water use efficiency can reduce water supply impacts and help offset reductions in surface water supplies from the Tuolumne River. The SED should be revised to account for these potential measures.

1. *Stormwater Capture:*

In the 2014 *Untapped Potential* report, NRDC and the Pacific Institute estimated potential increases in urban water supply from stormwater capture within counties in the SFPUC service area as follows:

County	Potential yield of stormwater capture
San Francisco	5,427 Acre Feet
San Mateo	7,466 Acre Feet
Santa Clara County	58,000 Acre Feet
Alameda County	17,937 Acre Feet
Total	88,831 Acre Feet

Of course, the SFPUC wholesale area is not conterminous with these county boundaries, particularly for Santa Clara and Alameda Counties, so the total potential for increased water supply from stormwater capture within the wholesale service area is lower than that shown in the table above.

In addition, SFPUC's 2015 Potable Offset Investigation Summary Report found that onsite non-potable water supplies could offset up to 6.73 MGD (approximately 7,500 acre feet per year) of retail potable demands from the Regional Water System by 2040, assuming 100% participation and installation of onsite infrastructure. *See* SFPUC, Potable Offset Report at ES-4.[36] This includes onsite non-potable supplies from rainwater and stormwater (e.g. rain barrels), graywater (e.g. retrofitted clothes washers, laundry-to-landscape systems), blackwater (e.g. in dual-plumbed buildings), and seepage water (e.g. in municipal open spaces). That report established a target of 1 MGD from onsite reuse by 2040. *Id*. at ES-5. The SFPUC's 2015 UWMP, in contrast, projects only 0.4 MGD of non-potable water supplies by 2040 (SFPUC 2015 UWMP, Table 6-7). While it may not be feasible to generate the full 6.73 MGD from non-potable supplies, there is clearly additional potential to develop onsite water reuse systems to reduce demand for water from the Tuolumne River. The SED should be revised to discuss how

[35] For information regarding the cost of these and similar sustainable water supplies, we recommend that the SWRCB consider the Pacific Institute's 2016 report entitled *The Cost of Alternative Water Supply and Efficiency Options in California*. That report and appendices are available online at: http://pacinst.org/publication/cost-alternative-water-supply-efficiency-options-california/ and are hereby incorporated by reference.
[36] That report is available online at: http://sfwater.org/Modules/ShowDocument.aspx?documentID=9363 and is hereby incorporated by reference.

stormwater capture and offsite non-potable water supply projects could reduce water supply impacts and help offset reductions in surface water supplies from the Tuolumne River.

2. *Wastewater recycling:*

There is tremendous potential for dramatic increases in sustainable water supplies through investments in wastewater recycling in the SFPUC retail and wholesale area. Currently, very little of the treated wastewater in the retail or wholesale area is recycled, and the vast majority of it is discharged into the ocean or bay. For instance, in its 2015 UWMP, SFPUC estimates that in the retail service area only 0.2MGD of recycled water was delivered in 2015, accounting for only 0.29% of retail water supply, and that this will increase to only 3.9MGD by 2040 (accounting for less than 5% of total supply).

	2015	2020	2025	2030	2035	2040
Recycled Water (all projects, in MGD)	0.2	1.9	1.9	3.9	3.9	3.9
Total Retail Supply (MGD)	70.1	77.5	79.0	82.3	85.9	89.9
Recycled Water % of Retail Supply	0.29%	2.45%	2.41%	4.74%	4.54%	4.34%

Source: SFPUC 2015 UWMP at Table 6-7.

Table 6-6 from the UWMP demonstrates that even in drought conditions in 2015, more than 65 MGD (approximately 72,800 acre feet per year) of treated wastewater was discharged from wastewater treatment plants in SFPUC retail service area. For both the retail and wholesale service area, there is substantial potential for increased water recycling. Data compiled from the SWRCB's California Integrated Water Quality System Project (except as noted below) identified the following discharges from wastewater treatment plants located in the SFPUC wholesale and retail service area:[37]

Agency	2014 Discharges	2015 Discharges
Palo Alto Regional WQCP	19.55 MGD	19.47 MGD
Millbrae WPCP	1.45 MGD	1.29 MGD
San Mateo WWTP	10.39 MGD	9.30 MGD
SFIA, Mel Leong Sanitary and Industrial Treatment Plants	2.27 MGD	1.99 MGD
South San Francisco / San Bruno WQCP	11.39 MGD	10.21 MGD
Southeast WPCP, North Point WWF, Bayside WWF (Flow	138.27 MGD	96.31 MGD

[37] Note that this table includes discharges in the retail service area that were included above.

average of wet and dry weather)		
Sunnyvale WPCP	11.95 MGD	9.42 MGD
Burlingame WWTF	2.95 MGD	2.73 MGD
Oceanside WWTP	14.90 MGD	13.95 MGD
San Jose / Santa Clara Regional Wastewater Facility[38]	Not available	28,733 acre feet discharged (3,607 acre feet recycled)
Total	213.12 MGD Approx. 238,000 Acre Feet	Approx. 213,000 Acre Feet

Sources: SWRCB, 2015 San Jose Municipal Water System UWMP

Of course, increases in indoor water use in the retail or wholesale service area will also increase potential for wastewater recycling; indeed, the table above shows that in some areas, there were substantial declines in wastewater discharges between 2014 and 2015 as urban water use declined. While SFPUC has not identified significant increases in water recycling in its UWMP, other agencies in the service area have done so. For instance, San Jose's UWMP explains that the Santa Clara Valley Water District is in the process of developing at least 20,000 acre feet per year, and up to 45,000 acre feet per year of potable reuse capacity. *See* San Jose 2015 UWMP at 61. Ultimately, while not all of these discharges may feasibly be recycled, there can be no question that there is substantial untapped potential in terms of increased water supply from water recycling in the service area that were not considered in the SED. The SED should be revised to discuss how water recycling could reduce water supply impacts and help offset reductions in surface water supplies from the Tuolumne River.

3. *Urban Water Use Efficiency:*

San Francisco is rightfully proud of its urban water use efficiency, and residents in the City have substantially reduced per capita water use in recent years. As the table below shows, in 2015 SFPUC's retail per capita water use was 81 gallons per capita day (GPCD) and its residential per capita water use was 44 residential gallons per capita day (R-GPCD). In addition, SFPUC estimates that it achieved approximately 9.6 MGD in water savings through conservation from 2005-2015. SFPUC 2015 Retail Water Conservation Plan at ES-2.[39]

	2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
Gross Per Capita Use	110	95	81	86	84	83	83	82

[38] 2015 Urban Water Management Plan San Jose Municipal Water System, at Table 6-4. This UWMP is available online at: https://www.sanjoseca.gov/DocumentCenter/View/57483 and is hereby incorporated by reference.
[39] This document is available online at: https://sfwater.org/modules/showdocument.aspx?documentid=8760 and is incorporated by reference.

(GPCD)								
Residential GPCD (R-GPCD)	61	53	44	44	43	44	44	45
Population (1,000)	782	807	859	892	937	984	1,034	1,087

Source: SFPUC 2015 Retail Water Conservation Plan, Table 1

In contrast, water use within the wholesale service area is higher than within the retail service area. In 2014-2015, per capita water use amongst the member agencies of the Bay Area Water Supply and Conservation Agency (BAWSCA), all of whom are SFPUC wholesale customers, averaged 105.7 GPCD and a residential average of 64.7 R-GPCD. *See* BAWSCA Annual Survey FY2014-15 at ES-9.[40] Only 8 of the BAWSCA member agencies had a residential per capita water use less than 50 R-GPCD.

More importantly, the UWMP predicts dramatic increases in wholesale demand that greatly outpace population growth. According to data in the UWMP, from 2015-2020, the retail population is expected to increase by 3.8%, while demand is expected to increase by 10.6%; the wholesale population is expected to increase by 4.6%, with an expected increase in demand of 24.2%. *See* 2015 SFPUC UWMP at Tables 3-3, 3-4, 4-1, and 4-2. As the table below demonstrates, this results in a dramatic increase in demand that outpaces population growth.

	2015	**2020**	**2025**	**2030**	**2035**	**2040**
Total Population (Retail + Wholesale)	2,660,173	2,775,511	2,908,876	3,045,995	3,191,733	3,330,074
		4.34%	4.81%	4.71%	4.78%	4.33%
Total Demand (Retail + Wholesale)	198.1	236.5	243.1	249.7	256.2	263.8
		19.38%	2.79%	2.71%	2.60%	2.97%

Source: SFPUC 2015 UWMP, Tables 3-3, 3-4, 4-1, and 4-2

The dramatic increase in demand between 2015 and 2020 is not a function of population growth; indeed, the UWMP estimates that water demand will increase at a *slower* rate than population growth from 2025 to 2040. As discussed above, even SFPUC's outside economist has acknowledged that urban water agencies routinely overestimate future water demand. Buck et al.

[40] This report is available online at: http://bawsca.org/uploads/userfiles/files/BAWSCA_AnnualSurvey_FY2014-15.pdf and is hereby incorporated by reference.

2015. Other experts have reached similar conclusions. *See, e.g.*, Matthew Herberger et al., A Community Guide for Evaluating Future Urban Water Demand, Pacific Institute 2016.[41]

For instance, if demand in the SFPUC service area increases by only 4.34% between 2015 and 2020 (identical to rate of population growth), then demand in 2020 would be 206.7 MGD, and demand in 2035 would be 223.9 MGD, as shown in the table below. Instead of assuming an unrealistic and dramatic increase in demand between 2015 and 2020, which is necessary to justify use of a 260 MGD demand estimate, the SED should use an estimated demand of 223 MGD for SFPUC.

	2015	**2020**	**2025**	**2030**	**2035**	**2040**
Increase in Demand *(identical to population growth)*		4.34%	2.79%	2.71%	2.60%	2.97%
Total Demand	198.1	206.7	212.5	218.2	223.9	230.5

Reductions in demand in recent years have demonstrated that the region can successfully reduce per capita water use without impacting the economy. If per capita demand remains near 2015 levels, overall demand will be substantially lower than predicted in the UWMP and could help reduce or avoid impacts from reduced surface water supplies from the Tuolumne River. The SED should be revised to analyze how improved water use efficiency could reduce water supply impacts and help offset reductions in surface water supplies from the Tuolumne River.

4. Groundwater Banking and Recovery Projects

According to materials provided by the SFPUC, the San Francisco groundwater project is expected to begin operating in 2017, and will reduce demand by 4 MGD. *See* Appendix F. In addition, SFPUC anticipates that the Westside Basin Conjunctive Use project could reduce drought year demand by 7 MGD on the San Francisco Peninsula. *Id.* The SED should be revised to discuss how these and related projects could reduce water supply impacts and help offset reductions in surface water supplies from the Tuolumne River.

5. Los Vaqueros Reservoir Expansion

The Contra Costa Water District is currently evaluating a substantial additional expansion of the Los Vaqueros reservoir, increasing storage capacity to as much as 275,000 acre feet. *See* Contra Costa Water District, Los Vaqueros Reservoir Expansion, available online at:

[41] This report is available online at: http://pacinst.org/app/uploads/2016/08/A-Community-Guide-for-Evaluating-Future-Urban-Water-Demand-1.pdf and is hereby incorporated by reference.

http://www.ccwater.com/706/Los-Vaqueros-Studies. SFPUC and other wholesale customers are helping to fund completion of studies of the reservoir expansion and are considering partnering in this project. The SED should be revised to discuss the potential for this project to reduce water supply impacts and help offset reductions in surface water supplies from the Tuolumne River.

c. SFPUC's analyses of potential impacts are deeply flawed and misleading.

In 2013, SFPUC presented highly misleading and inaccurate estimates of potential economic impacts from reductions in water supply, which have been proven faulty by SFPUC's reduction in demand during the drought without major economic impacts. Unfortunately, in recent months SFPUC has continued to publicly present highly misleading and inaccurate analyses and claims regarding water supply impacts from implementation of the preferred alternative. *See* Appendix F. It is important for the SWRCB and public to understand the significant flaws in their analysis.

First, SFPUC has not analyzed potential water supply impacts from the preferred alternative, but instead has analyzed how SFPUC might *choose* to implement any water supply impacts. In order to calculate potential rationing, SFPUC's model assumes an 8.5 year design drought (1987-1992 followed by 1976-1977), and therefore assumes that any dry or critically dry year is the beginning of an 8.5 year drought sequence that is longer and more severe than any drought in the modern record. While it is clearly commendable to plan for droughts, these model assumptions predict rationing in many years where SFPUC has substantial water in storage. Indeed, our review of their spreadsheet model results indicate that total storage in the SFPUC system over the period of record analyzed in the model never drops below 400,000 acre feet (and does so only after the 1987-1992 5 year drought sequence). For example, under the 265 MGD demand assumption and 40% unimpaired flow scenario,[42] the following amounts of water are in system storage:

Year (June of that year)	SFPUC Estimated Rationing	Total System Storage (June of prior FY)
FY24-25	40%	1,105,173
FY29-30	40%	1,075,401
FY30-31	40%	987,671
FY31-32	54%	724,619
FY33-34	40%	1,149,109
FY34-35	40%	912,257
FY64-65	40%	1,185,547
FY92-93	54%	497,122
FY94-95	54%	972,422

[42] Storage levels are generally higher under lower demand scenarios, which makes intuitive sense.

FY08-09	40%	1,000,809

The extremely conservative nature of SFPUC's 8.5 year design drought drives these conclusions, and SFPUC can of course modify that design drought. SFPUC's model simply does not demonstrate water supply impacts, but instead how they may choose to implement those impacts – assuming that SFPUC does not take any other actions to develop water supplies.

However, that assumption – that the model fails to consider reasonable investments in improved water use efficiency, wastewater recycling, stormwater capture, and other projects – is unreasonable, and is the second flaw in their analysis. The model results demonstrate that at lower levels of system demand, the frequency and severity of rationing declines even using their model assumptions:

	265MGD Base (Max contract)	**223MGD Base (FY 12-13 demand)**	**175MGD Base (FY 15-16 demand)**
# of years with Rationing under 40% Alt	24 years (15 years at 40%, 9 years at 54%)	19 years total (16 years at 39%, 3 years at 49%)	16 years total (13 years at 20%, 3 years at 32%)
Max rationing under 40% Alt	54%	49%	32%
Delivery shortfall under maximum rationing under 40% Alt	142MGD (121MGD deliveries vs 265MGD Demand)	110MGD (113 MGD deliveries vs 223MGD demand)	57MGD (118 MGD deliveries vs 175MGD demand)
# of years with no rationing under 40% Alt	68 (92-24)	73 (92-19)	76 (92-16)

This demonstrates that improvements to water use efficiency and development of local and regional water supplies will reduce or avoid these impacts. Yet SFPUC only included a few potential projects in the 265 MGD model scenario (Westside Basin Conjunctive Use, SF Groundwater, and existing SF recycled water), and their analysis did not include those projects in the lower demand scenarios. As discussed above, there are substantial opportunities for improved water use efficiency and local water supply projects in the SFPUC service area that are ignored in this analysis.

Third, SFPUC's model assumes that water supply impacts will be split between SFPUC and agricultural districts in a manner similar to the SWRCB's Scenario 2 in the SED. This would suggest that even in years when SFPUC would otherwise divert no water from the river, they would have to contribute substantial flow from the water bank in the reservoir. However, if the split between SFPUC and the agricultural districts is more similar to Scenario 1 in the SED, the impacts on SFPUC would be lower.

Fourth, like the SED, SFPUC's model fails to consider the authority to waive or weaken instream flow requirements during drought emergencies, as authorized in the Program of Implementation. This is likely to dramatically change the model results, particularly as suggested in our comments, because it would provide greater certainty regarding the hydrologic conditions that would trigger that authority and the default flow conditions that would result.

Ultimately, like their deeply flawed economic analysis in 2013, SFPUC's rationing analysis in 2016 is substantially flawed, and overestimates how SFPUC is likely to implement changes resulting from the Board's decision. Rather than continuing to provide such misleading analyses, we hope and expect that SFPUC will work with the conservation community and the public to help develop sustainable water supply projects, including expanded wastewater recycling and continued water use efficiency efforts, which help reduce reliance on the Delta and sustain the economy and the environment.

XI. Conclusion

Now is the time for the SWRCB to act decisively to restore ecological balance and protect the Public Trust by requiring the flows necessary to achieve the narrative salmon protection objective, the proposed narrative San Joaquin migratory fish viability objective, and maintain salmon and other native fish in good condition. For the reasons stated herein, we urge the SWRCB to adopt an alternative that establishes a range of 40-60% of unimpaired flow, with a starting point of 50%, and to revise the SED consistent with the comments herein.

Thank you for consideration of our views. We would be happy to answer any questions regarding these comments or work with staff to help address these comments.

Sincerely,

Doug Obegi
Natural Resources Defense Council

Jon Rosenfield
The Bay Institute

Ben Eichenberg
San Francisco Baykeeper

Rachel Zwillinger
Defenders of Wildlife

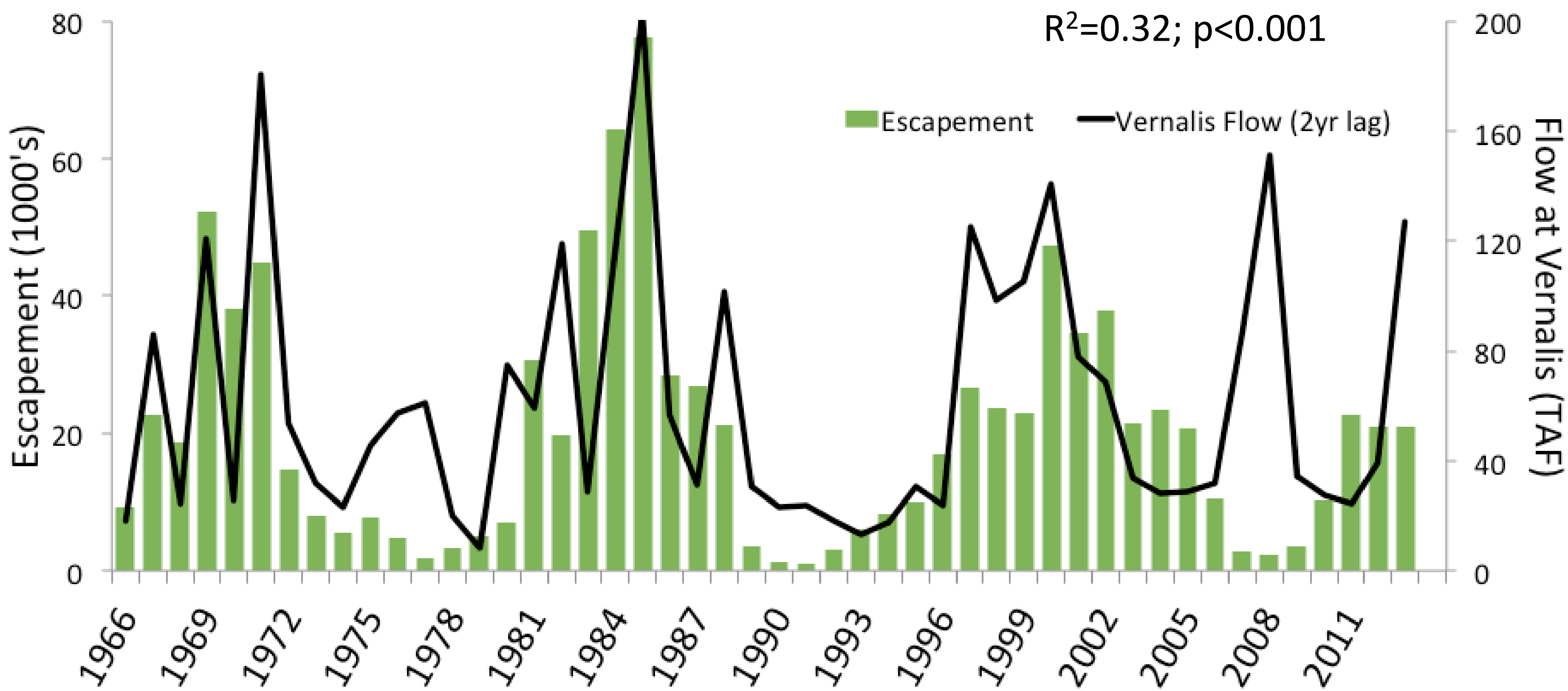
Enclosures:

Appendix A: Redline of Proposed Revisions to Appendix K (Program of Implementation and Table 3)
Appendix B: SEP 2016
Appendix C: Documentation Regarding the Central Valley Flood Protection Plan, Emigrating Salmonid Habitat Estimation model
Appendix D: Floodplain Inundation Appendix and Figures
Appendix E: Temperature Appendix and Figures
Appendix F: Documents from SFPUC regarding potential rationing and system storage
Appendix G: Literature Cited in Section III

Figures Referenced in Section III

San Joaquin Salmon Escapement

strongly correlated with winter-spring flows



Modifed from Sturrock et al. 2015

Figure 1

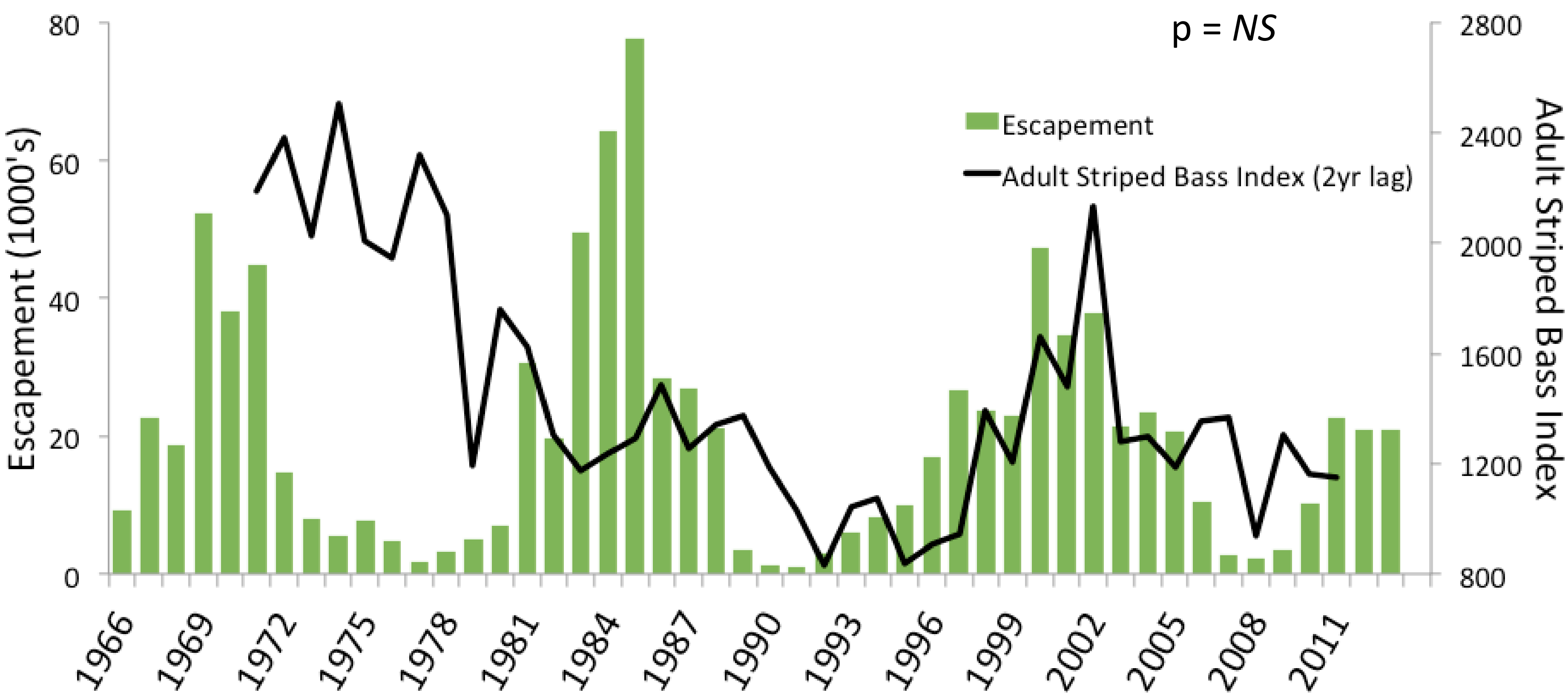


Figure 2: Striped bass abundance in the Delta v. Chinook salmon escapement 2.5 years later. If Striped Bass abundance explained the pattern of salmon escapement, there would be a negative correlation between the two parameter, because striped bass are expected to prey on migrating juvenile salmon. No significant correlation was detected.

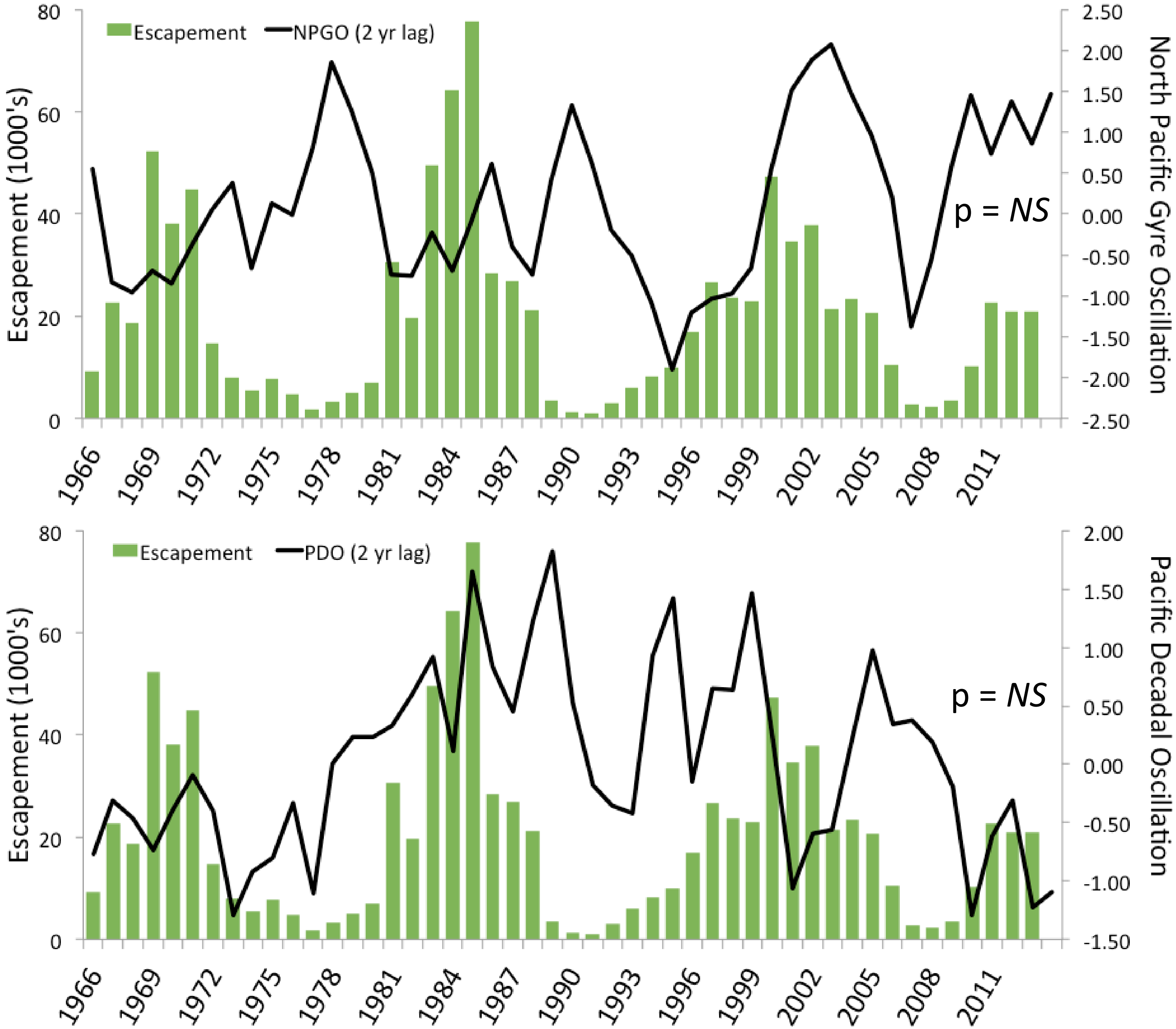


Figure 3: Two measures of ocean condition hypothesized to be relevant to Central Valley Chinook salmon success in the ocean vs. Chinook salmon escapement 2.5 years later. No significant correlation was detected.

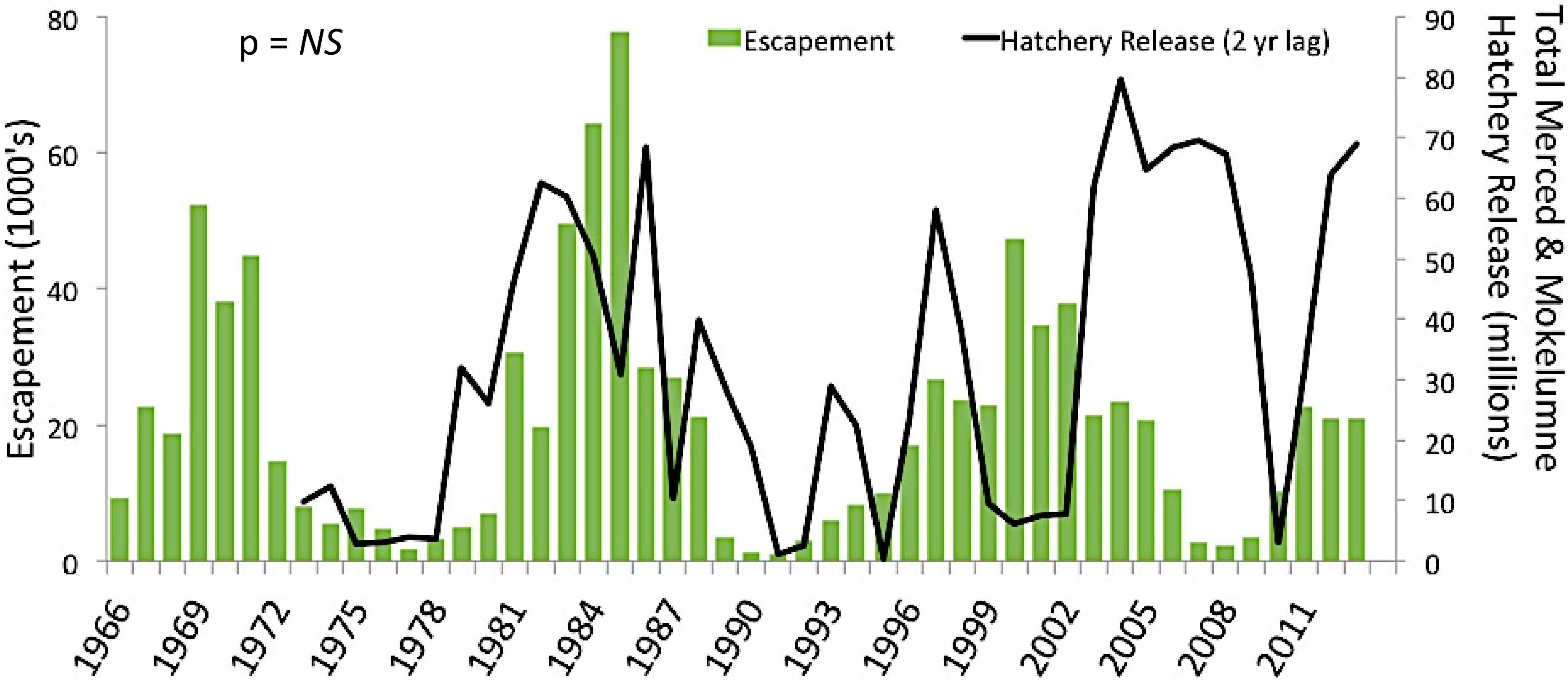
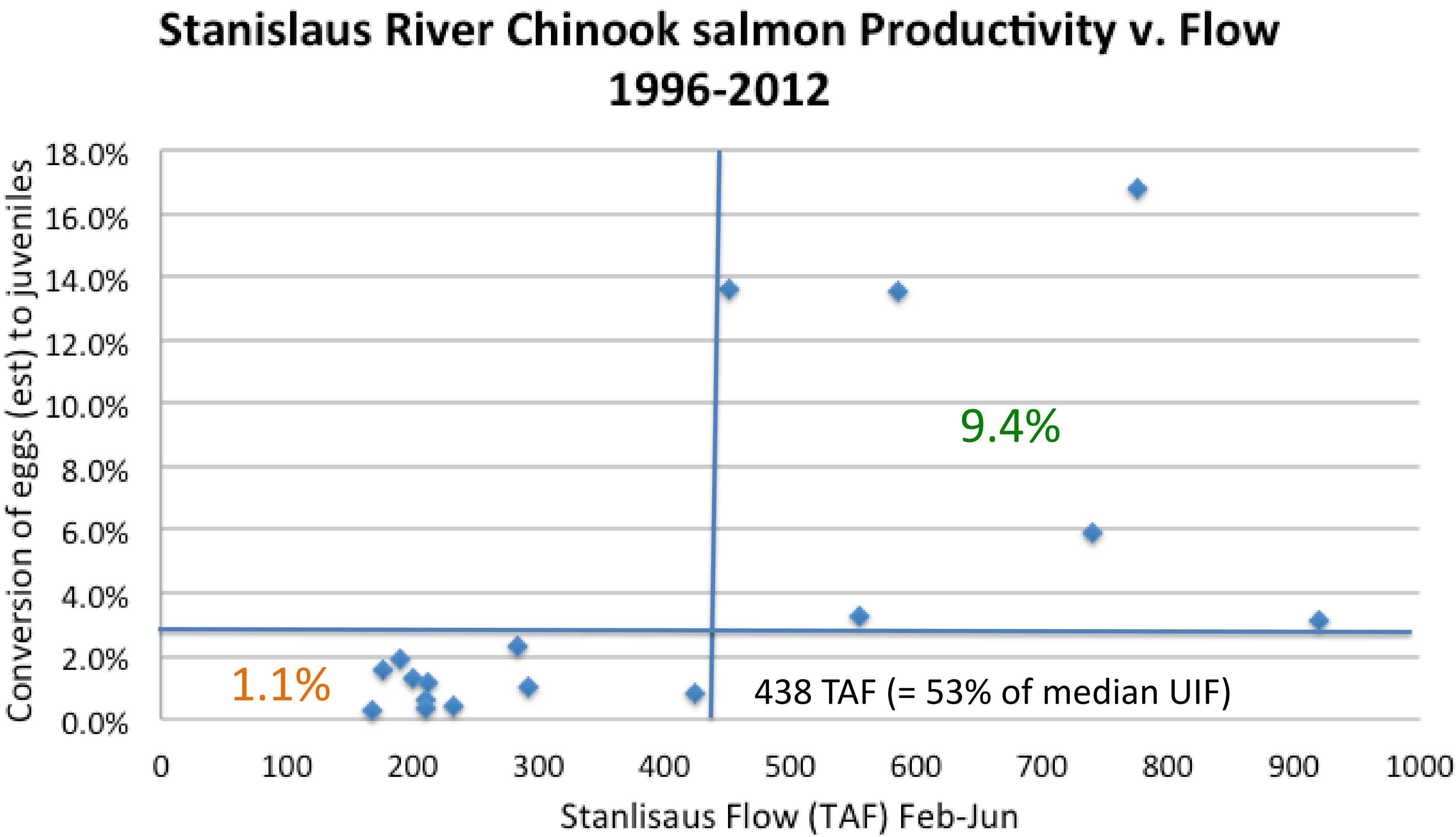
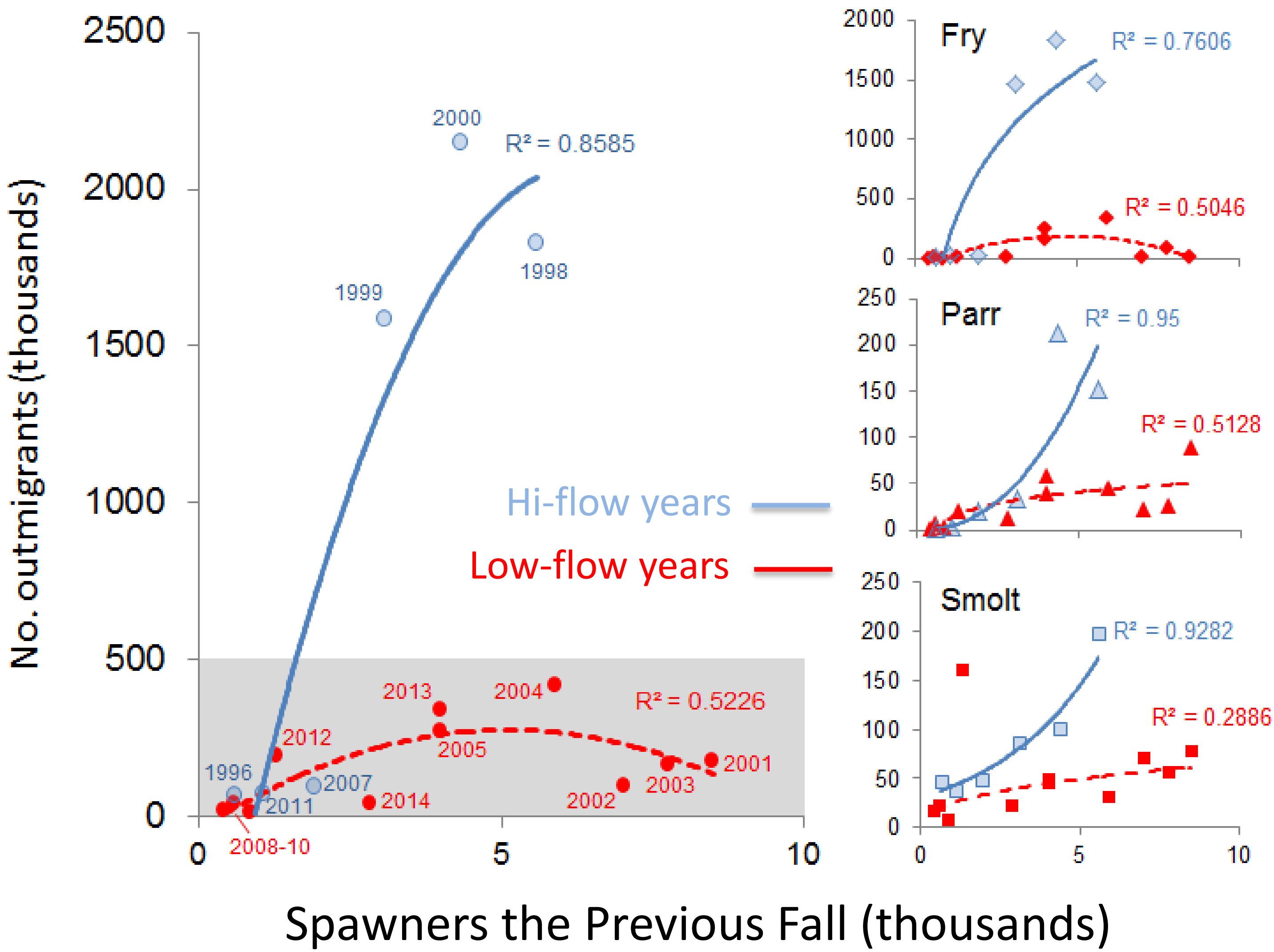


Figure 4: Combined releases of fall-run Chinook salmon at Merced and Mokelumne River hatcheries vs. Chinook salmon escapement to the San Joaquin River 2.5 years later. No significant correlation was detected.



Data from USF&WS

Figure 5: Estimated survival of fall-run Chinook salmon versus flow in the Stanislaus River. Survival is calculated as [expanded juvenile production as detected by Caswell Rotary Screw Trap] divided by {Chinook salmon escapement to the Stanislaus River the previous fall (GrandTab) * estimated sex ratio * eggs per spawning female).



Sturrock et al., *in preparation*

Figure 6

TABLE 3
WATER QUALITY OBJECTIVES FOR FISH AND WILDLIFE BENEFICIAL USES

COMPLIANCE LOCATIONS	INTERAGENCY STATION NUMBER	PARAMETER	DESCRIPTION (UNIT)[2]	WATER YEAR TYPE	TIME PERIOD	VALUE
San Joaquin River at Airport Way Bridge, Vernalis	*C-10*	*Flow Rate*	*Narrative & Minimum 7-day running average flow rate (cfs) for February through June* [14]	*All*	*February through June*	*Maintain inflow conditions from the San Joaquin River watershed to the Delta at Vernalis sufficient to support and maintain the natural production of viable native San Joaquin River watershed fish populations migrating through the Delta, including but not limited to doubling of natural production of San Joaquin River Chinook salmon and steelhead populations migrating through the Delta from the average production of 1967 – 1991. Inflow conditions that reasonably contribute toward maintaining viable native migratory San Joaquin River fish populations include, but may not be limited to, flows that more closely mimic the natural hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, variability, and spatial extent of flows as they would naturally occur. Indicators of viability include population abundance, spatial extent, distribution, structure, genetic and life history diversity, and productivity.* [15] *A percent of unimpaired flow between 30% - 50%, inclusive, from each of the Stanislaus, Tuolumne, and Merced Rivers shall be maintained from February through June.* ~~[14]~~[16] *Notwithstanding the above unimpaired flow requirement, a minimum base flow value between 800 – 1,200 cfs, inclusive, at Vernalis shall be maintained at all times during February through June.*
Stanislaus River at Koetitz	*DWR Gage KOT*					
Tuolumne River at Modesto	*USGS Gage 1129000*					
Merced River near Stevenson	*DWR Gage MST*					

Table 3 Footnotes:

[14] From February 1 to May 31, any deviations from the minimum 7 day running average flow rate shall be made solely to achieve the narrative salmon protection and San Joaquin migratory fish viability objectives and SMART targets. Any such deviations must be approved in advance by the Executive Director, with the concurrence of the Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Wildlife after consultation with the STM Working Group. The volume of water available under the unimpaired flow standard shall be fully utilized within this time period and shall not be shifted to later in the year. From June 1 to June 30, any deviations from the minimum 7 day running average flow rate shall be made solely to achieve the narrative salmon protection objective, this narrative objective, and SMART targets, and such deviations must be approved in advance by the Executive Director, with the concurrence of the Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Wildlife after consultation with the STM Working Group. Notwithstanding any approved deviations from the minimum 7 day running average flow rate, the minimum base flow value shall be achieved at all times during February through June.

[15] Specific, measureable, attainable, relevant, and time bound (SMART) biological and environmental targets will be used to measure progress towards meeting the narrative objectives, as defined by the following indicators of viability: average annual natural production of 78,000 fall-run Chinook salmon (22,000 from the Stanislaus; 38,000 from the Tuolumne; and 18,000 from the Merced);maintenance of viable spring-run Chinook salmon populations; natural production of 10,000 steelhead from at least two rivers in the San Joaquin basin; successful splittail spawning once in every three years; and successful green and white sturgeon spawning once in every seven years.

~~[14]~~ [16] Unimpaired flow represents the natural water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. The total volume of water must be at least equal to the volume of water that would be released each day by tracking the minimum unimpaired flow percentage on a daily basis from February through June. The percent of unimpaired flow required to be dedicated to instream flow shall be reassessed every five years, based on the progress in achieving the narrative salmon protection objective, this narrative objective, the indicators of viability, and SMART targets, including independent scientific review by the Delta Science Program. Any changes to the percent of unimpaired flow within the identified range shall be adopted after a public hearing before the State Water Resources Control Board and shall be made solely in order to achieve the narrative salmon doubling objective, this narrative objective, and quantified biological metrics.

Implementation of February through June LSJR Flow Objectives

By 2022, the State Water Board will fully implement the February through June LSJR flow objectives through water right actions or water quality actions, such as Federal Energy Regulatory Commission (FERC) hydropower licensing processes.[8]

The State Water Board ~~will~~ shall exercise its water right and water quality authority to ~~help~~ ensure that the flows required to meet the LSJR flow objectives are used for their intended purpose and are not diverted for other purposes. The State Water Board shall consider, on the request of any water rights holder, the dedication of these flows to instream use and Delta outflow under section 1707(c) of the Water Code. However, the State Water Board may also approve water transfers between downstream water users and upstream water rights holders, provided that plan requirements, including objectives for Delta outflow, are being achieved. In order to help ensure that actions taken in response to implementation of the LSJR flow objectives do not result in unreasonable redirected impacts to groundwater resources, the State Water Board will take actions as necessary pursuant to its authorities, including its authorities to prevent the waste, unreasonable use, unreasonable method of use, and unreasonable method of diversion of water (Cal. Const., art. X, § 2; Wat. Code, §§ 100, 275) and to enforce the Sustainable Groundwater Management Act (SGMA) (Wat. Code, § 10720 et seq.).

When implementing the LSJR flow objectives, the State Water Board ~~will~~ shall include minimum reservoir carryover storage requirements, consistent with those measures analyzed in the Substitute Environmental Document, ~~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~~. The State Water Board will also 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. Actions may include, but are not limited to, assistance with funding and development of water conservation efforts and regional water supply reliability projects and regulation of public drinking water systems and water rights.

Although the lowest downstream compliance location for the LSJR flow objectives is at Vernalis, the objectives are intended to protect migratory LSJR fish in a larger area, including within the Delta, where fish that migrate to or from the LSJR watershed depend on adequate flows from the LSJR and its salmon-bearing tributaries.

It is the State Water Board's intention that an entity's implementation of the LSJR flow objectives, including implementation through flow requirements imposed in a FERC process, will meet any responsibility to contribute to the LSJR inflow component of the Delta outflow objective in this Plan. The

[8] To refine the implementation actions and provide for coordination with ongoing FERC proceedings in the LSJR watershed, the February through June LSJR flow objective may be phased in over time, but must be fully implemented by 2022.

State Water Board, however, may further consider and reallocate responsibility for implementing the Delta outflow objective in any subsequent proceeding, including a water right proceeding.

Flow Requirements for February through June

The LSJR flow objectives for February through June shall be implemented by requiring 5~~4~~0 percent of unimpaired flow, based on a minimum 7-day running average, from each of the Stanislaus, Tuolumne, and Merced Rivers. This required percentage of unimpaired flow, however, may be adjusted within the range allowed by the LSJR flow objectives through adaptive methods detailed below. The required percentage of unimpaired flow is in addition to flows in the LSJR from sources other than the LSJR Tributaries. The required percentage of unimpaired flow does not apply to an individual tributary during periods when flows from that tributary could cause or contribute to flooding or other related public safety concerns, as determined by the State Water Board or Executive Director through consultation with federal, state, and local agencies and other persons or entities with expertise in flood management.

In addition, the LSJR base flow objective for February through June shall be implemented by requiring a minimum base flow of ~~1~~2,000 cfs, based on a minimum 7-day running average, at Vernalis at all times. This minimum base flow, however, may be adjusted within the range allowed by the LSJR base flow objective through adaptive methods detailed below. When the percentage of unimpaired flow requirement is insufficient to meet the minimum base flow requirement, the Stanislaus River shall provide 29 percent, the Tuolumne River 47 percent and the Merced River 24 percent of the additional total ~~out~~flow needed to achieve and maintain the required base flow at Vernalis.

The Executive Director may approve changes to the compliance locations and gage station numbers set forth in Table 3 if information shows that another location and gage station more accurately represent the flows of the LSJR tributary at its confluence with the LSJR.

Adaptive Methods for February through June Flows

Adjustments to the February through June unimpaired flow requirements allowed by the LSJR flow objectives should be implemented in a coordinated ~~and adaptive~~ manner to achieve maximum benefit for fish and wildlife beneficial uses in that year, taking into account current information. Specifically, FERC licensing proceedings on the Merced and Tuolumne Rivers, other scientific review processes initiated to develop potential management strategies on a tributary basis, and the San Joaquin River Monitoring and Evaluation Program (SJRMEP) described below are expected to yield additional scientific information that will inform future management of flows for the protection of fish and wildlife beneficial uses.

Adaptive implementation shall ~~could also~~ optimize flows to achieve the narrative salmon protection and San Joaquin migratory fish viability objectives and associated indicators of viability, as measured by attainment of SMART (specific, measurable, attainable, relevant, and time-bound) biological and environmental targets~~while also allowing for consideration of other beneficial uses, provided that these other considerations do not reduce intended benefits to fish and wildlife~~.

Every five years, the State Water Resources Control Board shall evaluate potential modifications to the percent of unimpaired flow required to be dedicated to instream flow within the range of 40 percent to 60 percent, inclusive. The evaluation shall be based on the progress in achieving the narrative salmon protection and San Joaquin migratory fish viability objectives, and SMART targets, as identified in the comprehensive report, including independent scientific review by the Delta Science Program. Any changes to the percent of unimpaired flow within the identified range shall be adopted after a public hearing before the State Water Resources Control Board and shall be made solely in order to achieve the narrative objectives and SMART targets.

Adaptive adjustments to the flow requirements as forth in (a) – (c~~d~~) below may be approved by the State Water Board on an annual or long-term basis, or by the Executive Director as provided below, if information produced through the monitoring and review processes described in this program of implementation, or other best available scientific information, indicates that the change for the period at issue will satisfy the following criteria for adaptive adjustments: (1) it will be sufficient to achieve the narrative salmon protection and San Joaquin migratory fish viability objectives~~support and maintain the natural production of viable San Joaquin River watershed fish populations migrating through the Delta~~; and (2) it will meet ~~any~~ all SMART targets ~~existing biological goals~~ approved by the State Water Board.

~~a) The required percent of unimpaired flow may be adjusted to any value between 30 percent and 50 percent, inclusive. The Executive Director may approve changes within this range on an annual basis if all members of the Stanislaus, Tuolumne, and Merced Working Group (STM Working Group), described below, agree to the changes.~~

~~b)~~a) The required percent of unimpaired flow for February through June may be managed as a total volume of water and released on a~~n adaptive~~ schedule during that period that deviates from the 7 day running average, provided that ~~where~~ scientific information indicates a flow pattern different from that which would occur by tracking the unimpaired flow percentage would better protect fish and wildlife beneficial uses and is necessary to achieve the narrative salmon protection and San Joaquin migratory fish viability objectives and SMART targets. The total volume of water must be at least equal to the volume of water that would be released each day by tracking the minimum unimpaired flow percentage on a daily basis from February through June. The total volume of water for the February 1 to May 31 period shall be used within the months of February to May each year. The Executive Director may approve such changes on an annual basis if the change is recommended by the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Wildlife after consultation with ~~one or more members of~~ the STM Working Group.

~~c)~~b) The release of a portion of the ~~February through~~ June 1 to June 30 unimpaired flow may be shifted earlier in the migration season (February 1 through May 31) or delayed until after June to prevent adverse effects to fisheries, including temperature, that would otherwise result from implementation of the February through June flow requirements. The ability to advance release of flow prior to June or delay release of flow until after June is only allowed when the unimpaired flow requirement is greater than ~~3~~40 percent. If the requirement is greater than ~~3~~40 percent but less than 60~~40~~ percent under (a) above, the amount of flow that may be released after June is limited to the portion of the unimpaired flow requirement over ~~3~~40 percent in the month of June. ~~(For example, if the flow requirement is 35 percent, 5 percent may be released after June.) If the requirement is 40 percent or greater under (a) above, then 25 percent of the total volume of the flow requirement may be released after June. (For example, if the requirement is 50 percent, at least 37.5 percent unimpaired flow must be released in February through June and up to 12.5 percent unimpaired flow may be released after June.) If after June the STM Working Group determines that conditions have changed such that water held for release after June should not be released by the fall of that year, the water may be held until the following year.~~ Any changes shall be approved by t~~T~~he Executive Director ~~may approve changes~~ on an annual basis, provided that ~~if~~ the change is recommended jointly by the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Wildlife, after consultation with the STM Working Group~~one or more members of the STM Working Group~~.

~~d)~~c) The required base flow at Vernalis for February through June may be adjusted to any value between 1,800 and ~~1~~2,200 cfs, inclusive. The Executive Director may approve changes within this range on an annual basis, provided that the change is recommended jointly ~~if~~ by the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Wildlife after consultation with the STM Working Group ~~all members of the STM Working Group~~ agree to the changes.

Any of the adjustments in (a)-(~~d~~c) above may be made independently of each other or combined. The adjustments in (a) and~~,~~ (b)~~, and (c)~~ may also be made independently on each of the Stanislaus, Tuolumne, and Merced Rivers, so long as the flows are coordinated to achieve the narrative salmon protection and San Joaquin migratory fish viability objectives and SMART targets ~~beneficial results~~ in the LSJR related to the protection of fish and wildlife beneficial uses. ~~Experiments may also be conducted within the adaptive adjustments in (a)-(d), subject to the approvals provided therein, in order to improve scientific understanding of needed measures for the protection of fish and wildlife beneficial uses, such as the optimal timing of required flows. Any experiment shall be coordinated with the SJRMEP and identify the scientific uncertainties to be addressed and the actions that will be taken to reduce those uncertainties, including monitoring and evaluation.~~

Stanislaus, Tuolumne and Merced Working Group

The State Water Board will establish a STM Working Group to assist with the implementation, monitoring and effectiveness assessment of the February through June LSJR flow requirements. Specifically, the State Water Board will seek recommendations from the STM Working Group on SMART targets~~biological goals~~; procedures for implementing the adaptive methods described above; annual ~~adaptive~~ operations plans; and the SJRMEP, including special studies and reporting requirements. Each of these activities is described in more detail below.

The State Water Board will seek participation in the STM Working Group by the following entities who have expertise in LSJR, Stanislaus, Tuolumne, and Merced Rivers fish population ~~fisheries~~ management, hydrology, operations, and monitoring and assessment needs: the DFW; NMFS; USFWS; and water users on the Stanislaus, Tuolumne, and Merced Rivers. The STM Working Group will also include State Water Board staff and may include any other persons or entities the Executive Director determines to have appropriate expertise. Subgroups of the STM Working Group may be formed as appropriate and State Water Board staff may also initiate activities in coordination with members of the STM Working Group.

SMART Biological and Environmental Targets ~~Goals~~

~~Biological goals~~ SMART targets will be used to inform the ~~adaptive methods~~adaptation of the program of implementation and ~~,~~ evaluate the effectiveness of this program of implementation, the SJRMEP, and future changes to the Bay-Delta Plan. The development of SMART targets will be overseen by the Delta Science Program. The State Water Board will also seek recommendations on these SMART targets ~~biological goals~~ from the STM Working Group, State Water Board staff, and other interested persons. The SMART targets shall be consistent with the narrative salmon protection and San Joaquin migratory fish viability objectives. The State Water Board shall ~~will consider~~ approv~~eal of the~~ SMART targets for each tributary and the LSJR ~~goals~~ within 180 days from the date of the Office of Administrative Law's (OAL) approval of this amendment to the Bay-Delta Plan. ~~and~~ The State Water Board may subsequently modify the SMART targets, after notice and comment, based on new information developed through the monitoring and evaluation activities described below or other pertinent sources of scientific information, provided that the revised SMART targets are consistent with the narrative salmon protection and San Joaquin migratory fish viability objectives and are developed with the input of the Delta Science Program. ~~Biological~~ SMART targets ~~goals will~~ shall ~~specifically~~ be developed for LSJR salmonids ~~, as salmonids are among the fish species most sensitive to LSJR flow modifications. The State Water Board may seek recommendations on biological goals for~~ and other ~~LSJR species as~~ fish and wildlife beneficial uses as appropriate. ~~Biological goals~~ SMART targets will ~~specifically~~ be developed for abundance; productivity as measured by population growth rate; genetic and life history diversity; and population spatial extent, distribution, and structure. Within a given tributary, reasonable contributions to productivity ~~may include meeting measures of quality and quantity of spawning and rearing habitat, fry production, and~~shall include juvenile outmigrant survival to the confluence of each tributary to the LSJR and survival through the SSJR corridor to the Delta.

The salmonid SMART targets ~~biological goals~~ for this program of implementation will be specific to the LSJR and its tributaries and will be consistent with the narrative salmon protection and San Joaquin migratory fish viability objectives ~~contribute to meeting the overall goals for each population, including the salmon doubling objective established in state and federal law~~. ~~Biological goals~~ SMART targets for salmonid populations will be consistent with best available scientific information, including information regarding viable salmonid populations, recovery plans for listed salmonids, or other appropriate information.

Unimpaired Flow Compliance

Implementation of the unimpaired flow requirement for February through June will require the development of information and specific measures to achieve the flow objectives and to monitor and evaluate compliance. The STM Working Group, or State Water Board staff as necessary, will, in consultation with the Delta Science Program, develop and recommend such proposed measures. The State Water Board or Executive Director ~~will consider~~ shall approve~~ing~~ ~~the~~ a final set of measures within 180 days from the date of OAL's approval of this amendment to the Bay-Delta Plan. The approved measures will inform State Water Board water right proceedings, FERC licensing proceedings, or other implementation actions to achieve the February through June flows.

Procedures for Implementation of Adaptive Methods

~~The~~ Upon concurrence of the U.S. Fish and Wildlife Service, National Marine Fisheries Service, California Department of Fish and Game, in consultation with the STM Working Group~~, or~~ the Executive Director ~~State Water Board staff as necessary, will~~shall, in consultation with the Delta Science Program, develop proposed procedures for allowing ~~the adaptive~~ adjustments to the February through June flow requirements discussed above. The State Water Board or Executive Director will consider approving procedures for allowing those ~~adaptive~~ adjustments within one year following the date of OAL's approval of this amendment to the Bay-Delta Plan.

Annual ~~Adaptive~~ Operations Plan

The STM Working Group or members or subsets of the STM Working Group, as appropriate, will be required to submit proposed annual plans for ~~adaptive~~ implementation actions (annual operations plans) for the coming season by January 10 of each year for approval by the State Water Board or Executive Director. The State Water Board recognizes that an annual operations plan is based on a forecast from the best available information and may not accurately reflect actual conditions that occur during the February through June period. Accordingly, the State Water Board will consider this factor and whether the hydrologic condition could have been planned for in evaluating deviations from approved operations plans. Annual operations plans shall describe operational alternatives under a range of potential hydrological exceedence scenarios (wetter than normal, drier than normal, and median exceedence). ~~An annual operations plan shall include actions and operations that consider and will work under a reasonable range of hydrological conditions.~~ It shall also identify how unimpaired flows are calculated and adjustments to be made as updated information becomes available, such as DWR's Bulletin 120.[9] An annual operations plan shall be informed by the review activities described below and may be modified with the approval of the State Water Board or Executive Director.

Implementation of October Pulse Flow Objective

[9] Bulletin 120 is a publication issued four times a year, in the second week of February, March, April, and May by the California Department of Water Resources. It contains forecasts of the volume of seasonal runoff from the state's major watersheds, and summaries of precipitation, snowpack, reservoir storage, and runoff in various regions of the State.

The October pulse flow objective is currently implemented through water right actions. The State Water Board will reevaluate the assignment of responsibility for meeting the October pulse flow objective during a water right proceeding, FERC licensing proceeding, or other proceeding no later than 2022.

Through water right, FERC licensing, or other processes, the State Water Board will require monitoring and special studies to determine what, if any, changes should be made to the October pulse flow objective and its implementation. The State Water Board may require such monitoring and special studies to be part of the SJRMEP. The State Water Board will evaluate the need to modify the October pulse flow objective in a future update of the Bay-Delta Plan based on information developed through these processes.

Variances Upon Determination of a State of Emergency

At its discretion, or at the request of any affected responsible agency or person, the State Water Board may authorize a temporary variance ~~change~~ in the ~~implementation of the~~ LSJR flow objectives in a water right proceeding if the State Water Board determines that ~~either (i) there is an emergency as defined in the California Environmental Quality Act (Pub. Resources Code, § 21060.3) or (ii)~~ the Governor of the State of California ~~or a local governing body~~ has declared a state ~~or local~~ emergency pursuant to the California Emergency Services Act (Gov. Code, §§ 8550 et seq.) and LSJR flow requirements affect or are affected by the conditions of such emergency. Before authorizing any temporary ~~change~~variance, the State Water Board must find that measures will be taken to reasonably protect the fish and wildlife beneficial use in light of the circumstances of the emergency. These provisions regarding variances shall not apply to drought conditions that have lasted less than two consecutive years that are identified as Critically Dry water year types in the San Joaquin River basin.

San Joaquin River Monitoring and Evaluation Program

In order to determine compliance with the LSJR flow objectives, inform adaptive implementation, investigate the technical factors involved in water quality control, and potential needed future changes to the LSJR flow objectives, including flows for other times of the year, a comprehensive monitoring, special studies, evaluation, and reporting program is necessary. The State Water Board will require in water right permits and water quality certifications, as appropriate, annual and comprehensive monitoring, evaluation, and reporting. Pursuant to its authorities, including Water Code section 13165, comprehensive monitoring will be required to address both the individual and cumulative impacts of diversions and discharges to fish and wildlife beneficial uses. The following requirements, at a minimum, shall be imposed:

1) Monitoring, special studies, and evaluations of the effects of flow and other factors on the viability of native LSJR watershed fish populations throughout the year, including assessment of abundance, spatial extent (or distribution), diversity (both genetic and life history), and productivity. In particular, regular monitoring of juvenile salmon production and size and timing of migration will be required on each of the three tributaries and in the lower San Joaquin River and regular adult migration monitoring (which will, at a minimum, produce an estimate of the

number and timing of adult salmon migrants) will be implemented in the lower San Joaquin River below its confluence with the Stanislaus River).

2) Consideration of recommendations from entities with relevant Central Valley monitoring plans to improve standardization of methods, including the quantification of bias and precision of population estimates.
3) Regular external scientific review of monitoring, evaluation, and reporting.

Monitoring should be integrated and coordinated with new and ongoing monitoring and special studies programs in the LSJR, including pursuant to federal biological opinion requirements, FERC licensing proceedings for the Tuolumne and Merced Rivers, Central Valley Regional Water Board requirements, and the Delta Science Program.

Annual reporting

To inform ~~the next year's~~ operations and other activities in subsequent years, the State Water Board will require preparation and submittal of an annual report to the State Water Board by December 31 of each year. The annual report shall describe implementation of flows, including any flow shifting done pursuant to the annual adaptive operations plan, monitoring and special studies activities, and implementation of other measures to protect fish and wildlife during the previous water year, including the actions by other entities identified in this program of implementation. The annual report shall also identify any deviations from the annual adaptive operations plan and describe future special studies. The State Water Board may hold public meetings to receive and discuss the annual report.

Comprehensive Reporting

Additionally, every ~~three to~~ five years following implementation of this update to the Bay-Delta Plan, the State Water Board will require preparation and submittal of a comprehensive report that, in addition to the requirements of annual reporting:~~,~~ ~~reviews~~ (1) describes the progress toward meeting the narrative salmon protection and San Joaquin migratory fish viability objectives and SMART targets; (2) reviews information gained regarding testable hypotheses that were the basis of management and operations during the report period; and, (3) identifies any recommended ~~changes~~ adaptations to the implementation of the flow objectives. The comprehensive report and any recommendations shall be peer-reviewed by an appropriate independent science panel, which will make its own conclusions and recommendations. The State Water Board will hold public meetings to consider the comprehensive report, technical information, and conclusions or recommendations developed through the peer review process. This information will be used to inform potential adaptive changes to the implementation of the flow objectives and, as appropriate, future potential changes to the Bay-Delta Plan.

In order to leverage expertise and limited resources (financial and otherwise), parties are encouraged to work collaboratively in one or more groups and in consultation with the STM Working Group, USBR and DWR, in meeting the above monitoring and reporting requirements. The State Water Board may streamline monitoring and reporting obligations of parties working collaboratively with each other, the STM Working Group, USBR, DWR, the Delta Science Program or other appropriate parties.

APPENDIX A
STANISLAUS RIVER SURVIVAL MODE

In Microsoft Excel file

APPENDIX B
ENVIRONMENTAL OBJECTIVES FOR ACHIEVING THE STANISLAUS RIVER BIOLOGICAL OBJECTIVES

These matrices have been created to assist the SEP Group in evaluating conservation measures within a comprehensive framework documenting habitat needs (and stressors) of three runs of anadromous salmonids in the Stanislaus River.

Table B-1
Adult Upstream Migration Environmental Objectives

Desired Habitat Parameter	Physical Parameter	Units	Metric	Fall-run Chinook			Spring-run Chinook			Steelhead		
				Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental
Water Quality	Temperature [1,2,3]	°C (°F)	Daily Average	8 to 14 (46.4 to 57.2)	14 to 19 (57.2 to 66.2)	> 19 (66.2)	8 to 14 (46.4 to 57.2)	14 to 19 (57.2 to 66.2)	> 19 (66.2)	Less direct evidence; assume similar to Chinook salmon		
Water Quality	Temperature [1,2,3]	°C (°F)	7DADM	9.5 to 15.5 (49.1 to 59.9)	15.5 to 20.5 (59.9 to 68.9)	> 20.5 (68.9)	9.5 to 15.5 (49.1 to 59.9)	15.5 to 20.5 (59.9 to 68.9)	> 20.5 (68.9)	Less direct evidence; assume similar to Chinook salmon		
Water Quality	Temperature [1,2,3]	°C (°F)	Weekly Average			> 18 (64.4)			> 18 (64.4)	Less direct evidence; assume similar to Chinook salmon		
Water Quality	Temperature [1,2,3]	°C (°F)	Instantaneous			> 22 (71.6)			> 22 (71.6)	Less direct evidence; assume similar to Chinook salmon		
Water Quality	Dissolved Oxygen [4,5,6,7,8]	mg/L	Daily Minimum	> 8	6 to 8	< 6.0	> 8	6 to 8	< 6	Less direct evidence; assume similar to Chinook salmon		
Water Quantity/ Physical Habitat	Channel – Depth[9]	m (ft)		1. Shallowest riffle: at least 10% of the entire length of a transect (perpendicular to the flow) in the shallowest riffle in the migratory corridor (critical riffle) must be contiguous for a depth no less than 0.3 meter (m) (at least 1 foot [ft]) and at least 25% of the entire transect must be greater than or equal to 0.3 m (1 ft; CDFW 2013). 2. Frequency of shallow riffles:90% of the riffles in the migratory corridor must satisfy the requirements of the critical riffle for depths greater than or equal to 0.46 m (1.5 ft) instead of greater than or equal to 0.3 m (1.0 ft).			1. Shallowest riffle: at least 10% of the entire length of a transect (perpendicular to the flow) in the shallowest riffle in the migratory corridor (critical riffle) must be contiguous for a depth no less than 0.3 meter (m) (at least 1 foot [ft]) and at least 25% of the entire transect must be greater than or equal to 0.3 m (1 ft; CDFW 2013). 2. Frequency of shallow riffles:90% of the riffles in the migratory corridor must satisfy the requirements of the critical riffle for depths greater than or equal to 0.46 m (1.5 ft) instead of greater than or equal to 0.3 m (1.0 ft).			1.Shallowest riffle: at least 10% of the entire length of a transect (perpendicular to the flow) in the shallowest riffle in the migratory corridor (critical riffle) must be contiguous for a depth no less than 0.3 meter (m) (at least 1 foot [ft]) and at least 25% of the entire transect must be greater than or equal to 0.23 m (0.77 ft; (CDFW 2013). 2. Frequency of shallow riffles:90% of the riffles in the migratory corridor must satisfy the requirements of the critical riffle for depths greater than or equal to 0.35 m (1.15 ft)		
Water Quality	Pesticides (including Copper)	Risk – Frequency of Benchmark Exceedances	Frequency of Exceedances	≤ 0.017	0.018 to 0.303	≥ 0.304	≤ 0.017	0.018 to 0.303	≥ 0.304	≤ 0.017	0.018 to 0.303	≥ 0.304
Water Quantity	Flow – Attraction	To be determined		**Basin-wide Environmental Objective needed**			**Basin-wide Environmental Objective needed**			**Basin-wide Environmental Objective needed**		
Water Quantity	Flow – Base	To be determined		At least the minimum necessary to provide target levels for each of the other water quality and physical habitat parameters identified here.			At least the minimum necessary to provide target levels for each of the other water quality and physical habitat parameters identified here.			At least the minimum necessary to provide target levels for each of the other water quality and physical habitat parameters identified here.		
Physical Habitat	Connectivity/ Unimpaired Passage / Window	Hours of Delay		0 ⍰	< 24	> 24	0 ⍰	< 24	> 24	0 ⍰	< 24	> 24
Physical Habitat	Structure – Hydraulic Refuge and Predation Cover	Suitable Area/River Mile		Basin-wide Environmental Objective needed: Hydraulic refuge/Predation Cover will be a function of returns expected from all rivers in the basin			Basin-wide Environmental Objective needed: Hydraulic refuge/Predation Cover will be a function of returns expected from all rivers in the basin			Basin-wide Environmental Objective needed: Hydraulic refuge/Predation Cover will be a function of returns expected from all rivers in the basin		

Table B-1
Adult Upstream Migration Environmental Objectives

Notes:

[1] Chinook optimal: Weekly average: 8 - 12°C (Raleigh et al. 1986) to avoid egg impacts, daily average <17°C (USEPA 2003)

[2] Chinook sub-optimal: Weekly average 14 - 17°C - disease rate elevated risk (USEPA 2001 and Richter and Kolmes 2005); Daily average 17 - 18°C (McCullough as cited in USEPA 2001); Instantaneous average 19°C (Williams 2006; Richter and Kolmes 2005)

[3] Chinook migration blocked/lethal: Instantaneous average 20 - 22°C (See Hicks 2000, as cited by Richter and Kolmes 2005; USEPA 1999, 2001, 2003)

[4] Detrimental/avoidance: <6 mg/L (WDOE 2002a)

[5] Detrimental/distress: 6.0 mg/L (Davis 1975 and WDOE 2002a)

[6] Sub-optimal/poor: <6.5 mg/L (USEPA 1986; WDOE Water Quality Standards; and Canadian Council of Ministers of the Environment 1999)

[7] Sub-optimal [<8 mg/L]: ≥7 mg/L for all waterbodies other than bays and reservoirs (SWRCB 2001 Water Quality Control Plan, North Coast region TABLE 3-1. 10% reduction in swimming speed at 7mg/L [vs saturation]; See Davis 1963 as cited by WDOE 2002b and Dahlberg 1968 as cited by British Columbia, Ministry of the Environment)

[8] Optimal: >8 mg/L USEPA 1986 (no production impairment); 8-9 mg/L WDOE 2002b (swimming of fitness of salmonids maximized). 9 mg/L (at <10°C) or 13 mg/L (at >10°C) optimal (Raleigh et. al. 1986).

[9] DFG 2013.

°C = degrees Celsius
7DADM = 7-day average of the daily maximum
cfs = cubic feet per second
ft = feet
mg/L = milligram per liter
SJR = San Joaquin River
">" = greater than
"<" = less than
"≤" = less than or equal to
"≥" = greater than or equal to

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Table B-2
Adult Holding Environmental Objectives

Desired Habitat Parameter	Physical Parameter	Units	Metric	Goodwin Dam to Knights Ferry Reach[1]		
				Spring-Run Chinook & Steelhead		
				Optimal	Sub-optimal	Detrimental
Water Quality	Temperature	°C(°F)	Daily Average	< 13 (55.4)	13 to 17 (55.4 to 62.6)	18 to 20 (64.4 to 68)
Water Quality	Temperature	°C(°F)	7DADM	< 14.5 (58.1)	14.5 to 18.5 (58.1 to 65.3)	
Water Quality	Temperature	°C(°F)	Prolonged Exposure			17 to 18 (62.6 to 64.4)
Water Quality	Dissolved Oxygen	mg/L	Daily Minimum	> 8	6 to 8	< 6
Physical Habitat	Water Depth	m (ft)	Minimum	≥ 1.5 (4.9)		
Physical Habitat	Velocity	m/s (ft/s)	Maximum	< 0.37 (1.2)		
Water Quality	Pesticides, including Copper	Risk - Frequency of Benchmark Exceedances	Frequency of Exceedances	≤ 0.017	0.018 to 0.303	≥ 0.304
Other Non-Physical Parameters	Predation (Anglers/Poachers)	% Mortality		0		

Notes:

[1] Geographic range guidance provided to indicate those reaches where inherent characteristics of the system (e.g. geologic, topographic, and geomorphic) suggest that a particular type of habitat may be created in service of the overall need to increase spatial habitat extent. The reach is defined as broadly as possible to allow for maximum flexibility in the attainment of environmental objectives given the inherent constraints of the system. The location of sufficient area of holding habitat required to meet Environmental Objectives determines the number of river miles in which high-quality holding habitat must occur. For example, no holding habitat is expected or needed downstream of Knights Ferry, and this guidance does not require that such habitat be created as far downstream as Knights Ferry.

µg/L = microgram per liter
^{o}C = degrees Celsius
7DADM = 7-day average of the daily maximum
d.w. = dry weight

"≤" = less than or equal to
"≥" = greater than or equal to
">" = greater than
"<" = less than

ft/s = feet per second

ppm = parts per million

w.w. = wet weight

ft/s = feet per second

References:

EPA 2003 (temperature); Moyle et al. 1995 (depths); Moyle 2003b (velocity)

Table B-3
Spawning Habitat Environmental Objectives

Desired Habitat Parameter	Physical Parameter	Units	Metric	Fall-run Chinook			Spring-run Chinook			Steelhead		
				Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental
Water Quality	Temperature[1, 2]	°C (°F)	Daily Average	6 to 12 (42.8 to 53.6)	4 to 6 (39.2 to 42.8) 12 to 13.3 (53.6 to 55.9)	> 13.3 (55.9)	6 to 12 (42.8 to 53.6)	4 to 6 (39.2 to 42.8) 12 to 13.3 (53.6 to 55.9)	> 13.3 (55.9)	7 to 10 (44.6 to 50)	4 to 6.9 (39.2 to 44.4) 10 to 13.5 (50 to 56.3)	> 13.5 (56.3)
Water Quality	Temperature[1, 2]	°C (°F)	7DADM	< 12.5 (54.5)	12.5 to 13.8 (54.5 to 56.8)	> 13.8 (56.8)	< 12.5 to 13 (54.5 to 55.4)	12.5 to 13.8 (54.5 to 56.8)	> 13.8 (56.8)	10.5 (50.9)	10.5 to 14 (50.9 to 57.2)	> 14.0 (57.2)
Water Quality	Dissolved Oxygen	mg/L	Daily Minimum	> 8	6 to 8	< 6	> 8	6 to 8	< 6	> 8	6 to 8	< 6
Physical Habitat	Depth	m (ft)		0.3 to 0.76 (1 to 2.5) (HSI > 0.6)	0.15 to 0.3 (0.5 to 1) and 0.76 to 3.05 (2.5 to 10)	< 0.15 (0.5) or > 3.05 (10)	0.3 to 0.76 (1 to 2.5) (HSI > 0.6)	0.15 to 0.3 (0.5 to 1) and 0.76 to 3.05 (2.5 to 10)	< 0.15 (0.5) or > 3.05 (10)	0.15 to 0.61 (0.5 to 2)	0.08 to 0.15 (0.26 to 0.5) and 0.61 to 1(2 to 3.3)	< 0.08 (0.26) or > 1 (3.3)
Physical Habitat	Velocity[4]	m/s (ft/s)		0.3 to 1.2 (1 to 4)	0.12 to 0.3 (0.4 to 1) and 1.2 to 1.5 (4 to 5)	< 0.12 (0.4) or > 1.5 (5)	0.3 to 1.2 (1 to 4)	0.12 to 0.3 (0.4 to 1) and 1.2 to 1.5 (4 to 5)	< 0.12 (0.4) or > 1.5 (5)	0.5 to 1.1 (1.6 to 3.6)	0.32 to 0.4 (1.1 to 1.3)	< 0.3 (< 0.98) or > 1.2 (4)
Water Quality	Pesticides, including Copper[3]	% days in a month	Risk - Frequency of Benchmark Exceedances	≤ 1.7%	1.8% to 30.3%	≥ 30.4%	≤ 1.7%	1.8% to 30.3%	≥ 30.4%	≤ 1.7%	1.8% to 30.3%	≥ 30.4%
Physical Habitat	Spawning Area - Sediment Size Distribution[6]	Gravel Size: D_{50} mm (in)	Majority Composition	55 to 25 (2.17 to 0.98)	80 to 56 (3.15 to 2.20) and 24 to 10 (0. 94 to 0.39)	Not spawning habitat <9 (0.35) or > 81 (3.19)	55 to 25 (2.17 to 0.98)	80 to 56 (3.15 to 2.20) and 24 to 10 (0. 94 to 0.39)	Not spawning habitat <9 (0.35) or > 81 (3.19)	30 to 15 (1.18 to 0.59)	50 to 30 (1.97 to 1.18) and 15 to 10 (0.59 to 0.39)	Not spawning habitat <9 (0.35 in) or > 51 (2)
Physical Habitat	Spawning Area - Extent[5]	Acres	Entire Spawning Area	14.7			14.7			2.7		
Physical Habitat	Spawning Area - Habitat Heterogeneity			Geomorphic processes should be operating naturally so that there is a natural alternation of pools and riffles.			Geomorphic processes should be operating naturally so that there is a natural alternation of pools and riffles.			Spawning areas need to be adjacent to deep pools and cover.		
Physical Habitat	Spawning Area - Distribution			Fall-run Chinook salmon spawning area must be segregated from spring-run Chinook salmon spawning area temporally, spatially, or both.								
Other Non-Physical Parameters	Predation (Anglers/Poachers)[7]			0			0			0		

Table B-3
Spawning Habitat Environmental Objectives

Notes:

[1] Chinook Optimal: USEPA (2003) 4 to 12°C result in good egg survival and that a narrower range (6 to 10°C) is optimal, USFWS (1999 cited by Myrick and Cech 2004) concluded that temperature-related egg mortality in Chinook salmon increased at temperatures above 13.3°C (56°F), 6 and 12°C were optimal for Central Valley Chinook salmon (Myrick and Cech 2004)

[2] Myrick and Cech (2004), Richter and Kolmes (2005) see also McEwan and Jackson (1996)

[3] Hoogeweg et al. 2011

[4] Steelhead: Bovee 1978 as cited in McEwan and Jackson 1996

[5] 5 to 7 square yards/redd (Orcutt et al. 1968)

[6] 1/2" to 3" diameter (Orcutt et al. 1968); D_{50} of redds from smaller steelhead (65 - 68 cm) was about 0.5 in to 1.5 in (Kondolf and Wolman 1993) Orcutt et al. 1968, Kondolf and Wolman 1993: See calculation in notes for combination of anadromous/resident spawning

[7] Target of zero poaching; eventual target (successful restoration) would be increased fishing mortality as the population recovers and fishing pressure increases.

°C = degrees Celsius

°F = degrees Fahrenheit

µg/L = microgram per liter

cm = centimeter

d.w. = dry weight

ft/s = feet per second

HSI = habitat suitability index

in = inch

m/s = meter per second

mg/L = milligram per liter

mm = millimeter

ppm = parts per million

w.w. = wet weight

">" = greater than

"<" = less than

"≤" = less than or equal to

"≥" = greater than or equal to

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Table B-4
Egg Incubation Environmental Objectives

Desired Habitat Parameter	Physical Parameter	Units	Metric	Goodwin Dam to Riverbank [1]			Upstream to Knights Ferry [1]			Goodwin Dam to Oakdale [1]		
				Fall-run Chinook			Spring-run Chinook			Steelhead		
				Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental
Water Quality	Temperature	°C (°F)	Daily Average	6 to 12 (42.8 to 53.6)	4 to 6 (39.2 to 42.8) 12 to 13.3 (53.6 to 55.9)	> 13.3 (55.9)	6 to 12 (42.8 to 53.6)	4 to 6 (39.2 to 42.8) 12 to 13.3 (53.6 to 55.9)	> 13.3 (55.9)	7 to 10 (44.6 to 50)	4 to 6.9 (39.2 to 44.4) 10 to 13.5 (50 to 56.3)	> 13.5 (56.3)
Water Quality	Temperature	°C (°F)	7DADM	< 12.5 (54.5)	12.5 to 13.8 (54.5 to 56.8)	> 13.8 (56.8)	< 12.5 (54.5)	12.5 to 13.8 (54.5 to 56.8)	> 13.8 (56.8)	< 10.5 (50.9)	10.5 to 14.0 (50.9 to 57.2)	> 14.0 (57.2)
Water Quality	Dissolved Oxygen	mg/L	Daily Minimum	> 8	6 to 8	< 6	> 8	6 to 8	< 6	> 8	6 to 8	< 6
Physical Habitat	Water Depth	m (ft)		0.3 to 0.76 (1 to 2.5) (HSI > 0.6)	0.15 to 0.3 (0.5 to 1) and 0.76 to 3.05 (2.5 to 10)	< 0.15 (0.5) or > 3.05 (10)	0.3 to 0.76 (1 to 2.5) (HSI > 0.6)	0.15 to 0.3 (0.5 to 1) and 0.76 to 3.05 (2.5 to 10)	< 0.15 (0.5) or > 3.05 (10)	0.15 to 0.61 (0.5 to 2)	0.08 to 0.15 (0.26 to 0.5) and 0.61 to 1(2 to 3.3)	< 0.08 (0.26) or > 1 (3.3)
Physical Habitat	Velocity	m/s (ft/s)		0.3 to 1.2 (1 to 4)	0.12 to 0.3 (0.4 to 1) and 1.2 to 1.5 (4 to 5)	< 0.12 (0.4) or > 1.5 (5)	0.3 to 1.2 (1 to 4)	0.12 to 0.3 (0.4 to 1) and 1.2 to 1.5 (4 to 5)	< 0.12 (0.4) or > 1.5 (5)	0.5 to 1.1 (1.6 to 3.6)	0.32 to 0.4 (1.1 to 1.3)	< 0.3 (< 0.98) or > 1.2 (3.9)
Water Quality	Pesticides, including Copper	Risk – Frequency of Benchmark Exceedances	Frequency of Exceedances	≤ 0.017	0.018 to 0.303	≥ 0.304	≤ 0.017	0.018 to 0.303	≥ 0.304	≤ 0.017	0.018 to 0.303	≥ 0.304
Water Quality	Other Contaminants – Selenium	mg/kg (d.w., tissue) µg/L (water)	Maximum Concentration	15.2 mg/kg (egg/ovary) 4.8 µg/L (water, lotic)			15.2 mg/kg (egg/ovary) 4.8 µg/L (water, lotic)			15.2 mg/kg (egg/ovary) 4.8 µg/L (water, lotic)		
Water Quality	Other Contaminants – Mercury	mg/kg (w.w., tissue, eggs/larvae)	Maximum Concentration	< 0.02	0.02 to 0.1	> 0.1	< 0.02	0.02 to 0.1	> 0.1	< 0.02	0.02 to 0.1	> 0.1
Physical Habitat	Spawning Area – Gravel Quality – Fine Sediment	Percent (%) of fines		< 5 smaller than 4.8 mm (0.189 in)	5 to 15 finer than 4.8 mm (0.189 in) or 5 to 10 finer than 0.85 mm (0.033 in)	> 15 smaller than 4.8 mm (0.189 in) or > 10 smaller than 0.85 mm (0.033 in)	< 5 smaller than 4.8 mm (0.189 in)	5 to 15 finer than 4.8 mm (0.189 in) or 5 to 10 finer than 0.85 mm (0.033 in)	> 15 smaller than 4.8 mm (0.189 in) or > 10 smaller than 0.85 mm (0.033 in)	< 5 smaller than 4.8 mm (0.189 in)	5 to 15 finer than 4.8 mm (0.189 in) or 5 to 10 finer than 0.85 mm (0.033 in)	> 15 smaller than 4.8 mm (0.189 in) or > 10 smaller than 0.85 mm (0.033 in)

[1] Geographic range guidance provided to indicate those reaches where inherent characteristics of the system (e.g. geologic, topographic, and geomorphic) suggest that a particular type of habitat may be created in service of the overall need to increase spatial habitat extent. The reach is defined as broadly as possible to allow for maximum flexibility in the attainment of environmental objectives given the inherent constraints of the system. The location of sufficient acreage of spawning habitat required to meet Environmental Objectives determines the number of river miles in which high-quality spawning habitat must occur. Environmental objectives for incubation begin as soon as spawning has occurred through the full time period needed for incubation

Table B-4
Egg Incubation Environmental Objectives

Notes:
^{o}C = degrees Celsius
µg/L = microgram per liter
7DADM = 7-day average of the daily maximum
d.w. = dry weight
ft/s = feet per second
HSI = habitat suitability index
in = inch
m/s = meter per second
mg/L = milligram per liter
ppm = parts per million
w.w. = wet weight
">" = greater than
"<" = less than
"≤" = less than or equal to
"≤" = greater than or equal to

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Table B-5a

Juvenile Rearing Environmental Objectives (Floodplain, Long Inundation)

Desired Habitat Parameter	Physical Parameter	Units	Metric	Below Ripon								
				Fall-run Chinook			Spring-run Chinook			Steelhead		
				Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental
Water Quality	Temperature	^oC (^oF)	7DADM	10 to 18 (50 to 64.4)	18 to 25 (64.4 to 77)	> 25 (77)	10 to 18 (50 to 64.4)	18 to 25 (64.4 to 77)	> 25 (77)	10 to 18 (50 to 64.4)	18 to 25 (64.4 to 77)	> 25 (77)
Water Quality	Dissolved Oxygen	mg/L	Daily Minimum	> 8[1]	6 to 8	< 6	> 8[1]	6 to 8	< 6	> 8[1]	6 to 8	< 6
Water Quantity	Water Depth	m (ft)	Averaged Spatially	0.15 to 1.22 (0.5 to 4)	1.23 to 2.13 (4 to 7)		0.15 to 1.22 (0.5 to 4)	1.23 to 2.13 (4 to 7)		0.15 to 1.22 (0.5 to 4)	1.23 to 2.13 (4 to 7)	
Water Quantity	Velocity	m/s (ft/s)		0 to 0.9 (0 to 3)	> 0.9 (3)		0 to 0.9 (0 to 3)	> 0.9 (3)		0 to 0.9 (0 to 3)	> 0.9 (3)	
Water Quality	Pesticides, including Copper[2]	Risk – Frequency of Benchmark Exceedances	Frequency of Exceedances	≤0.017	0.018 to 0.303	≥ 0.304	≤0.017	0.018 to 0.303	≥ 0.304	≤0.017	0.018 to 0.303	≥ 0.304
Water Quality	Other Contaminants – Selenium	mg/kg (d.w., tissue) µg/L (water)	Maximum Concentration	8.1 mg/kg (whole body) 11.8 mg/kg (muscle) 4.8 µg/L (water, lotic)			8.1 mg/kg (whole body) 11.8 mg/kg (muscle) 4.8 µg/L (water, lotic)			8.1 mg/kg (whole body) 11.8 mg/kg (muscle) 4.8 µg/L (water, lotic)		
Water Quality	Other Contaminants – Mercury	mg/kg (w.w., tissue, whole body, juvenile)	Maximum Concentration	< 0.2	0.2 to 1.0	> 1.0	< 0.2	0.2 to 1.0	> 1.0	< 0.2	0.2 to 1.0	> 1.0
Physical Habitat	Inundation	Wetted Acre-Days	Duration	10 to 21			10 to 21			10 to 21		
Physical Habitat	Inundation	events/year	Recurrence Interval (RI)	≥ 1 in 3 years; (minimum of 1 week drawdown to distinguish discrete event)			≥ 1 in 3 years; (minimum of 1 week drawdown to distinguish discrete event)			≥ 1 in 3 years; (minimum of 1 week drawdown to distinguish discrete event)		
Landform and Cover	Cover	% suitable; HSI score		Presence and diversity of suitable cover type(s); Average HSI score ≥ 0.5			Presence and diversity of suitable cover type(s); Average HSI score ≥ 0.5			Presence and diversity of suitable cover type(s); Average HSI score ≥ 0.5		
Landform and Cover	Substrate	grain size; % fines		> X% fines			> X% fines			> X% fines		

Table B-5a
Juvenile Rearing Environmental Objectives (Floodplain, Long Inundation)

Desired Habitat Parameter	Physical Parameter	Units	Metric	Below Ripon								
				Fall-run Chinook			Spring-run Chinook			Steelhead		
				Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental
Landform and Cover	Spatial Extent and Distribution			Ripon To Caswell: ≥ X% Caswell to Confluence: ≥ X%			Ripon To Caswell: ≥ X% Caswell to Confluence: ≥ X%			Ripon To Caswell: ≥ X% Caswell to Confluence: ≥ X%		

Notes:
[1] Bell 1986
[2] Hoogeweg et al. 2011
°C = degrees Celsius
°F = degrees Fahrenheit
7DADM = 7-day average of the daily maximum
ft = feet
ft/s = feet per second
HSI = habitat suitability index
m = meter
in = inch
m/s = meter per second
mg/L = milligram per liter
ppm = parts per million
">" = greater than
"<" = less than
"≤" = less than or equal to
"≥" = greater than or equal to
w.w. = wet weight
d.w. = dry weight
µg/L = microgram per liter

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Table B-5b

Juvenile Rearing Environmental Objectives (Off-Channel, Short Inundation)

Desired Habitat Parameter	Physical Parameter	Units	Metric	Above Ripon								
				Fall-run Chinook			Spring-run Chinook			Steelhead		
				Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental
Water Quality	Temperature	°C (°F)	7DADM	10 to 18 (50 to 64.4)	18 to 20 (64.4 to 68)	> 20 (68)	10 to 18 (50 to 64.4)	18 to 20 (64.4 to 68)	> 20 (68)	10 to 18 (50 to 64.4)	18 to 20 (64.4 to 68)	> 20 (68)
Water Quality	Dissolved Oxygen	ppm	Daily Minimum	> 8[1]	6 to 8	< 6	> 8[1]	6 to 8	< 6	> 8[1]	6 to 8	< 6
Water Quantity	Water Depth	m (ft)	Averaged Spatially	0.15 to 1.22 (0.5 to 4)	1.23 to 2.13 (4 to 7)		0.15 to 1.22 (0.5 to 4)	1.23 to 2.13 (4 to 7)		0.15 to 1.22 (0.5 to 4)	1.23 to 2.13 (4 to 7)	
Water Quantity	Velocity	m/s (ft/s)		0 to 0.9 (0 to 3)	> 0.9 (3)		0 to 0.9 (0 to 3)	> 0.9 (3)		0 to 0.9 (0 to 3)	> 0.9 (3)	
Water Quality	Pesticides, including Copper[2]	Risk – Frequency of Benchmark Exceedances	Frequency of Exceedances	≤ 0.017	0.018 to 0.303	≥ 0.304	≤ 0.017	0.018 to 0.303	≥ 0.304	≤ 0.017	0.018 to 0.303	≥ 0.304
Water Quality	Other Contaminants – Selenium	mg/kg (d.w., tissue) µg/L (water)	Maximum Concentration	8.1 mg/kg (whole body) 11.8 mg/kg (muscle) 4.8 µg/L (water, lotic)			8.1 mg/kg (whole body) 11.8 mg/kg (muscle) 4.8 µg/L (water, lotic)			8.1 mg/kg (whole body) 11.8 mg/kg (muscle) 4.8 µg/L (water, lotic)		
Water Quality	Other Contaminants – Mercury	mg/kg (w.w., tissue, whole body, juvenile)	Maximum Concentration	< 0.2	0.2 to 1.0	> 1.0	< 0.2	0.2 to 1.0	> 1.0	< 0.2	0.2 to 1.0	> 1.0
Physical Habitat	Inundation	Wetted Acre-Days	Duration	1 to 9			1 to 9			1 to 9		
Physical Habitat	Inundation	Events/Year	Recurrence Interval (RI)	≥ 2 in 3 years; (minimum of 1 week drawdown to distinguish discrete event); >1 event per year in years when innundation occurs			≥ 2 in 3 years; (minimum of 1 week drawdown to distinguish discrete event); >1 event per year in years when innundation occurs			≥ 2 in 3 years; (minimum of 1 week drawdown to distinguish discrete event); >1 event per year in years when innundation occurs		
Landform and Cover	Cover	% Suitable; HSI Score		Presence and diversity of suitable cover type(s); Average HSI score greater ≥ 0.5 (see table)			Presence and diversity of suitable cover type(s); Average HSI score greater ≥ 0.5 (see table)			Presence and diversity of suitable cover type(s); Average HSI score greater ≥ 0.5 (see table)		
Landform and Cover	Substrate	grain size; % fines		Greater than X% cobble/ gravel Less than X% fines			Greater than X% cobble/ gravel Less than X% fines			Greater than X% cobble/ gravel Less than X% fines		

Table B-5b

Juvenile Rearing Environmental Objectives (Off-Channel, Short Inundation)

Desired Habitat Parameter	Physical Parameter	Units	Metric	Above Ripon								
				Fall-run Chinook			Spring-run Chinook			Steelhead		
				Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental
Landform and Cover	Spatial Extent and Distribution			Upstream of Goodwin: ≥ X% Goodwin to Knights Ferry: ≥ X% Knights Ferry to Oakdale: ≥ X% Oakdale to Riverbank: ≥ X% Riverbank to Ripon: ≥ X%			Upstream of Goodwin: ≥ X% Goodwin to Knights Ferry: ≥ X% Knights Ferry to Oakdale: ≥ X% Oakdale to Riverbank: ≥ X% Riverbank to Ripon: ≥ X%			Upstream of Goodwin: ≥ X% Goodwin to Knights Ferry: ≥ X% Knights Ferry to Oakdale: ≥ X% Oakdale to Riverbank: ≥ X% Riverbank to Ripon: ≥ X%		

Notes:

[1] Bell 1986

°C = degrees Celsius

°F = degrees Fahrenheit

7DADM = 7-day average of the daily maximum

ft = feet

ft/s = feet per second

HSI = habitat suitability index

m = meter

in = inch

m/s = meter per second

mg/L = milligram per liter

ppm = parts per million

">" = greater than

"<" = less than

"≤" = less than or equal to

"≥" = greater than or equal to

w.w. = wet weight

d.w. = dry weight

µg/L = microgram per liter

References:

Bell, M.C., 1986. *Fisheries Handbook of Engineering Requirements and Biological Criteria* , edited by U.S. Army Corps of Engineers, Portland, Oregon, p. 320.

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Table B-5c
Juvenile Rearing Environmental Objectives (Channel)

Desired Habitat Parameter	Physical Parameter	Units	Metric	Entire River to Confluence								
				Fall-run Chinook			Spring-run Chinook			Steelhead		
				Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental	Optimal	Sub-optimal	Detrimental
Water Quality	Temperature	°C (°F)	7DADM	6 to 16 (42.8 to 60.8)	17 to 20 (62.6 to 68)	> 20 (68)	6 to 16 (42.8 to 60.8)	17 to 20 (62.6 to 68)	> 20 (68)	6 to 16 (42.8 to 60.8)	17 to 20 (62.6 to 68)	> 20 (68)
Water Quantity	Flow Variability			TBD (X to X applicable during X time of year)			TBD (X to X applicable during X time of year)			TBD (X to X applicable during X time of year)		
Water Quality	Pesticides, including Copper[2]	Risk - Frequency of Benchmark Exceedances	Frequency of Exceedances	≤ 0.017	0.018 to 0.303	≥ 0.304	≤ 0.017	0.018 to 0.303	≥ 0.304	≤ 0.017	0.018 to 0.303	≥ 0.304
Water Quality	Other Contaminants - Selenium	mg/kg (d.w., tissue) µg/L (water)	Maximum Concentration	8.1 mg/kg (whole body) 11.8 mg/kg (muscle) 4.8 µg/L (water, lotic)			8.1 mg/kg (whole body) 11.8 mg/kg (muscle) 4.8 µg/L (water, lotic)			8.1 mg/kg (whole body) 11.8 mg/kg (muscle) 4.8 µg/L (water, lotic)		
Water Quality	Other Contaminants - Mercury	mg/kg (w.w., tissue, whole body, juvenile)	Maximum Concentration	< 0.2	0.2 to 1.0	> 1.0	< 0.2	0.2 to 1.0	> 1.0	< 0.2	0.2 to 1.0	> 1.0
Landform and Cover	Substrate	Grain Size; % Suitable		> X% cobble/gravel < X% fines			> X% cobble/gravel < X% fines			> X% cobble/gravel < X% fines		

Notes:
°C = degrees Celsius
°F = degrees Fahrenheit
7DADM = 7-day average of the daily maximum
ppm = parts per million

">" = greater than
"<" = less than
"≤" = less than or equal to
"≥" = greater than or equal to
w.w. = wet weight
d.w. = dry weight
µg/L = microgram per liter

Sources:

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Table B-5d
Juvenile Migration (Smoltification) Environmental Objectives (Channel)

Desired Habitat Parameter	Physical Parameter	Units	Metric	Entire River to Confluence								
				Fall-Run Chinook			Spring-Run Chinook			Steelhead		
				Optimal	**Sub-Optimal**	**Detrimental**	**Optimal**	**Sub-Optimal**	**Detrimental**	**Optimal**	**Sub-Optimal**	**Detrimental**
Water Quality	Temperature	^{o}C (^{o}F)	7DADM	6 to 16 (42.8 to 60.8)			6 to 16 (42.8 to 60.8)			12.5 (54.5)		> 12.5 (54.5)
Water Quality	Temperature	^{o}C (^{o}F)	Weekly Average							< 11 (51.8)		> 11 (51.8)

Notes:
^{o}C = degrees Celsius
^{o}F = degrees Fahrenheit
7DADM = 7-day average of the daily maximum
">" = greater than
"<" = less than

Sources:
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APPENDIX C
ENVIRONMENTAL OBJECTIVES THAT APPLY ACROSS ALL SPECIES AND LIFE STAGES

November 2016

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ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
µg/g	micrograms per gram
µg/L	micrograms per liter
7DADM	7-day average of daily maximum temperature
ATP	adenosine triphosphate
Basin Plan	Sacramento and San Joaquin River Basins Water Quality Control Plan
CDFG	California Department of Fish and Game
CDPR	California Department of Pesticide Regulation
CFR	Code of Federal Regulations
ChE	cholinesterase
CRWQCBSDR	California Regional Water Quality Control Board San Diego Region
CTR	California Toxics Rule
CVRWQCB	Central Valley Regional Water Quality Control Board
Delta	Sacramento-San Joaquin Delta
DO	dissolved oxygen
DWR	California Department of Water Resources
ELS	early-life stages
ESA	Endangered Species Act
Hg	mercury
IULT	Incipient Upper Lethal Temperatures
mg/kg	milligram per kilogram
mg/L	milligram per liter
NAWQA	National Water-Quality Assessment
ng/L	nanogram per liter
NMFS	National Marine Fisheries Service
OPP	Office of Pesticide Programs
SEP	Scientific Evaluation Process
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute

SWRCB	State Water Resources Control Board
TDC	TDC Environmental
TMDL	Total Maximum Daily Load
t-TEL	tissue threshold-effect level
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WDOE	Washington State Department of Ecology
WQC	Water Quality Criterion

1 ENVIRONMENTAL OBJECTIVES AND SUPPORTING RATIONALE FOR VARIABLES THAT APPLY ACROSS ALL SPECIES AND LIFE STAGES

In order to facilitate an integrated understanding of temperature, dissolved oxygen (DO), and contaminants, which are critical to all life stages, the following sections summarize the temperature, DO, and contaminants dynamics and physiological responses broken down in the life stage specific sections.

1.1 Temperature Objectives

1.1.1 Rationale

Salmonid growth and incubation rates, life-stage duration, and metabolic efficiency are directly influenced by water temperature (Quinn 2005). Temperature also has indirect effects on growth rate and incubation rates and success through its interaction with DO concentrations and pathogen activity. Water temperature and developmental rate are tightly and positively correlated (Healey 1991; Quinn 2005); however, beyond certain thresholds, temperature correlates negatively with efficient use of food resources and proper enzymatic functioning. For example, eggs and alevins incubated at temperatures just below their lethal limit produce smaller juveniles than they would at optimal temperatures.

Temperature effects on timing of juvenile emergence and juvenile size at emergence have large impacts on the early life-history and success of developing salmonids. Numerous studies document these sub-lethal effects in different life stages (Healey 1991; Quinn 2005); however, their importance in the overall population dynamics of Chinook salmon populations is not often considered by water and fishery managers.

High water temperatures are a widespread and frequent challenge for several life stages of Central Valley Chinook salmon and steelhead, whereas negative impacts of temperatures near or below low temperature thresholds are uncommon. Several authors have hypothesized that Central Valley populations of Chinook salmon and steelhead may tolerate warmer temperatures than those of other populations (Myrick and Cech 2004). In San Joaquin basin's Tuolumne River, there is limited evidence to support this in *O. mykiss* populations (Farrell et al. 2015), and in general published data do not entirely support the hypothesis.

Temperature-related mortality and habitat-limitation are likely to become even more serious problems for Central Valley salmonids in the future because of global climate change. This makes restoration of salmonid populations in the San Joaquin Valley particularly important as the river and its tributaries drain the highest elevation basins in the lower 48 United States; these watersheds are expected to maintain snowpack (the source of reservoir cold-water pools) further into the future than are watersheds in the northern Central Valley (DWR 2010). San Joaquin Valley Chinook salmon are at the southern edge of their range and access to the coldest waters in this watershed are currently blocked by impassable dams. The dams form reservoirs where water gains heat during the spring and summer before it is released downstream into salmon incubation and rearing habitats. Water management strategies that provide sufficient supplies of cold water for incubating and rearing salmonids are constrained by increasing human demands on water stored in reservoirs and projections of increasing temperatures in the Central Valley (CDFG 2004a, 2004b; Lindley et al. 2007). Reservoir management practices that increase cold-water supplies (e.g., Nickel et al. 2004), measures that limit temperature gain of flowing waters (e.g., planting of riparian forests that shade waterways), and restoration of migratory access to colder habitats (NMFS 2009a, 2014) are potential approaches to preserving and expanding incubation and rearing habitat for salmonids in the Central Valley.

In the Central Valley, human ability to actively manage temperatures through reservoir releases diminishes with distance from the reservoir during the late-spring through the mid fall period. Certain riparian and aquatic habitats can limit seasonal temperature gain as water flows to the estuary. Some areas that may have once been used for rearing by juvenile salmonids may no longer be suitable for those functions (even if habitats were restored) because water temperatures have or are expected to increase in those regions as a result of global climate change. Thus, decisions about how and whether to restore salmon rearing habitats at lower elevation are intimately tied to an understanding of thermal limitations of the parr and smolt life stages.

1.1.2 Approach

The Scientific Evaluation Process (SEP) Group identified temperature objectives as ranges that are optimal (little or no negative effects), sub-optimal (demonstrably negative, though perhaps not directly lethal), and detrimental for various salmonid life stages and transitions. In the case of juvenile salmon, temperature objectives were expressed as habitat-specific ranges within a life stage (that reflect the impact of food-availability on temperature response norms) and special attention was given to the metamorphosis of parr to smolt (smoltification) as the success of this transformation is known to be sensitive to elevated temperatures among salmonids.

Estimates of the lethal, sub-optimal, and optimal temperature limits for various life stages of Chinook salmon and *O. mykiss* are myriad and variable. Within a species, different life stages have different temperature response curves. Within life stages, variance in estimates of temperature thresholds may result from a combination of factors, including: 1) natural genetic and phenotypic variation among individuals' studied; 2) genetic differences among populations studied; 3) experimental methods and protocols employed by the researchers; and 4) the manner in which experimental data were interpreted and presented in published papers.

The SEP Group relied primarily on U.S. Environmental Protection Agency (USEPA; 2003) guidance for temperature effects on Pacific salmon and supplemented that information when newer information and Central Valley-specific studies were available. Except where otherwise noted, temperatures reported here reflect ranges derived from experiments where temperature is held constant throughout the experimental period (i.e., there is no diurnal variation). USEPA (2003) notes that daily average temperatures in the field do not translate directly to static temperatures in a laboratory-diurnal variation in temperatures exposes fish to higher, and potentially injurious, conditions in the field that are not reflected in a situation where temperatures are held constant. Thus, USEPA (2003) recommends use of a 7-day average of daily maximum temperature (7DADM) metric for evaluating temperature impacts on salmonid life stages. Where temperatures in the field exceed those that are optimal, USEPA (2003) proposes a simple conversion of observed (or modeled) temperatures to values that can be compared to static temperatures used in laboratory experiments:

> *When the mean temperature is above the optimal growth temperature, the "midpoint" temperature between the mean and the maximum is the "equivalent"*

> *constant temperature. This "equivalent" constant temperature then can be directly compared to laboratory studies done at constant temperatures.* (19)

In the Stanislaus River, the difference between daily maximum and daily mean temperatures stays roughly constant across seasons, but it does increase with distance downstream from the dam. The difference between the daily maximum and daily mean at the Goodwin Dam gage is approximately 1 degree Celsius (°C) or 1.8 degrees Fahrenheit (°F), while this difference further downstream at the Orange Blossom Bridge gage is approximately 3°C (5.4°F) (J.D. Wikert, personal communication 2014). Thus, the SEP Group added approximately 0.5°C (0.9°F) to incubation and early life stage constant temperature thresholds and approximately 1.5°C (2.7°F) to rearing and migration temperature thresholds to provide a 7DADM expression of temperature requirements.

1.1.3 Objectives

1.1.3.1 Chinook Salmon

Life stage specific temperature thresholds were assumed to be the same for spring-run and fall-run Chinook salmon.

1.1.3.1.1 Spawning and Egg Incubation

Adult spawning Chinook salmon temperature needs are generally similar to their eggs. Considerations specific to spawning habitat include temperature triggers for spawning and potential thermal stress that could lead to high rates of prespawn mortality and egg retention. In general, the temperature criteria for eggs are protective of spawning as well as the subsequent egg incubation phase. Salmonid eggs and larvae require cold water to successfully complete incubation. With the construction of impassable dams, Chinook salmon spawning in the San Joaquin Valley became dependent on cold-water storage in reservoirs to provide sufficient cold-water storage to protect their incubating eggs. The accessible supply of cold-water storage limits successful spawning habitat for Chinook salmon populations in the Central Valley in general, and the San Joaquin River basin in particular.

The impact of water temperatures on developing embryos is not well understood. Because the temperature tolerances of fertilized eggs are much lower than those that adult salmon tolerate, there is concern that developing reproductive tissues exposed to high temperatures may be less viable than those that are formed under cooler temperatures. USEPA (2003) indicates that eggs in holding females exposed to constant temperatures greater than 13°C (55.4°F) suffer reduced viability. Berman (USEPA 1999) found that offspring of adult Chinook salmon that had been held for 2 weeks at temperatures between 17.5°C to 19°C (63.5°F to 66.2°F) had higher pre-hatch mortality and developmental abnormality rates and lower weight than a control group.

USEPA (2003) found that constant temperatures between 4°C and 12°C (39.2°F and 53.6°F) result in good egg survival and that a narrower range (6°C to 10°C [42.8°F to 50°F]) is optimal; a 7DADM of less than 13°C (55.4°F) is recommended (Table C-1). In a review, the U.S. Fish and Wildlife Service (USFWS; 1999, cited by Myrick and Cech 2004) concluded that temperature-related egg mortality in Chinook salmon increased at temperatures above 13.3°C (55.9°F) and this is the limit applied in most regulatory arenas (NMFS 2009a; SWRCB Order 90-05). A review of research on different populations of Chinook salmon from within and outside of the Central Valley indicated that temperatures between 6°C and 12°C (42.8°F and 53.6°F) were optimal for Central Valley Chinook salmon (Myrick and Cech 2004).

Table C-1 identifies the optimal, sub-optimal, and detrimental temperature conditions for Chinook salmon spawning and egg incubation.

Table C-1
Temperature Objectives for Chinook Salmon Spawning and Egg Incubation

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Gravel	Fall-run: Late October to March Spring-run: Late August to March	Optimal	6°C to 12°C (42.8°F to 53.6°F) (Daily Average)
			< 12.5°C to 13°C (54.5°F to 55.4°F) (7DADM)
		Sub-optimal	4°C to 6 °C (Daily Average)
			12°C to 13.3°C (53.6°F to 55.9°) (Daily Average)
			12.5°C to 13.8°C (54.5°F to 56.8°F) (7DADM)
		Detrimental	> 13.3°C (55.9°F) (Daily Average)
			> 13.8°C (56.8°F) (7DADM)

Notes:
“>” = greater than
“<” = less than

1.1.3.1.2 Juvenile Rearing and Migration

Temperatures that produce mortality among Pacific salmon depend, to some extent, on acclimation temperatures—higher acclimation temperatures produce higher Incipient Upper Lethal Temperatures (IULT; Myrick and Cech 2004). Various sources indicate an IULT for Chinook salmon in the range of 24°C to 25°C (75.2°F to 77°F) (Myrick and Cech 2004). Baker et al. (1995) found that Central Valley Chinook salmon had an IULT between approximately 22°C to 24°C (71.6°F to 75.2°F).

Negative sub-lethal effects (those that may increase susceptibility to other mortality mechanisms) begin to occur at temperatures lower than the IULT. In the laboratory, when fish have access to full rations, growth of juvenile salmonids increases with temperature up to fishes’ physiological limits; however, when food supply is limited (as it often is under normal conditions in the field) optimal and sub-optimal growth and even mortality occur at lower temperatures. For example, Mesa et al. (2002) detected increased levels of heat shock proteins (an indicator of stress) after several hours of exposure to 20°C (68°F) for Columbia River fall-run Chinook salmon. Among juvenile fall-run Chinook salmon from California’s Central Valley population, Marine and Cech (2004) found decreased growth, reduced smoltification success, and impaired ability to avoid predation at temperatures above 20°C (68°F). They also reported that fish reared at temperatures from 17°C to 20°C (62.6°F to 68°F) experienced increased predation relative to fish raised at 13°C to 16°C (55.4°F to 60.8°F), although they found no difference in growth rate among fish reared in these two temperature ranges. The finding of decreased performance at temperatures above 17°C (62.6°F) is consistent with several studies that suggest, when food supplies are not super-abundant, optimal growth and survival among Chinook salmon occurs at temperatures somewhat lower than 17°C (62.6°F). USEPA (2003) identifies constant temperatures of identifies constant temperatures of 10°C to 17°C (50°F to 62.6°F) (and a 7DADM less than 18°C [64.4°F]) as being optimal conditions for juvenile Chinook salmon when food supplies are limiting. USEPA (2003) recommends 16°C (60.8°F) 7DADM as a maximum criterion to:

- Safely protect juvenile salmon and trout from lethal temperatures;
- Provide upper optimal conditions for juvenile growth under limited food during the period of summer maximum temperatures and optimal temperatures for other times of the growth season;
- Avoid temperatures where juvenile salmon and trout are at a competitive disadvantage with other fish;
- Protect against temperature induced elevated disease rates; and
- Provide temperatures that studies show juvenile salmon and trout prefer and are found in high densities.

Based on this recommendation, 16°C (60.8°F) 7DADM or less has been established as the optimal water temperature for juvenile rearing and migration in the river channel.

As indicated, the temperatures that can be tolerated by rearing juvenile Chinook salmon depend to a great extent on food availability. USEPA (2003) indicates that, when food supplies are "unlimited," temperatures from 13°C to 20°C (55.4°F to 68°F) (constant) may be optimal. Recent studies on Central Valley Chinook salmon rearing on inundated floodplains reveal excellent survival and growth rates at even higher temperatures. Growth and survival have been recorded at temperatures as high as approximately 25°C (77°F) (Katz unpublished data; Jeffres unpublished data). The increased tolerance for high temperatures in these fish is believed to be related to the relatively high abundance of high quality food available to Chinook salmon rearing on floodplains and suggests that, when food is not limiting, Chinook salmon can tolerate and even thrive in the wild at temperatures approaching the physiological limits observed in the laboratory (i.e., IULT). As a result, the SEP Group assumed that, following successful restoration of floodplain habitats (and during periods when juvenile Chinook salmon actually occupy inundated floodplains), rearing Chinook salmon juvenile salmon could survive temperatures approaching 25°C (77°F). For example, the life-history timing and productivity objectives for both spring and fall-run Chinook salmon salmon could survive temperatures approaching 25°C (77°F) for limited periods of time. Based on these distinctions, temperatures greater than 25°C were established a detrimental for salmon rearing on long-inundation floodplains only. However, the SEP Group also recognizes that exposure to such warm water temperatures greatly increases disease risk, and stress from other water quality factors (e.g., DO or contaminants) likely reduces thermal tolerance. When Chinook salmon are not in habitats that support super-abundant food resources (e.g., in mainstem channel habitats), lower temperatures are required to avoid negative sub-lethal effects.

Elevated water temperatures can inhibit the parr-smolt metamorphosis (smoltification) in salmonids. Chinook salmon can smolt at temperatures ranging from 6°C to 20°C (42.8°F to 68°F) (Myrick and Cech 2004). However, salmon that smolt at higher temperatures (greater than 16°C (60.8°F) tend to display impaired smoltification patterns and reduced saltwater survival (Myrick and Cech 2004). Marine and Cech (2004) found that Central Valley Chinook salmon rearing in temperatures greater or equal to 20°C (68°F) suffered altered smolt physiology, and other studies from within this ecosystem suggest that negative effects of temperature on the parr-smolt transition may occur at temperatures less than 20°C (68°F). Richter and Kolmes (2005) cite two studies that indicated negative impacts on Chinook salmon smoltification success at temperatures greater than 17°C (62.6°F) and USEPA (2003) indicates that smoltification impairment may occur at temperatures between 12°C to 15°C (53.6°F to 59°F).

Table C-2 identifies the optimal, sub-optimal, and detrimental temperature conditions for juvenile Chinook salmon rearing and migration.

Table C-2
Temperature Objectives for Juvenile (Fry, Parr, and Smolt) Chinook Salmon Rearing and Migration

Spatial Extent (Habitat Type)	Temporal Extent	Condition[1]	Range (Metric)
Channel	Fall-run: Last week of January to the 2nd week of June Spring-run: First week of January to the 2nd week of June	Optimal	6°C to 16°C (42.8°F to 60.8°F) (7DADM)
		Sub-optimal	17°C to 20°C (62.6°F to 68°F) (7DADM)
		Detrimental	> 20°C (68°F) (7DADM)
Off-Channel – (Short Inundation)		Optimal	10°C to 18°C (50°F to 64.4°F) (7DADM)
		Sub-optimal	18°C to 20°C (64.4°F to 68°F) (7DADM)
		Detrimental	> 20°C (68°F) (7DADM)
Inundated Floodplain – (Long Inundation)		Optimal	10°C to 18°C (50°F to 64.4°F) (7DADM)
		Sub-optimal	18°C to 25°C (7DADM)
		Detrimental	> 20°C (68°F) (7DADM)

Notes:
1 These temperatures apply all along the juvenile migratory corridor. Because water temperatures are expected to increase as water travels downstream during warmer months, temperatures measured or modeled upstream that are at or near the limit of a given range would be expected to exceed that range further downstream. Thus, temperatures at the high end of the sub-optimal range that are measured or modeled in upstream locations indicate potentially detrimental temperature conditions further downstream, including into the San Joaquin mainstem.

1.1.3.1.3 Adult Migration

High water temperatures can lead to direct mortality and indirect loss of fitness for migrating salmon. The IULT may be as low as 21°C to 22°C (69.8°F to 71.6°F) for both adult Chinook salmon and steelhead during migration (USEPA 1999, 2003; Richter and Kolmes 2005). Swimming performance is reduced at temperatures greater than 20°C (68°F) (USEPA 2003). High water temperatures also facilitate infection among migrating adult salmonids (Noga 1996); USEPA (2003) identifies an elevated risk of infection at temperatures above 13°C (55.4°F) and a high risk of infection at temperatures greater than 18°C (64.4°F). Temperatures greater than 13°C are also expected to result in reduced viability of gametes in holding adults (USEPA 2003), and presumably the same effect would occur among salmon migrating at such temperatures. Unlike juvenile salmon, the response of adult salmon to high temperatures is not related to food availability—adult salmon typically do not feed during their freshwater migration or holding period.

Water temperatures below the IULT may also impede spawning migrations. Prolonged exposure to temperatures greater than 17°C (62.6°F) reduce fitness during migration due to cumulative stresses (USEPA 2003); in fact, McCullough et al. (2001), writes: "Migration blockages, susceptibility to disease, impaired maturation process, increases to stress parameters, reduced efficiency of energy use, and reduced swimming performance were all cited [by MacDonald in press] as potentially serious hazards as daily mean temperatures exceed 62.6°F (17°C)" (p. 9). Higher temperatures may produce acute distress.

Williams (2006) reported that salmon returning to the Stanislaus River in 2003 endured water temperatures greater than 21°C (69.8°F) on their migration; however, there is no indication that these fish spawned successfully or that they produced viable offspring. Williams (2006) reported that migrating Sacramento River fall-run Chinook adult salmon appeared to avoid temperatures greater than approximately 19°C (66.2°F), an observation consistent with reports for Chinook salmon from other watersheds (Richter and Kolmes 2005). Many sources recommend maintaining temperatures less than 20°C to 21°C (68°F to 69.8°F) to prevent direct impairment of Chinook salmon migrations (USEPA 1999, 2003; Richter and Kolmes 2005).

Table C-3 identifies the range in temperatures associated with optimal, sub-optimal, and detrimental conditions for Chinook salmon adult migration and holding.

Table C-3
Temperature Objectives for Chinook Salmon Adult Migration and Holding

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Main Channel	Fall-run: Late September to December Spring-run: March to July (Migration); March to September (Holding)	Optimal	Holding: 8°C to 13°C (46.4°F to 55.4°F) (Daily Average) Migration: 8°C to 14°C (46.4°F to 57.2°F) (Daily Average)
			Holding: 9.5°C to 14.5°C (49.1°F to 58.1°F) (7DADM) Migration: 9.5°C to 15.5°C (49.1°F to 59.9°F) (7DADM)
		Sub-optimal	Holding: >13°C to 19°C (>55.4°F to 66.2°F) (Daily Average) Migration: >14°C to 19°C (>57.2°F to 66.2°F) (Daily Average)
			Holding: >14.5°C to 20.5°C (>58.1°F to 68.9°F) (7DADM) Migration: >15.5°C to 20.5°C (>59.9°F to 68.9°F) (7DADM)
		Detrimental	> 18°C (64.4°F) (weekly mean)
			> 19°C (66.2°F) (Daily Average)
			> 20.5°C (68.9°F) (7DADM)
			> 22°C (71.6°F) (instantaneous)

1.1.3.2 O. Mykiss

1.1.3.2.1 Spawning and Egg Incubation

As with Chinook salmon, adult spawning *O. mykiss* temperature needs are generally similar to their eggs. Considerations specific to spawning habitat include temperature triggers for spawning and potential thermal stress that could lead to high rates of prespawn mortality and egg retention. In general, the temperature criteria for eggs are protective of spawning as well as the subsequent egg incubation phase. *O. mykiss* eggs and larvae require cold water to successfully complete incubation. With the construction of impassable dams, *O. mykiss* eggs incubating in the San Joaquin Valley became dependent on cold-water storage in reservoirs. The accessible supply of cold-water storage limits successful spawning habitat for *O. mykiss* populations in the southern Central Valley. There is a serious lack of peer-reviewed studies on the temperature tolerances of Central Valley anadromous *O. mykiss* eggs, and additional study of temperature impacts on this species' eggs is needed (Myrick and Cech 2004). Optimal incubation temperatures for *O. mykiss* occur in a narrower range than those for Chinook salmon. Indeed, Myrick and Cech (2004) warned against managing water temperatures for the upper end of the Chinook salmon thermal tolerance range in waterways and during periods when *O. mykiss* are also incubating because incubating *O. mykiss* cannot tolerate such high temperatures. Richter and Kolmes (2005) concluded that egg mortality increased as incubation temperatures exceeded 10°C (50°F) and substantial mortality may occur when temperatures exceed 13.5°C to 14.5°C (56.3°F to 58.1°F). Based on experience at hatcheries in the Central Valley, optimal incubation temperatures appear to be in the 7°C to 10°C (44.6°F to 50°F) range (Myrick and Cech 2004). California's steelhead management plan (McEwan and Jackson 1996) suggests a slightly higher temperature range (from 9°C to 11°C [48.2°F to 51.8°F]).

Table C-4 identifies optimal, sub-optimal, and detrimental temperature conditions for *O. mykiss* spawning and egg incubation.

Table C-4
Temperature Objectives for *O. mykiss* Spawning

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Gravel	December to June	Optimal	7°C to 10°C (44.6°F to 50°F) (Daily Average)
			10.5°C (50.9°F) (7DADM)
		Sub-optimal	4°C to 6.9°C (39.2°F to 44.4°F) (Daily average)
			10°C to 13.5°C (50°F to 56.3°F) (Daily Average)
			10.5°C to 14.0°C (50.9°F to 57.2°F) (7DADM)
		Detrimental	> 13.5°C (56.3°F) (Daily Average)
			> 14.0°C (57.2°F) (7DADM)

1.1.3.2.2 Juvenile Rearing and Migration

Laboratory studies show that incipient lethal temperatures for juvenile *O. mykiss* occur in a range between 27.5°C to 29.6°C (81.5°F to 85.3°F), depending on acclimation temperatures (Myrick and Cech 2005). Optimal temperatures for *O. mykiss* juvenile growth occur between 15°C to 19°C (59°F to 66.2°F) (Moyle 2002; Richter and Kolmes 2005). Temperature also mediates the impact of competition between species. For example, *O. mykiss* juveniles suffer adverse impacts of competition with pikeminnow at temperatures greater than 20°C (68°F), though no competitive impact is detectable at lower temperatures (Reese and Harvey 2002).

Table C-5 identifies optimal, sub-optimal, and detrimental temperature conditions for *O. mykiss* juvenile rearing.

Table C-5
Temperature Objectives for *O. mykiss* Juvenile Rearing

Spatial Extent (Habitat Type)	Temporal Extent	Condition[1]	Range (Metric)
Mainstem	January to December (i.e., year round)	Optimal	15°C to 19°C (59°F to 66.2°F) (Daily Average)
			16.5°C to 21.5°C (61.7°F to 70.7°F) (7DADM)
		Sub-optimal	20°C to 25°C (68°F to 77°F) (Daily Average)
			21.5°C to 26.5°C (70.7°F to 79.7°F) (7DADM)
		Detrimental	> 25°C (77°F) (Daily Average)
			26.5°C (79.7°F) (7DADM)
			> 27.5°C (81.5°F) (Instantaneous)

Notes:
1 These temperatures apply all along the juvenile migratory corridor. Because water temperatures are expected to increase as water travels downstream during warmer months, temperatures measured or modeled upstream that are at or near the limit of a given range would be expected to exceed that range further downstream. Thus, temperatures at the high end of the sub-optimal range that are measured or modeled in upstream locations indicate potentially detrimental temperature conditions further downstream, including into the San Joaquin mainstem.

Steelhead may be particularly sensitive to high temperatures during the smoltification process. USEPA (2003) indicates that temperatures greater than 12°C (53.6°F) inhibit steelhead metamorphosis into smolts. Richter and Kolmes (2005) and USEPA (1999) cited studies that present a range of temperatures, between 11°C and 14°C (51.8°F and 57.2°F) that may inhibit steelhead smoltification. Myrick and Cech (2005) cautioned that smolting steelhead in the Central Valley must experience temperatures less than 11°C (51.8°F) to successfully complete this metamorphosis. The critical temperature at which smoltification becomes inhibited may vary from run-to-run (Richter and Kolmes 2005).

Table C-6 identifies the optimal, sub-optimal, and detrimental temperature conditions for juvenile steelhead smoltification.

Table C-6

Temperature Objectives for Steelhead Juvenile Migration (Smoltification)

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Main Channel	December to March	Optimal	11°C (51.8°F) (Weekly Average)
			12.5°C (54.5°F) (7DADM)
		Detrimental	> 11°C (51.8°F) (Weekly Average; i.e., detrimental if necessary temperature is not achieved during appropriate annual window)
			> 12.5°C (54.5°F) (7DADM)

1.1.3.2.3 Adult Migration and Holding

The IULT may be as low as 22 °C (71.6°F) for migrating steelhead (USEPA 1999; Richter and Kolmes 2005). Although steelhead have been known to migrate in most months of the year, they are mostly present from mid fall to early spring (Hallock et al. 1961; Harvey 1995; McEwan 2001) when temperatures are generally well-below the lethal threshold. For purposes of this report, the SEP Group has assumed that temperatures, which are acceptable to migrating Chinook salmon adults are also acceptable to migrating steelhead adults.

Table C-7 provides the optimal, sub-optimal, and detrimental temperature conditions for adult steelhead migration.

Table C-7
Temperature Objectives for Steelhead Migration, Holding, and Post-spawning Adults (Kelts)

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Main Channel	Mid-September to Mid-May	Optimal	8°C to 13°C (46.4°F to 55.4°F) (Daily Average)
			9.5°C to 14.5°C (49.1°F to 58.1°F) (7DADM)
		Sub-optimal	>13°C to 19°C (>55.4°F to 66.2°F) (Daily Average)
			>14.5°C to 20.5°C (>58.1°F to 68.9°F) (7DADM)
		Detrimental	> 18°C (64.4°F) (Weekly average)
			> 19°C (66.2°F) (Daily Average)
			20.5°C (68.9°F) (7DADM)
			> 22°C (71.6°F) (Instantaneous)

1.2 Dissolved Oxygen Objectives

1.2.1 Rationale

Adequate concentrations of DO in water are critical for salmon and *O. mykiss* survival. In freshwater streams, hypoxia can impact the growth and development of salmon and *O. mykiss* eggs, alevins, and fry, as well as the swimming, feeding, and reproductive ability of juveniles and adults. If salmonids are exposed to hypoxic conditions for too long, mortality can result (Carter 2005). Without achieving some combination of optimal and/or sub-optimal environmental objectives for DO described below, the biological objectives for Chinook salmon and *O. mykiss* most certainly will not be met.

1.2.2 Approach

The SEP Group relied on DO criteria established by the USEPA (1986) and the Central Valley Regional Water Quality Control Board (CVRWQCB 2015a) as well as relevant technical literature (WDOE 2002) to identify DO objectives that are optimal (no negative effects), sub-optimal (observably negative, though not significantly harmful), and detrimental (clearly harmful) ranges for various salmonid life stages and/or transitions. The approach the SEP Group used to translate available information on impairment levels into optimal, sub-optimal, and detrimental objectives is shown in Table C-8.

Table C-8
Recommended Cold-water Species Dissolved Oxygen Levels for Spawning, Egg Incubation, and Larval Life Stages

Level of Impairment to Embryo and Larvae Stages	Water Column Minimum Average Concentration	Intra-gravel Minimum Average Concentration	Optimal, Sub-optimal, Detrimental[1]
No production impairment	11 mg/L	8 mg/L	Optimal
Slight production impairment	10 mg/L	7 mg/L	Sub-optimal
Slight production impairment	9 mg/L	6 mg/L	Sub-optimal
Moderate production impairment	8 mg/L	5 mg/L	Detrimental
Severe production impairment	7 mg/L	4 mg/L	Detrimental
Limit to avoid acute mortality	6 mg/L	3 mg/L	Detrimental

Notes:
1 Relationship of recommended DO levels to optimal, sub-optimal, and detrimental levels identified by the SEP Group
Table adapted from USEPA 1986
mg/L = milligram per liter

The criteria established by the USEPA and Central Valley Regional Water Quality Control Board (CVRWQCB) covered cold-water species in one category; separate criteria for Chinook salmon and *O. mykiss* were not provided. This blanket approach of protecting salmon and *O. mykiss* with one set of DO criteria is supported by the available literature, and as such, the SEP Group followed that approach. While it was not necessary to have species-specific DO objectives, life stage-specific ones are needed because dissolved oxygen requirements for eggs and larvae slightly differ from those for juveniles and adults.

The following summaries of egg incubation mortality through hatching, incubation growth rates, juvenile rearing and migration, and adult migration and holding provide life-stage specific rationale for the DO objectives presented in Section 1.2.3.

1.2.2.1 Egg Incubation Mortality through Hatching (from WDOE 2002)

At favorable incubation temperatures mortality rates should be expected to remain less than 1% at a concentration of 9 milligrams per liter (mg/L) or greater, less than 2% at a concentration of 7 mg/L, and between 2% and 6% percent at a concentration of 6 mg/L.

While mean oxygen concentrations over the development period below 6 mg/L are sometimes associated with significant increases in mortality rates, the overall pattern is for mortality rates and the occurrence of abnormalities to remain low (less than 7%) at concentrations above 4 mg/L. Survival rates at oxygen concentrations below 4 mg/L are highly variable. While mortality rates were low (4% to 7%) in some studies, they ranged from 25% to 100% in others. All tests at concentrations below 1.7 mg/L resulted in 100% mortality. While mortality rates related to low oxygen concentrations remain relatively minor at favorable incubation temperatures (averages below 11°C [51.8°F]), they increase rather substantially at temperatures that are warmer than ideal. In warmer waters (13.4°C [56.1°F]) even a decrease from 11 to 10 mg/L would be associated with causing a 4% reduction in survival through hatching. A decrease to 7 mg/L would be associated with a 19% reduction in survival. An important point to recognize is that in the laboratory studies the developing alevin did not need to push their way up through gravel substrate as would wild fish. The studies above focused on survival through hatching and did not consider this rather substantial final act for emerging through the redds. Optimal fitness will likely be required for optimal emergence in the natural environment, and the metabolic requirements to emerge would be expected to be substantial. Thus higher oxygen levels may be needed to fully protect emergence than to just fully support hatching alone.

1.2.2.2 Incubation Growth Rates (from WDOE 2002)

Any decrease in the mean oxygen concentration during the incubation period appears to directly reduce the size of newly hatched salmonids. At favorable incubation temperatures the level of this size reduction, however, should remain slight (2%) at mean oxygen concentrations of 10.5 mg/L or more and still remain below 5% at concentrations of 10 mg/L or more. At 9 mg/L, the size of hatched fry would be reduced approximately 8%. Mean concentrations of 7mg/L and 6 mg/L would be expected to cause 18 and 25% reductions in size.

1.2.2.3 Juvenile Rearing and Migration

Salmonids may be able to survive when DO concentrations are low (less than 5 mg/L), but growth, food conversion efficiency, and swimming performance will be adversely affected (Bjornn and Reiser 1991). Davis (1975) reviewed numerous studies and reported no impairment to rearing salmonids if DO concentrations averaged 9 mg/L, while at oxygen levels of 6.5 mg/L "the average member of the community will exhibit symptoms of oxygen distress," and at 4 mg/L a large portion of salmonids may be affected. WDOE (2002) concludes that a monthly or weekly average concentration of 9 mg/L, and a monthly average of the daily minimum concentrations should be at or above 8.0 to 8.5 mg/L to have a negligible effect (5% or less) on growth and support healthy growth rates. USEPA (1986) states that due to the variability inherent in growth studies, the reductions in growth rates seen above 6 mg/L are not usually statistically significant, while reductions in growth at DO levels below 4 mg/L are considered severe. WDOE (2002) recommended that DO levels below 5.0 to 6.0 mg/L should be considered a potential barrier to the movement and habitat selection of juvenile salmonids. Given that recommendation, DO levels below 6.0 mg/L have been established as detrimental for juvenile salmon.

1.2.2.4 Adult Migration and Holding

WDOE (2002) reported that DO concentrations above 8 to 9 mg/L are needed for maximum swimming performance and concentrations below 5 to 6 mg/L elicited avoidance. Hallock et al. (1970) found that adult Chinook salmon migrating up the San Joaquin River avoided DO concentrations below 5 mg/L. DO concentrations above 8 mg/L were assumed to represent optimal conditions and concentrations below 6 mg/L were detrimental. Between 6 and 8 mg/L was identified as sub-optimal for migrating and holding adults.

1.2.3 Objectives

DO objectives are provided in Tables C-9 and C-10 by the following two life stage groupings:

- Spawning adults, eggs, and larvae
- Rearing and emigrating fry and juveniles and immigrating and holding adults

These groupings are consistent with the USEPA and CVRWQCB DO criteria and the supporting technical literature. Anadromous salmonid eggs and larvae are more sensitive to low DO concentrations than rearing juveniles and adults that are immigrating or holding.

Table C-9

Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Spawning and Egg Incubation

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
Gravel (Measurement must occur in gravel, not water column)	Fall-run: Late October to March Spring-run: Late August to March *O. mykiss*: December to June	Optimal	> 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	< 6 mg/L (Daily Minimum)

Table C-10

Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Fry/Juveniles and Migrating and Holding Adults

Spatial Extent (Habitat Type)	Temporal Extent	Condition	Range (Metric)
River Channel or Floodplain (Water column measurement)	Fall-run: Last week of January to 2nd week of June (fry/juveniles) Late September to December (migration and holding) Spring-run: January to December (i.e., year-round) (fry/juveniles) March to July (migration) March to September (holding) *O. mykiss*: January to December (i.e., year-round) (fry/juveniles) Mid-September to mid-May (migration and holding)	Optimal	> 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	< 6 mg/L (Daily Minimum)

1.3 Contaminant Objectives

1.3.1 Rationale

The Stanislaus River, between Goodwin Dam and Caswell State Park, has been identified as being impaired on the USEPA Clean Water Act Section 303(d) list for not meeting water quality standards since the early 1990s. The pollutants or stressors that have been identified to cause the impairments are: diazinon, chlorpyriphos, Class A pesticides (e.g., organochlorines, DDT, and legacy pesticides), unknown toxicity, mercury, and temperature (USEPA 2011). In addition, mercury, selenium, and nutrients have been identified as impairing beneficial uses in the San Joaquin River, the Sacramento-San Joaquin Delta (Delta), and the San Francisco Bay, which are downstream salmonid rearing and migratory habitats (SWRCB 2010; USEPA 2011). Beneficial uses that are not being supported include: cold freshwater habitat; migration; spawning, reproduction and early development; and warm freshwater habitat. Other contaminants that were evaluated, but were found not to exceed water quality standards included ammonia, arsenic, cadmium, and nickel (SWRCB 2010).

The large majority of currently available spawning habitat and subsequent rearing habitat in the Stanislaus River is below Knights Ferry (ESA 2013), and this reach coincides with increased amounts of anthropogenic disturbances, primarily agricultural and urban development. In a review of toxicity monitoring data conducted in California, Anderson et al. (2011) found that sites located near agriculture and urban areas had statistically greater occurrences of toxicity in water and sediment samples than near undeveloped areas. In all, 51% and 45% of the streams, rivers, canals, and lakes monitored from 2001 to 2010 had some toxicity in the water column and sediment, respectively. Toxicological effects ranged from sublethal endpoints to full organism mortality. Using correlation analyses and toxicity identification evaluations, Anderson et al. (2011) determined that the vast majority of toxicity was caused by pesticides (e.g., insecticides, herbicides, and fungicides). However, pesticides were not the cause of all toxicity, and some other contaminants that were identified included metals and ammonia.

The CVRWQCB has recently developed a control program and adopted water quality objectives for diazinon and chlorpyriphos in the Central Valley (CVRWQCB 2014), so the implementation of the program should reduce the adverse impacts of these two constituents.

However, the use of organophosphate pesticides like diazinon and chlorpyriphos have declined in California since the mid-1990s, and USEPA actions resulted in the phase out of these two pesticides for urban use in the early 2000s (Spurlock and Lee 2008). Much of the pesticide use has shifted to pyrethroids, especially for urban use, and in 2006 pyrethroids accounted for greater than 40% of the insecticide registrations in California. Pyrethroids have been identified as causing much of the surface water and sediment toxicity in California (Anderson et al. 2011). More recently, the use of the systemic pesticides neonicotinoids has increased, and their use has been implicated in global declines of some wildlife (Mason et al. 2013; Gibbons et al. 2014). Current use pesticides are ever changing, and this makes it difficult for regulatory agencies to control the adverse effects that these contaminants create.

Mercury and selenium both occur naturally in the environment; however, anthropogenic activities have resulted in elevated concentrations in surface waters that are a detriment to aquatic life. For centuries, the smelting of large quantities of ore has contributed to the emissions of trace metals worldwide (Nriagu 1996). Recently, mercury water quality impairments in California have been linked to local and international industrial emissions (SFEI 2001; USEPA 2008). Extensive historical mining in California contributed to heavy metal emissions, as well abandoned mine waste material continues to pollute Central Valley waterbodies (Alpers and Hunerlach 2000; Domagalski 2001; and USEPA 2006). Oil refining and agricultural irrigation have contributed to selenium contamination in the San Francisco Bay and the San Joaquin River watershed, respectively (McCarthy and Grober 2001; Presser and Luoma 2006, 2013). In addition, urban storm water runoff has been shown to be a major source of metals to California surface waters (TDC 2004; CRWQCBSDR 2007; SFBRWQCB 2007).

Nutrients occur naturally; however, anthropogenic activities create imbalances which can result in impairments to aquatic life. For example, ammonia, nitrite, and to a lesser extent nitrate have been found to be toxic to fish by disrupting oxygen transport by the blood (Russo et al. 1974; Camargo et al. 2005; USEPA 2013). Anthropogenic sources of nutrients (e.g., nitrogen and phosphorus) from activities like agriculture, urbanization, sewage treatment, and livestock operation have been shown to cause eutrophication in the Central Valley rivers which impair aquatic uses (CVRWQCB 2013a; Gowdy and Grober 2005; Schlegel and Domagalski 2015). Furthermore, in the Delta changes in the types of algae that form the base of the food web have been linked to excessive amounts or altered ratio of nutrients discharged to the Delta (DSC 2013).

The following sub-sections will describe the major contaminants (pesticides[1], mercury, selenium, and nutrients) that have been identified as impairing beneficial uses in the Stanislaus River and downstream migratory corridor. The descriptions of each contaminant will include the general background and the toxicological effects of each contaminant to fish, with emphasis on salmonids where available. If other contaminants or toxins are identified to impeded Chinook salmon and *O. mykiss* recovery in the San Joaquin River basin, then their impacts can be evaluated in the future.

1.3.1.1 Pesticides

Fish are not the target organisms of the pesticides; however, pesticides have been found to cause adverse impacts to fish in surface waters. For example, in a review of Central Valley toxicity data, Markiewicz et al. (2012) found that the fish species tests, *Pimephales promelas*, had a higher frequency of toxicity than the other species, *Ceriodaphnia dubia* (invertebrate) and *Selenastrum capricornutum* (algal). Samples were toxic to fish in 62% of the tests versus 49% for invertebrates and 40% for algae. Similar to the statewide survey of Anderson et al. (2011), pesticides were found to be the primary cause of toxicity in the Central Valley (Markiewicz et al. 2012). Importantly, salmonids generally tend to be more sensitive to chemical stressors than many other species of fish; and, if other freshwater fish are killed by use of pesticides, then it is likely that salmonids have also died (NMFS 2012).

Moreover, the life-history strategies salmonids evolved to rely on exposes them to higher risks from contaminants. For example, juvenile salmonids typically occupy and rely on shallow freshwater habitats (e.g., floodplains, off-channel, and low flow alcoves) during critical rearing and migratory life-history periods. These near-shore, low flow habitats are expected to have higher pesticide loading and concentrations, which subject developing salmonids to higher exposures to pesticides in their preferred habitats (NMFS 2008, 2009b, and 2011). Even if salmonids can avoid the elevated concentrations of contaminants in these

[1] The pesticide section will include a discussion on copper effects because copper is widely used as pesticide (e.g., fungicide, herbicide, and antifouling paint).

areas, salmonids may be adversely impacted by not benefitting from the uses these habitats provide (e.g., food and cover).

Typically, adult organisms will have a lower risk of mortality to contaminants than the sensitive larval fish used for toxicity tests. As a result, toxicity tests with larval fish could overestimate the mortality that might occur to adult salmonids. However, pre-spawn adult salmonids are likely less tolerant to chemical stressors because they have used most of their accumulated fat stores for gamete production (NMFS 2008, 2010, and 2013). It is probable that the some pre-spawn returning adults will die as a result of short-term exposures to pesticides, especially when subjected to additional stressors like elevated temperatures. Additionally, pre-spawn mortality can be cause by other contaminants. For example, metals and petroleum hydrocarbons likely contributed to pre-spawn mortality of Coho salmon in urban streams in Washington State (Scholz et al. 2011). Pre-spawn mortality is a particularly important factor in the recovery of salmonid populations with low abundance because every adult is crucial to the population's viability (NMFS 2013).

While direct mortality is an obvious detriment to salmonid populations, many sublethal effects of pesticide can also contribute to population declines. Sublethal toxicant exposure often eliminates the performance of fish behaviors, such as predator avoidance, orientation, reproduction, kin recognition, etc. that are essential to fitness and survival in natural ecosystems (Potter and Dare 2003; Scott and Sloman 2004). The most commonly observed links with behavioral disruption include cholinesterase (ChE) inhibition, altered brain neurotransmitter levels, sensory deprivation, and impaired gonadal or thyroid hormone levels (Scott and Sloman 2004). For example, Scholz et al. (2000) concluded that olfactory disruption by anti-cholinesterase neurotoxins reduced Chinook salmon anti-predator responses from short-term, sublethal exposures to diazinon. As well, they also concluded that 24-hour exposures to diazinon likely increased the straying of the adult hatchery Chinook salmon over the control group. Furthermore, juvenile salmonids exposed to pesticides during development may fail to imprint to their natal waters, which can lead to increased adulthood straying (NMFS 2009b).

Additional evidence of the sublethal effects of pesticides on fish populations have been demonstrated though reproduction experiments. For example, the pyrethroid insecticide cypermethrin inhibited male Atlantic salmon from detecting and responding to the reproduction priming pheromone prostaglandin, which is released by ovulating females (Moore and Waring 2001). The males exposed to cypermethrin did not respond to prostaglandin with the expected increased levels of plasma sex steroids and expressible milt. In addition, zebrafish exposed to low concentrations (96-hour LC5) of deltamethrin and Achook (a synthetic pyrethroid and a neem based pesticide, respectively) resulted in significant reductions (54% and 18%, respectively) in female fecundity when compared to the controls (Sharma and Ansari 2010). Additionally, both of the studies found that exposures to pesticides decreased the abundance of hatchlings. The percentage of unhatched fertilized eggs increased in adult zebrafish exposures, and the number of unfertilized eggs increased in salmon egg and milt exposures (Moore and Waring 2001; Sharma and Ansari 2010). Furthermore, the disruption of spawning synchronization could also result in an increase in the number of unfertilized eggs (NMFS 2009b).

Herbicide pesticides also have been shown to reduce fish's ability to perform necessary physiological activities. For example, Waring and Moore (1996) observed that concentrations of the herbicide atrazine that showed no lethal effects to Atlantic salmon in freshwater resulted in physiological stress and increased mortality once the fish were exposed to seawater. Subsequent investigations determined that sublethal concentrations of atrazine can reduce Na^{+} K^{+} ATPase activity and the ability of salmon to osmoregulate (Moore and Fewings 2003). Nieves-Puigdoller et al. (2007) found similar disruptions in osmoregulation as well as other endocrine disruption, however at higher concentrations of atrazine. Other investigations have concluded that another herbicide, trifluralin, can cause vertebral deformities, which would likely also result in the eventual mortality from predators or reduced prey capture (NMFS 2012). Because pesticides are developed and used for multiple target organisms (e.g., plants, invertebrates, and vertebrates), their mechanisms of action are very diverse. This results in a multitude of ways that pesticides can affect salmonid physiology, biochemistry, and behavior, and subsequently, many different life stages of salmonids can be adversely impacted.

Copper compounds are also often used as herbicides in addition to other types of pesticides, and copper is one of the most widely applied pesticides in the Central Valley (Johnson et al. 2010). Additionally, copper is a naturally occurring trace element, and non-pesticide related anthropogenic activities have increased copper pollution to surface waters. For example, other sources of copper to surface waters include: urban runoff (e.g., vehicle brake pads, architectural features, and industrial uses), mining waste, soil erosion, etc. (CVRWCB 2002; TDC 2004). Extreme cases of copper and other heavy metal contamination resulted in acid mine drainage that contributed to fish kills and significant declines in Chinook salmon and *O. mykiss* populations in the Sacramento River from the 1960s to the 1980s (CVRWQCB 2002). Heavy metal pollution from the Iron Mountain Mine to the Sacramento River contributed to the listing of winter-run Chinook salmon as endangered (CVRWQCB 2002).

Current copper pollution from pesticides and urban runoff are not as extreme as the Iron Mountain Mine example; however, low levels of copper can have adverse effects on salmonids, other fish, invertebrates, and algae (Hecht et al. 2007; USEPA 2007). The most studied toxicity pathway of copper is its ability to disrupt ATP-driven pumps and ion channels, which results in impaired osmoregulation and ion regulation in gills (Kiaune and Singhasemanon 2011). However, fish sensory systems are likely the most sensitive to sub-lethal copper toxicity. For example, low-level copper exposures have been shown to disrupt olfactory receptor neurons and lateral line mechanosensory neurons in fish (Hansen et al. 1999a; Hecht et al. 2007; Sandahl et al. 2007; McIntyre et al. 2008; Linbo et al. 2009). In addition, these copper exposures resulted in measured behavior alterations (e.g., predator avoidance response, contaminant avoidance, and swimming) in Chinook salmon and rainbow trout that could result in reduced growth, survivability, and reproduction in salmonid populations (Hansen et al. 1999b; Sandahl et al. 2007).

Through bioenergetics modeling, researchers have worked to understand the metabolic cost of contaminant pollution to fish. For example, Beyer et al. (1999) found that largemouth bass metabolic rates (measured by O_2 consumption) increased in short-term exposures to dieldrin (1-4 days). However, in longer (16 days) exposures the fish metabolic rates increased to compensate for the exposure, but at the cost of reduce growth rates. Similarly, Atlantic salmon survival, growth rates, and growth indices decreased proportionally along a pollution gradient in Onondaga Creek, New York (Coghlan and Ringer 2005). Other factors that could lead to an overall reduced survival of salmonids that are exposed to contaminants included: reduced food comsumption, reduced tolerance to other insults (e.g., temperature, low D.O., and pathogens), and reduced food conversion efficiencies (Beyer et al. 1999; Coghlan and

Ringler 2005). Bioenergetic modeling is a useful tool for demonstration the biological significance of pesticide and other contaminant exposures (Beyers et al. 1999).

Indirect Effects

Salmonid populations can also be adversely impacted indirectly by pesticides acting upon their target species. For example, herbicides and insecticides target the food web organisms that the salmonids depend on during rearing and migration. In addition, pesticides in the aquatic environment can shift algal or invertebrate communities to ones that are less nutritious or preferable to salmonids. Modifications to prey and prey food sources can have noticeable effects on fish populations (NMFS 2012). Reduced food for developing salmonids will result in greater competition, reduced fish growth, and possible starvation during critical life stages (NMFS 2008). Other possible indirect impacts to salmonid populations include the destruction of riparian vegetation (NMFS 2012). Riparian vegetation is important for providing shade, stabilizing stream banks, and providing allochthonous inputs that are important to maintaining salmonid ecosystems.

Population-level Effects

It is very difficult to quantify actual impacts that pesticide stressors have on salmonid populations because the effects can be direct or indirect, lethal or sublethal, long-term or short-term. To determine the possible combined effects that pesticides might have on salmon populations, researchers at the Northwest Fisheries Science Center used models to predict the effects of ChE inhibitors on anadromous Chinook salmon populations in the western United States (Baldwin et al. 2009; Macneale et al. 2014). They linked ChE activity to the somatic growth of subyearling Chinook salmon using a series of linear relationships (e.g., linked brain enzyme activity to feeding behavior, feeding behavior to food uptake, and food uptake to somatic growth). In addition, the researchers predicted the reduction in Chinook salmon growth due to reduced prey as a result of invertebrate exposure to pesticides. The predicted size of Chinook salmon at ocean entry is used to predict ocean survival, and then subsequent population growth.

The model results indicated that short-term exposures that were representative of real-world seasonal use patterns were enough to reduce the growth and size of juvenile Chinook salmon at the time of ocean entry. Consequently, the reduced size at ocean entry was enough to reduce the survival of individuals, which would, over successive years, reduce the intrinsic productivity of the population. For example, a four-day exposure to an organophosphate pesticide at a level that would produce a 50% reduction in ChE activity would result in a 6% decrease in the intrinsic population growth rate (Baldwin et al. 2009). Furthermore, the model estimated that if similar conditions continued for 20 years, then the exposed population spawner abundance would be only 27% of the unexposed spawner abundance. Macneale et al. (2014) evaluated additional pesticide classes (e.g., carbamates), exposure durations, and exposure frequencies. Overall, the magnitude of the responses indicates that common pesticides may significantly limit the conservation and recovery of threatened and endangered species in California (Baldwin et al. 2009).

Unfortunately, the models only evaluated the direct and indirect effects of single pesticide exposures at a time, and they did not incorporate possible interactions of multiple pesticides, other environmental stressors (e.g., reduced habitat and sub-optimal temperatures), or other contaminants. Different pesticides can work additively to cause a toxic effect, and other contaminants and stressors can influence pesticides' effectiveness, as well. For example, through transcriptional assays Hasenbein et al. (2014) determined that ammonia likely enhanced the effect of multiple-contaminant exposures to Delta smelt. Similarly, concurrent exposure of salmonids to copper and olfactory inhibitory pesticides could result in toxicological effects, even if both are at concentrations that would not elicit a response in isolation. Furthermore, many pesticides have been found to be able to work synergistically to cause toxicity to salmonids that is multiplicative and not just additive (Laetz et al. 2009). Current estimates of the effects of pesticides on salmonids may underestimate the true responses of salmonid populations in surface waters (Baldwin et al. 2009).

These additive and synergistic effects from multiple contaminants are true concerns for aquatic environments. For example, in the National Water-Quality Assessment (NAWQA) Program's monitoring of pesticides, they found that more than 90% of the streams located in developed areas contained two or more pesticides or degradates (Gilliom et al. 2006). Furthermore, more than 50% of the streams had five or more pesticides or degradates, and the concentrations of the degradates were often higher than that of the parent pesticide. The degradate forms can be less toxic than the parent pesticide; however, some degradates have been found to be as toxic or more toxic than the parent (Gilliom et al. 2006). In addition, pesticide products typically contain additional chemicals like adjuvants, surfactants, and solvents. These chemicals are labeled as inert ingredients, but they increase the effectiveness of the active ingredients and can be toxic to non-target species (Cox and Surgan 2006; Beggel et al. 2010; Scholz et al. 2012). Very little is known about the fate of these “inert” labeled ingredients once they are in surface waters and their possible impacts on salmonid populations.

1.3.1.2 Mercury

Mercury is a persistent and bioaccumulative toxic pollutant. Methylmercury is the most toxic form in the freshwater environment because it is the form most readily bioaccumulated in fish and through the food web (Wiener et al. 2003). For example, the proportion of mercury that exists as methylmercury generally increases with each level of the food chain, and methylmercury comprises 80% to 100% of the total mercury measured in fish tissue (Bloom 1992; Becker and Bigham 1995; Nichols et al. 1999; Weiner et al. 2003; Slotton et al. 2004; Sveinsdottir and Mason 2005). Fish can absorb mercury through their epidermis (e.g., gills, skin) directly from water; however, fish accumulate the majority (greater than 85%) of their mercury through their diet in the form of methylmercury (Hall 1997; Weiner et al. 2003). There is evidence that methylmercury bioconcentrates (directly from water) in the laboratory (McKim et al. 1976; Fjeld et al. 1998); however, the minimum concentrations used in these dilution series exposures (160 nanograms per liter [ng/L] and 30 ng/L, respectively) were greater than 25-fold higher than the maximum aqueous methylmercury concentrations found in Central Valley mainstem rivers (Foe et al. 2008). It is the result of bioaccumulation and subsequent biomagnification that methylmercury concentrations typically become elevated in fish, and fish in the higher tropic levels tend to have the highest concentrations.

Fish have evolved in an environment that always contained mercury. Methylmercury is transported via the circulation system to all organs and tissue; however, methylmercury eventually redistributes to the skeletal muscles, where it becomes bound to proteins in the muscle tissue (Weiner et al. 2003). In an extensive review of mercury impacts on fish, Weiner and Spry (1996) determined that the binding of assimilated methylmercury to proteins in the skeletal muscles may function as the primary detoxification mechanism for methylmercury in fish. The use of this mechanism reduces exposure of the central nervous system and brain to methylmercury. Because of the eventual redistribution of methylmercury to muscle tissue, the rate of accumulation and exposure time seem to significantly affect the toxicity of methylmercury to fish (Weiner and Spry 1996).

Neurotoxicity seems to be the most probable chronic response of wild fishes to dietary methylmercury, and long-term dietary exposure to methylmercury can cause incoordination, inability to feed, and diminished responsiveness (Weiner and Spry 1996). Other toxicological effects include reproductive impairments (e.g., hatching success, fecundity, and sex steroids), growth inhibition, developmental abnormalities (spinal and jaw deformities), altered behavioral responses (e.g., lethargy, predator response, and aggressiveness), and mortality (Eisler 1987; Beckvar et al. 1996; Wiener and Spry 1996; Beckvar et al. 2005; Dillon et al. 2010; Depew et al. 2012; Weis 2014). Alterations in biochemistry, gene transcription, and tissue histology from exposure to mercury may also be the cause of the deleterious impacts to fish (Moran et al. 2007; Sandheinrich et al. 2011). For example, Moran et al. (2007) found differential gene expression in trout livers collected from two high elevation lakes in Washington. The fish collected from the more polluted lake, primarily higher mercury, exhibited upregulation of genes involved with a number of physiological processes including immune function, stress adaption, reproduction, and metabolism. Surprisingly, even the more contaminated lake fish had low levels of mercury contamination (less than 0.06 micrograms per gram [µg/g], wet weight, average of 2 years).

Mercury toxicity can have long lasting impacts well after exposure has ended. For example, Fjeld et al. (1998) found that sub-lethal methylmercury exposures permanently impaired graylings (*Thymallus thymallus*) three years after the exposure. The 10-day egg exposures that resulted in embryo graylings tissue methylmercury concentrations of 3.8 µg/g (wet weight) exhibited immediate effects (e.g., delayed hatching, reduce hatching success, and malformed embryos); however, the embryos with body methylmercury concentrations as low as 0.27 µg/g exhibited reduce foraging success (e.g., feeding efficiency and competitive ability) compared to the control group three years after the initial methylmercury exposure. Similarly, Matta et al. (2001) observed transgenerational effects with killifish (*Fundulus heteroclitus*) fed methylmercury contaminated food. The maternal transfer of methylmercury to offspring resulted in altered sex ratios and other reproductive abnormalities in the next generation.

Reproductive and early life stage endpoints appear to be some of the most sensitive for fish species, and these adverse effects are typically seen at methylmercury tissue concentrations about 10-fold lower than seen for adult effects (Wiener and Spry 1996; Beckvar et al. 2005; Dillon et al. 2010; Depew et al. 2012). Incubating salmonid eggs will be relatively unaffected by contaminants in the river because vitelline membrane, enveloping layer, and chorion provide defense from metals, pathogens, and xenobiotic chemicals (Finn 2007). Accordingly, the methylmercury accumulated in the eggs will be primarily derived from the maternal fish (Wiener and Spry 1996). Hammerschmidtt and Sandheinrich (2005) concluded that egg methylmercury was primarily derived from the maternal diet during oogenesis because offspring from adults fed mercury before and during oogenesis had similar concentrations as offspring from adults only fed during oogenesis; however, using stable isotope enriched methylmercury diets, Stefansson et al. (2014) found that both the maternal diet during oogenesis and the female tissue accumulated during preoogenesis contributed mercury proportionally to eggs.

The amount of methylmercury transferred from female to the egg appears to vary depending on contamination level, maternal length, species, etc. For example, the fathead minnow egg concentration percentages increased from 14% to 35% of maternal concentrations with increasing maternal methylmercury diets and maternal concentrations (Hammerschmidtt and Sandheinrich 2005). In another laboratory study with killifish, for the eggs that resulted in methylmercury concentrations above analytical detection limits the percentage of maternal muscle methylmercury concentration in eggs was 0.9% and 5.3%, also increasing with dosage and maternal concentration (Matta et al. 2001). In a field investigation, Johnston et al. (2001) found that egg methylmercury concentrations were 1.1% to 12% of female muscle concentrations for seven different walleye (*Stizostedion vitreum*) populations. In addition, the percentage of the maternal concentrations varied with maternal length, egg concentrations, maternal liver and muscle concentrations, female length, and population location. Finally, Niimi (1983) investigated the maternal transfer of multiple contaminants in five different species collected from Lake Ontario and Erie. The percentage of maternal methylmercury concentrations in eggs averaged: 0.6% for rainbow trout (*O. mykiss*), 1.8% for white sucker (*Catostomus commersoni*), 0.3% for white bass (*Morone chrysops*), 0.4% for smallmouth bass (*Micropterus dolomieui*), and 2.3% for yellow perch (*Perca flavescens*). The field investigations are likely most indicative of typical maternal transfer to eggs from the natural environment because these fish reflect the natural bioaccumulation rates, prey methylmercury concentrations, and growth rates.

1.3.1.3 Selenium

Selenium is an essential micronutrient for normal animal nutrition; however, selenium can bioaccumulate and biomagnify to levels that are toxic to fish and other wildlife. Selenium can bioconcentrate directly from water through gills, epidermis, or gut; however, like mercury, the primary route of exposure to levels that exhibit toxicological effects is through the food web (Lemly and Smith 1987; Hamilton 2004; Entrix 2009; Presser and Luoma 2013; USEPA 2015). When dissolved selenium enters the aquatic environment, it may do the following (Lemly and Smith 1987):

- Be absorbed or ingested by organisms
- Bind or complex with particulate matter
- Remain in solution

The speciation of dissolved selenium in its three dominant oxidation states (i.e., selenate, selenite, or dissolved organic selenium) is important because the oxidation state of the dissolved form influences the rate of transformations (e.g., oxidation and methylation) that create the particulate form (Lemly and Smith 1987; Presser and Luoma 2013). The uptake of selenate by plants and phytoplankton appears to be slower than the other two oxidation states (Presser and Luoma 2013).

Ecologically, the first and second mechanisms above are the most important because particulate selenium and selenium associated with plants and phytoplankton are the primary forms that enter the food web (Lemly and Smith 1987; Presser and Luoma 2013; USEPA 2015). Examples of the mechanisms where selenium is made available for biological uptake include the following (Lemly and Smith 1987; Presser and Luoma 2013):

- Oxidation and methylation of inorganic and organic selenium by plant roots and microorganisms
- Biological mixing and associated oxidation of sediments that results from the burrowing of benthic invertebrates and feeding activities of fish and wildlife

- Physical perturbation and chemical oxidation associated with water circulation and mixing
- Oxidation of sediments by plant photosynthesis
- Recycling of particulate phases back into water as detritus or dissolved organic selenium after organisms die and decay

In addition, rooted plants and detrital feeding organisms can input selenium into the food web, even when selenium is absent from the water column (Lemly and Smith 1987).

Selenium has three levels of biological activity in fish: 1) trace concentrations are required for normal growth and development, 2) moderate concentrations can be stored and homeostatic functions maintained, and 3) elevated concentrations can result in toxic effects (Hamilton 2004). Fish exposure to selenium typically follows a biphasic response (i.e., beneficial at low doses and toxic at high doses [Hilton et al. 1980; and Lemly and Smith 1987; USFWS 2008]). Toxic effects of selenium to fish typically fall into two categories (Lemly and Smith 1987; USEPA 2015):

- Chronic reproductive (e.g., effects to offspring survival and morphology)
- Chronic non-reproductive (e.g., adult and juvenile growth and survival)

Similar to mercury, reproductive function is the most sensitive to selenium toxicity, and the most documented impacts to reproduction are teratogenesis and larval mortality (USEPA 2015). Often, reproductive failure, whether through effects on adult ovaries or embryonic development, are the first obvious symptom of selenium contamination, and complete reproductive failure can occur with very little or no tissue pathology or mortality of the adult population (Lemly and Smith 1987). USFWS' (2008) review of selenium impacts to threatened and endangered species in the Delta reported statistically significant increases in pre-swimup mortality and increased percentages of edema and craniofacial deformities in swimup fry with increasing egg selenium concentrations in rainbow trout. In addition, others have reported that fish exposed to selenium exhibit ovaries with necrotic and ruptured egg follicles, anemia and reduced hatch in eggs, or chromosomal aberrations (Eisler 1985). Additional effects of selenium to early life stage fish include deformities that include: lordosis (concave curvature of lumbar and caudal regions of spine), kyphosis (convex curvature of thoracic region of the spine), scoliosis (lateral curvature of the spine); in addition to edema, and brain, heart, and eye problems (Hamilton 2004).

Selenium is transferred from the maternal diet to developing eggs during vitellogenesis, and the embryo is exposed to selenium during yolk absorption (Presser and Luoma 2013; USEPA 2015). The rate of maternal transfer of selenium to gonadal tissue is much greater than for mercury. For example, Linares-Casenave et al. (2014) found that white sturgeon (*Ancipenser transmontanus*) sampled from the San Francisco Bay and Delta had gonadal tissue selenium concentrations 100 and 200% that of muscle selenium concentrations in previtellogenic and vitellogenic females, respectively. This is compared to the maternal transfer of 0.3% to 12% of mercury concentrations in gonadal tissues observed in field collected fish (see above). For the development of their draft Aquatic Life Ambient Water Quality Criterion for Selenium, USEPA (2015) summarized paired maternal and egg-ovary selenium concentrations to estimate conversion factors between tissue concentrations. Individual species conversion factors (maternal muscle>egg-ovary) ranged from 1.0 to 5.8 (i.e., egg concentrations were 100% to 580% of maternal concentrations), with rainbow trout having the second highest transfer rate (out of 16 species) with a conversion factor of 1.9. The overall high ranking of salmonids continued at the genus level (average *Oncorhynchus* = 1.9) and family level (average *Salmonidae* = 1.5).

Beyond the reproductive and early life stages, additional effects can occur in fish at later exposures. For example, juvenile rainbow trout fed selenium supplemented diets exhibited reduce growth, higher feed:gain ratio, and higher number of mortalities after 20 weeks of feeding (Hilton et al. 1980). In addition, the juveniles exhibited behavior effects (e.g., feeding avoidance) as well as uncoordinated swimming and sensory deprivation approximately 24 hour priors to mortality. Similarly, Hamilton and Wiedmeyer (1990) found that reduced survival and growth of Chinook salmon were strongly correlated to tissue selenium concentrations in 90-day exposures. As well, selenium exposures to Chinook salmon resulted in reduced survival in the 15-day seawater challenge. Additional effects to fish include: loss of equilibrium, lethargy, contraction of dermal chromatophores, loss of coordination, muscle spasms, protruding eyes, swollen abdomen, liver degeneration, reduction in blood hemoglobin and erythrocyte number, increase in white blood cells, and swollen gill lamellae with extensive cellular vacuolization (Eisler 1985).

In addition to being an essential micronutrient for organisms, selenium has been found to have protective effects against mercury and other metal toxicity (Eilser 1987; USEPA 2015). However, the mechanism for the antagonistic interactions is not known, the degree of antagonism is highly variable, and some studies found additive and synergistic interactions with mercury. Laboratory studies by Bjerregaard et al. (2011) suggested that selenium increases the elimination of methylmercury in fish; however, the report acknowledges that other have suggested that selenium may reduce mercury toxicity by redistributing mercury to different tissues or by reducing the assimilation of mercury. Regardless of the mechanism, selenium availability (excess and deficiency) in the aquatic ecosystem must be considered, when considering optimal concentrations in the environment.

1.3.1.4 Nutrients

Nutrient imbalances have the ability to cause adverse impacts to all the life stages of salmonids through direct and indirect mechanisms. In addition to direct toxicological impacts to salmonids, nutrient imbalances can adversely impact salmonid habitat through cultural eutrophication or cultural oligotrophication. Detrimental impacts of excessive primary productivity include, but are not limited to, increased temperatures, hypoxia, disrupted migratory corridors, and reduced habitat associated with macrophytes or the release of biotoxins by cyanobacteria or other phytoplankton (Berg and Sutula 2015; Boyer and Sutula 2015; Gowdy and Grober 2005; Schlegel and Domagalski 2015).

Nutrient enrichment and subsequent eutrophication has been found to result in depressed dissolved oxygen levels in aquatic systems (Dodds 2007; Gowdy and Grober 2005; Tetra Tech 2006; USEPA 2000). Low DO can adversely impact all life stages of salmonids (see Chapter 7 and Appendix B). Although nutrient enrichment can be a primary driver of depressed DO, there are many other factors that also contribute to this aquatic impairment (e.g., elevated temperatures, excessive residence time, and channel morphology).

Nutrient enrichment has been found to increase the growth of nuisance aquatic plants in the Delta (DSC 2013). While a balance of macrophyte densities is beneficial for fish, excessive amounts of macrophytes can reduce the suitability of habitat for salmonids (Boyer and Sutula

2015). For example, dense canopies of macrophytes can shade phytoplankton and reduce productivity, draw down DO levels, shift pH levels, and harbor large non-native predator fish (Boyer and Sutula 2015). Dense stands of macrophytes may create conditions which stress adult and juvenile migration through the Delta, San Joaquin River, or Stanislaus River, if they exist across the rivers' channels. Likewise, if the dense canopies decrease or alter the phytoplankton communities and food web, then this could decrease the growth rates of rearing juveniles. As well, the dense macrophytes may increase the susceptibility of juveniles to predation.

Cultural oligotrophication or lack of primary productivity can also have adverse impacts to salmonid populations. Cultural oligotrophication is the anthropogenically induced decrease in nutrient concentrations and primary production (Stockner et al. 2000; Stockner and Ashley 2003). A couple mechanisms that could possibly contribute to cultural eutrophication in the Stanislaus River include, but are not limited to reservoir creation and reduced anadromous salmonid population returns. Reservoir impoundments tend to trap and settle sediment and particulate organic matter, which results in a net sink of phosphorus and subsequent reduction of primary productivity downstream (Stockner et al. 2000). In addition, the current reduction of anadromous salmonid populations and escapement has reduced the amount of marine-derived nutrients that historically were inputted in the watershed.

Several studies have documented the importance of marine-derived nutrients in the productivity levels in oligotrophic streams and rivers from Alaska to Northern California (Moore et al. 2011; Stockner et al. 2000). The net result of cultural oligotrophication is the reduction of juvenile growth rates which can reduce the overall survival and productivity of salmonid populations. The direct link between reduced nutrients and reduced salmonid growth rates has not been documented in Central Valley rivers; however, there is evidence that cultural oligotrophication has reduced fish growth rates and exacerbated mercury impairments in California reservoirs in upstream watersheds (Foe and Louie 2014). However, there is evidence that there are factors other than a lack of nutrients that may be causing reduced fish growth rates in the Stanislaus River, such as the reduced frequency and area of floodplain inundation (see Chapter 5).

1.3.2 Approach

1.3.2.1 Pesticides

The SEP Group relied on adopted numeric water quality objectives for pesticides from the Sacramento and San Joaquin River Water Quality Control Plan, and proposed pesticide water quality objectives from developing pesticide control programs (CVRWQCB 2014, 2015a, and 2015b) to determine pesticide levels that should provide no adverse impacts to salmonid populations. In addition, for pesticides that do not have state or federally promulgated objectives or criteria, the SEP Group used the USEPA Office of Pesticide Programs (OPP) aquatic-life benchmarks with a level of concern for impacts to endangered and threatened species as the safe level for pesticides.

Unfortunately, no pesticide monitoring program exists throughout Stanislaus River, San Joaquin River, Delta or Bay, nor is there likely a program that will exist in the future that will be able to monitor all possible pesticides that may adversely impact salmonids during entire life stages. Quantifying the concentrations of all the pesticides that salmonids are exposed to is difficult. For example, more than 1,000 pesticide chemicals were applied in California in 2012 (CDPR 2014). In addition, each commodity or crop type can have multiple pesticide chemicals that are applied to them (e.g., alfalfa crops were associated with greater than 200 pesticide chemicals). Performing chemical analyses, for all possible pesticides in the different reaches of the river where salmonids would be exposed, would not be cost feasible. Furthermore, current analytical methodologies do not allow for all pesticides to be detected at levels that may cause adverse effects to aquatic organisms (Hladik et al. 2009; Mekebri 2011; CVRWCB 2015).

Additionally, each of the specific pesticides has different impacts to the physiology of salmonids, as well as to their prey. For example, Macneale et al. (2014) population modeling determined that the magnitude of a pesticide’s effect on salmon population growth is dependent on the relative sensitivity of salmon olfactory senses and prey abundance to the pesticide. For instance, chlorpyriphos had a greater influence on salmon population growth by directly affecting salmon physiology, while another organophosphate, diazinon, had a greater impact by decreasing salmon prey abundance. Attempting monitor and evaluate the direct and indirect effects of the more than 1,000 possible pesticides and mixtures of pesticides that could occur in the Stanislaus River and downstream corridor would very difficult.

The SEP Group has relied on a pesticide prediction model (Hoogeweg et al. 2011) to estimate the current frequency of pesticide water quality objective or benchmark exceedances to categorize optimal, sub-optimal, and detrimental conditions for Chinook salmon and *O. mykiss* pesticide environmental objectives. That is, the categories are an evaluation of the risks that a species is exposed to pesticide concentrations that could cause harm in a river reach by month. The categories assume that, while zero occurrences of pesticides is preferred, such low levels of exposure may not be achievable considering the amount of urban and agricultural development in the Central Valley. Models, monitoring, toxicity bioassays, and other information, will need to be updated, developed, conducted, and further gathered as needed in the future to determine if pesticide concentrations are adversely impacting salmonids in through their life stages.

1.3.2.2 Mercury

Current mercury numeric water quality objectives or criteria were developed to protect human and other fauna that consume fish and not for the protection of fish themselves. For example, the USEPA-promulgated California Toxics Rule (CTR) numeric criteria for mercury are for the protection of human health only (40 Code of Federal Regulations [CFR] Part 131). As noted earlier, fish with elevated concentrations of mercury are frequently observed in waterbodies that do not exceed the CTR criterion of 0.05 micrograms per liter (μg/L) total mercury (Wood et al. 2010). Similarly, water quality objectives developed individually for the San Francisco Bay and the Delta were developed as fish tissue objectives for the protection of human and wildlife consumers of fish (SFBWQCB 2006; Wood et al. 2010). This is in part due to the fact that until recently (within the last decade), the majority of evidence supported that fish were relatively insensitive to mercury toxicity when compared to human and wildlife consumers of fish (Weiner and Spry 1996). For example, Wiener and Spry (1996) concluded that estimated no-observed-effect mercury concentrations for salmonids were 3 μg/g (wet weight, whole body), whereas fish tissue mercury concentrations to protect human and wildlife consumers of fish from the San Francisco Bay and Delta is greater than 10-fold lower at approximately 0.2 µg/g (wet weight, muscle tissue[2]) (SFBWQCB 2006; Wood et al. 2010).

Since 1996, many studies have reported adverse effects to fish species at concentrations lower than the papers reviewed by Wiener and Spry, and there is now evidence that fish species are more sensitive to mercury toxicity than previously thought (Dillon et al. 2010). For example, Beckvar et al. (2005) developed approaches (i.e., simple ranking, empirical percentile, tissue threshold-effect level (t-TEL), and cumulative distribution function) to determine the fish tissue mercury concentrations that would be protective against adverse mercury toxicity using studies that measured mercury tissue concentrations and corresponding biological responses (e.g., reproduction, growth, and behavior) in adult, juvenile eggs, and early-life stages (ELS) fish. Dillon et al. (2010) used dose-response curves on lethality-equivalent test endpoints to estimate the percent injury to fish by mercury. The SEP Group relied in these benchmark concentrations as the levels that would be optimal, sub-optimal, and detrimental to salmonids during their life stages.

1.3.2.3 Selenium

The SEP Group relied on the draft USEPA National Freshwater Selenium Ambient Water Quality Criterion for Aquatic Life (2014) for the environmental objectives to protect salmonid species in the Stanislaus River against adverse effects. The criteria have yet to be promulgated; however, the criteria are consistent with the relevant technical literature on selenium toxicology.

1.3.2.4 Nutrients

Nutrient imbalances can impair salmonid populations through both direct toxicity and ecological use impairments, so the SEP used two approached to develop nutrient environmental objectives. To evaluate the possible direct toxicity of ammonia, nitrite, and nitrate to salmonids in the Stanislaus River, the SEP used available aquatic-life criteria or other available toxicological benchmark values. Phosphate does not appear to have direct

[2] Muscle tissue (filet) mercury concentrations can be converted to whole-body mercury (Hg) concentrations using the following equation: Log [filet biopsy Hg] = 0.2545 + 1.0623 x Log [whole-fish Hg] (Peterson et al. 2007).

toxicological impacts to fish or daphnids at ecologically relevant concentrations (Kim et al. 2013), so it is not considered further for this evaluation.

The second category of nutrient environmental objective is ecological use impairments, which would include nutrient imbalances that result in a reduction of beneficial habitat for salmonids. Recent efforts for evaluating environmental impacts from nutrients have moved away from the strict application of a single nutrient concentration criterion across broad landscapes or watersheds (Tetra Tech 2006; USEPA 2000). These efforts were developed, in part, due to the fact that pre-defined nutrient limits may or may not result in eutrophication in all waterbodies. The evaluation of appropriate nutrient levels requires the evaluation of aquatic beneficial uses needing protection, classification of waterbodies by type and trophic status, as well as consideration of other external environmental factors (Tetra Tech 2006; USEPA 2000). For example, an indirect way to evaluate possible nutrient impairments is to examine some of the detrimental outcomes of nutrient impairments (e.g., depressed DO, excessive macrophytes, or chlorphyll-a concentrations).

1.3.3 Objectives

Some of the identified contaminants have associated USEPA promulgated numeric aquatic life water quality or human health criteria (CTR, 40 CFR Part 131) as well as each may have Regional Board specific water quality objectives. Unfortunately, most current use pesticides do not have promulgated water quality criteria or objectives. Additionally, the CTR criteria were developed to protect for human health or against short-term (4-day) effects on aquatic life, and these criteria may not be protective of long-term (e.g., weeks, months, and years) adverse impacts on salmonids and other wildlife. For example, the evaluation for the Sacramento-San Joaquin Delta Estuary Total Maximum Daily Load (TMDL) for methylmercury determined that even though the CTR criterion for mercury is never exceeded in the Delta, fish tissue mercury concentrations are a threat to threatened and endangered wildlife species and humans that consume Delta fish (Wood et al. 2010). As well, many of the toxicological studies to be discussed later have observed adverse effects to salmonids below established water quality criteria.

1.3.3.1 Pesticide Objectives

Numeric water quality objectives have not been established for vast majority of current use pesticides in the Central Valley. Table C-11 presents the pesticides that have adopted numeric water quality objectives in the Sacramento and San Joaquin River Basins Water Quality Control Plan (Basin Plan) and the proposed water quality objectives for pyrethroid pesticides (CVRWQCB 2014, 2015a, and 2015b).

Table C-11
Central Valley Regional Water Quality Control Board Adopted and Proposed Water Quality Objectives for Current Use Pesticides

Pesticide	Acute (µg/L)	Chronic (µg/L)
Adopted Water Quality Objectives[1]		
Diazinon	0.16	0.1
Chlorpyriphos	0.025	0.015
Carbofuran	40	40
Simazine	4	4
Thiobencarb	1	1
Pentachlorophenol	5.3	4
Copper	5.7	4.1
Proposed Water Quality Objectives[2]		
Bifenthrin	0.00006	0.00001
Cyfluthrin	0.0002	0.00004
Lambda-Cyhalothrin	0.00003	0.00001
Cypermethrin	0.00004	0.00001
Esfenvalerate	0.0002	0.00003
Permethrin	0.006	0.001

Notes:
1 CVRWQCB 2015a
2 Proposed water quality objectives for the Central Valley Pyrethroid Pesticides TMDL and Basin Plan Amendment (CVRWQCB 2015b)

USEPA OPP develops aquatic toxicity benchmarks for use in risk assessment and pesticide registration decisions under the Federal Insecticide, Fungicide, and Rodenticide Act (USEPA 2004). OPP has developed aquatic life benchmarks for over 400 registered pesticides. Table C-12 presents the benchmarks for the 40 pesticides that are predicted to pose the greatest risks in the Central Valley (Lu and Davis 2009; Hoogeweg et al. 2011). Included in Table C-12 are the benchmarks for the protection of the critical habitat for listed species, which includes an additional safety factor (USEPA 2004). The aquatic life benchmarks can be used for initial environmental assessments; however, a more detailed evaluation or site-specific evaluations may determine that the aquatic life benchmarks are not protective of the most sensitive species. For example, a comparison between the OPP benchmarks (Table C-12) and the established or proposed water quality objectives (Table C-11) shows that all but one of the water quality objectives predicts that a lower concentration than the OPP benchmarks is necessary to protect beneficial uses. Attaining the lower of either the aquatic life benchmarks or the water quality objectives should reasonably allow for the protection of salmonid species as well as their habitat.

Table C-12

U.S. Environmental Protection Agency Office of Pesticide Programs' Aquatic-life Benchmarks for the 40 Pesticides that Pose the Greatest Risk in the Central Valley Region

Pesticide	Pesticide Type	Acute Benchmark (µg/L)	Endangered and Threatened Acute Benchmark (µg/L)	Chronic Benchmark (µg/L)	Source of Acute/ Chronic Value[1]
Abamectin	Insecticide	0.17	0.017	0.006	IA/IC
Bifenthrin	Insecticide	0.075	0.0075	0.0013	FA/IC
Bromacil	Herbicide	6.8	0.68	3000	AA/FC
Captan	Fungicide	13.1	1.31	16.5	FA/FC
Carbaryl	Insecticide	0.85	0.085	0.5	IA/IC
Chlorothalonil	Fungicide	1.8	0.18	0.6	IA/IC
Chlorpyrifos	Insecticide	0.05	0.005	0.04	IA/IC
Clomazone	Herbicide	167	16.7	350	AA/FC
Copper hydroxide	Fungicide	5.9	0.59	4.3	IA/IC
Copper sulphide	Insecticide/Algaecide	5.9	0.59	4.3	IA/IC
Cyfluthrin	Insecticide	0.0125	0.00125	0.007	IA/IC
Cyhalofop butyl	Herbicide	245	24.5	134	FA/FC
Cypermethrin	Insecticide	0.195	0.0195	0.069	FA/IC
Deltamethrin	Insecticide	0.055	0.0055	0.0041	IA/IC
Diazinon	Insecticide	0.11	0.011	0.17	IA/IC
Dimethoate	Insecticide	21.5	2.15	0.5	IA/IC
Diuron	Herbicide	2.4	0.24	26	AA/FC

Pesticide	Pesticide Type	Acute Benchmark (µg/L)	Endangered and Threatened Acute Benchmark (µg/L)	Chronic Benchmark (µg/L)	Source of Acute/ Chronic Value[1]
Esfenvalerate	Insecticide	0.025	0.0025	0.017	IA/IC
Hexazinone	Herbicide	7	0.7	17000	AA/FC
Imidacloprid	Insecticide	35	3.5	1.05	IA/IC
Indoxacarb	Insecticide	12	1.2	3.6	FA/IC
Lambda cyhalothrin	Insecticide	0.0035	0.00035	0.002	IA/IC
Malathion	Insecticide	0.3	0.03	0.035	IA/IC
Mancozeb	Fungicide	47	4.7	N/A	AA/na
Maneb	Fungicide	13.4	1.34	N/A	AA/na
Methomyl	Insecticide	2.5	0.25	0.7	IA/IC
(s)-Metolachlor	Herbicide	8	0.8	30	AA/FC
Naled	Insecticide	25	2.5	0.045	AA/IC
Oxyfluorfen	Herbicide	0.29	0.029	1.3	AA/FC
Paraquat	Herbicide	0.396	0.0396	N/A	AA/na
Pendimethalin	Herbicide	5.2	0.52	6.3	AA/FC
Permethrin	Insecticide	0.01	0.001	0.0014	IA/IC
Propanil	Herbicide	16	1.6	9.1	AA/FC
Propargite	Insecticide	37	3.7	9	IA/IC
Pyraclostrobin	Fungicide	0.0015	0.00015	0.002	FA/FC
Simazine	Herbicide	36	3.6	960	AA/FC
Thiobencarb	Herbicide	17	1.7	1	AA/IC
Tralomethrin	Insecticide	0.055	0.0055	0.0041	IA/IC
Trifluralin	Herbicide	7.52	0.752	1.14	AA/FC
Ziram	Fungicide	9.7	0.97	39	FA/IC

Notes:
1 Identifies which taxa was the most sensitive to the pesticide from available toxicity evaluations defined as FA = fish acute; IA = invertebrate acute; AA = Algae Acute; FC = fish chronic; IC = invertebrate chronic; na = not available.
Sources: USEPA OPP. Table modified from Hoogeweg et al. (2011).
– Aquatic-life benchmarks are used by the USEPA OPP for risk assessments in the registration of pesticides. To assess a pesticide not listed, the entire list of nearly 500 pesticide benchmarks can be acquired at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-pesticide-registration

The pesticide criteria and benchmarks were developed assuming organismal exposure to single pollutants. Additional considerations are necessary, when multiple pesticides are present (e.g., additive toxicity equations) (CVRWQCB 2014, 2015a, and 2015b; Hasenbein et al. 2014). In addition, assessing the true impact on aquatic life may need to consider the bioavailability of the pesticides (CVRWQCB 2015a,b). For example, the majority of dissolved copper is likely bound as ligand complexes and largely not bioavailable (SFBRWQCB 2007; McIntyre et al. 2008; Linbo et al. 2009). Consequently, copper, pesticides, and other metals toxicity evaluations should involve adjustments for site-specific conditions (e.g., hardness, biotic ligand models, or dissolved organic concentrations) (SFBRWQCB 2007; CVRWQCB 2015a and 2015b).

The Hoogeweg et al. (2011) model allowed the determination of the magnitude of pesticide effects on Stanislaus River salmonids, and the relative risk of pesticide exposures by month and river reach (Figure B-1 and Table C-13). As mentioned earlier, limitations in monitoring and chemical analyses, the multitude of possible pesticide chemicals, etc. precludes the use of strict concentration limitations to evaluate overall pesticide impacts on salmonids throughout the Stanislaus River and downstream waterbodies. In turn, current pesticide impacts to salmonid life stages in the Stanislaus River are based on the relative frequency of pesticides exceeding aquatic-life benchmarks.

Table C-13
Categories of Predicted Pesticide Aquatic-life Benchmark Exceedances

Bin Category	Condition	Range of the Frequency of Benchmark Exceedances		
1	Optimal	0	-	0.017
2	Sub-optimal	0.018	-	0.055
3		0.056	-	0.1
4		0.101	-	0.153
5		0.154	-	0.206
6		0.207	-	0.303
7	Detrimental	0.304	-	0.447
8		0.448	-	0.5
9		0.501	-	0.589
10		0.59	-	0.994

Note:
Frequencies were calculated from the total number of predicted exceedance days for each month from 2000 to 2009. Any day that had at least one pesticide that exceeded benchmarks was counted as an exceedance day. – Source: Adapted from Hoogeweg et al. 2011.

To be fully protective of aquatic-life beneficial uses, current pesticide water quality objectives and criteria require that pesticide thresholds are not exceeded more than once every 3 years (40 CFR Part 131; CVRWQCB 2014). Similarly, meeting the frequency range of Bin 1 (Table C-13) of pesticide exposure in the Stanislaus River and freshwater migratory corridor should allow the full expression of salmonid life stages, and this represents the optimal condition. Furthermore, the analysis for the development of the Central Valley diazinon, chlorpyriphos, and pyrethroid TMDLs concluded that the adopted and proposed numeric criteria for these pesticides should be reasonably achievable (CVRWQCB 2014 and 2015b).

Determining the frequency of pesticide exposures that are predicted to result in sub-optimal versus detrimental impacts is much more difficult. For example, as mentioned previously the Northwest Fisheries Science Center modeling determined that the effect of pesticides on the intrinsic population growth of salmon was dependent on the relative sensitivity of salmon olfactory function versus prey abundance to specific pesticides, the binding affinity of specific pesticides, the concentration of pesticide in the habitat, and the duration and frequency of pesticide exposures (Baldwin et al. 2009; Macneale et al. 2014). However, overall the models predicted that the impact to prey abundances had a greater effect on the salmon intrinsic population growth than the direct physiological effects to salmon with regards to juvenile growth.

A single 4-day pulse of high pesticide concentrations (e.g., 1.15 x prey abundance EC50 or 60-fold acute WQO) resulted in a 1% to 11% reduction in salmonid population growth depending on prey recovery rates (Macneale et al. 2014). In terms of spawner abundance, a 1% and 7% decrease in intrinsic population growth would equate to a 14% and 73%, respectively, reduction in spawner abundance compared to an unexposed control after 20 years (Baldwin et al. 2009). However, this high concentration of pesticides is at the upper range of pesticides observed in salmonid habitats and may not represent typical conditions (Baldwin et al. 2009). Fortunately, the researchers modeled a continuous low pesticide concentration exposure (e.g., salmon olfaction inhibition EC10 or 6-fold acute WQO), which lasted 105 out of 140 or 75% of the modeled rearing period. The estimated reduction in population growth was 4% or a 53% reduction in spawner abundance after 20 years.

A 4% reduction in intrinsic population growth or 75% frequency of pesticide exposure would likely still represent detrimental conditions to salmonid populations; however, a 2% reduction in intrinsic population growth (e.g., 1.08 versus the 1.1 control population) would likely represent conditions where salmonid populations are impacted but can still attain biological objectives. Accordingly, Bin 7 or greater (Table C-13), which represent approximately one-half of the 75% exposure frequency and greater, is considered to be detrimental to salmonid populations. These reductions in population growth were through impairments in salmon olfaction. The SEP Group assumes that the degree of olfaction disruption would have equivalent impact on overall fitness during each life stage.

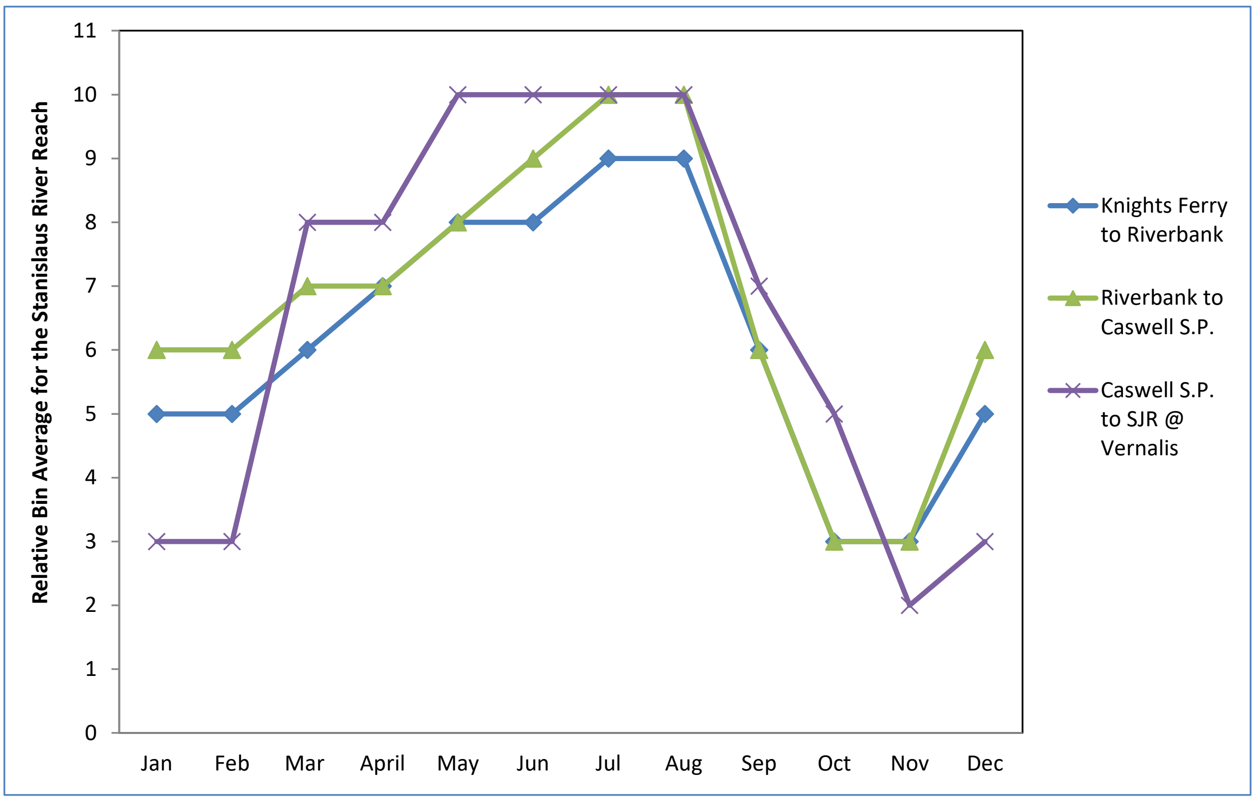

Figure C-1

Relative Bin Value of Specified Stanislaus River Reaches by Month

Note:
The values were derived from qualitative averaging of the frequency of benchmark exceedances model maps for years 2000 to 2009 in Hoogeweg and others (2011). Due to a lack of data, upstream of Knights Ferry in the Stanislaus River was not modeled.

1.3.3.2 Mercury Objectives

Using the methodology described in Section 1.3.2, a whole-fish mercury concentration of 0.2 µg/g (wet weight) (filet = 0.33 µg/g, wet weight) is predicted to be protective of juvenile and adult fish using the t-TEL method. Using the simple ranking method, Beckvar et al. (2005) estimated that 0.02 µg/g whole-body would be protective of early-life stage fish, which is consistent with the hypothesized higher sensitivity of sublethal effects to embryonic and larval stages mentioned earlier. These values are consistent with the percent of injury to fish by mercury estimate by Dillon et al. (2010) using dose-response curves on lethality-equivalent test endpoints. Sub-optimal and detrimental conditions are displayed in Table C-14. Both Beckvar et al. (2005) and Dillon et al. (2010) developed the fish mercury concentration thresholds using multiple species; however, these thresholds should also be protective of salmonids because the development of the thresholds considers the most sensitive species and endpoints. In addition, there is evidence that salmonid species are less sensitive to the toxicity of dietary methylmercury (Berntssen et al. 2004 as cited in Depew et al. 2012).

Table C-14
Mercury Objectives for Chinook Salmon and *O. mykiss* for Juveniles and Adults and Egg, Ovary, and Early-life Stages

Condition	Egg/Ovary/ELS mg/kg (wet wt.)	Adult and Juvenile Fish mg/kg whole body (wet wt.)
Optimal	< 0.02	< 0.20
Sub-optimal	0.02 to 0.10	0.20 to 1.0
Detrimental[1]	> 0.1	> 1.0

Notes:
1 Sub-lethal impacts to fish are estimated to occur above optimal conditions. Detrimental impacts are assumed to occur at mercury tissue concentrations that are expected to create 25% or greater injury to the fish. A 25% effect or EC25 metric is a consistent threshold to determine chronic toxicity assessments for regulatory compliance (SWRCB 2012).
ELS = early-life stages

1.3.3.3 Selenium Objectives

USEPA reserved the aquatic life criteria for selenium in the CTR because a USFWS and National Marine Fisheries Service (NMFS) biological opinion found that the proposed criteria for selenium may not be protective for threatened and endangered species (USFWS and

NMFS 2000). In 2015, USEPA drafted proposed selenium ambient chronic water quality criteria for the protection of aquatic life (Table C-15). The proposed criterion allows for multiple matrices to be evaluated (e.g., egg/ovaries, adult fish, and water); and, it takes into consideration that reproduction and early-life stages are the most sensitive to selenium toxicity. In addition, the criterion defaults to tissue selenium concentrations over aqueous selenium concentrations because aqueous concentrations may not reflect the principal exposure routes (e.g., food web and maternal transfer) (Entrix 2009; USEPA 2015).

Table C-15
U.S. Environmental Protection Agency Draft National Freshwater Selenium Ambient Water Quality Criterion for Aquatic Life

Media Type	Fish Tissue		Water Column	
Criterion Element	Egg/Ovary	Fish Whole Body or Muscle	Monthly Average Exposure	Intermittent Exposure
Magnitude	15.8 mg/kg (dry wt.)	8.0 mg/kg whole body or 11.3 mg/kg muscle (skinless, boneless filet) (dry wt.)	1.2 µg/L in lentic aquatic systems 3.1 µg/L in lotic aquatic systems	$WQC_{int} = \frac{WQC_{30\text{-}day} - C_{bkgrnd}(1 - f_{int})}{f_{int}}$
Duration	Instantaneous measurement	Instantaneous measurement	30 days	Number of days/month with an elevated concentration
Frequency	Never to be exceeded	Never to be exceeded	Not more than once in 3 years on average	Not more than once in 3 years on average

Notes:
From USEPA 2015. These draft criteria are presented to give a relative magnitude of selenium levels above which could pose risks to aquatic life. In addition, the criteria are presented as an example of the type of approach that could be used to assess selenium impacts to aquatic life.
µg/L = microgram per liter
WQC = Water Quality Criterion
wt. = weight

The proposed draft criterion for selenium is similar to other criteria and levels of concern determined by others. For example, the CVRWQCB water quality objectives for selenium are 5 µg/L and 2 µg/L in the San Joaquin River and Salt Slough, respectively. The draft USEPA aquatic life criterion presents 2 different concentrations because it considers the differences in selenium exposure and bioaccumulation rates of lentic and lotic systems. Based on laboratory toxicity tests, Hamilton and Wiedmeyer (1990) suggested that adverse effects for could occur between 3 and 5 µg/g in young salmon (5 g or less) and between 4 and

8 μg/g in older salmon (18 g or more). In a later review by Hamilton (2004), the author reported that no effects were typically not observed below 4 μg/g (whole body, dry weight) and suggested that the majority of the literature supports threshold starting around 4 μg/g. The environmental objective for selenium in the Stanislaus River should be re-evaluated, once the USEPA finalizes its criteria or studies reduce the uncertainty in selenium toxicology.

1.3.3.4 Nutrients

Nutrient environmental objectives for ammonia, nitrate, and nitrite toxicity are provided in Table C16.

Table C-16

Nutrient Toxicity Objectives for All Life Stages of Chinook Salmon and *O. mykiss*

Nitrogen Species	Maximum Average Continuous Concentration
Ammonia[1]	1.9 mg total NH_3-N/L @ pH 7.0 and 20°C (68°F)
Nitrate[2]	2 mg NO_3-N/L
Nitrite[3]	0.06 mg NO_2-N/L

Notes:
1 USEPA (2013) *Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater 2013*. Ammonia toxicity is temperature- and pH-dependent. Actual ammonia limits can be calculated using the following equation:

$$CCC = 0.8876 \times \left(\frac{0.0278}{1 + 10^{7.688-pH}} + \frac{1.1994}{1 + 10^{pH-7.688}}\right) \times \left(2.126 \times 10^{0.028 \times (20-MAX(T,7))}\right)$$

2 Camargo et al. (2005)
3 Russo et al. (1974)
– (Ammonia) NH_3 -N/L = milligrams of ammonium as nitrogen per liter
– (Nitrite) NO_2-N/L = milligrams of nitrite as nitrogen per liter
– (Nitrate) NO_3 – N/L = milligrams of nitrate as nitrogen per liter

USEPA (2013) has promulgated aquatic-life ambient water quality criteria for ammonia for the protection of sensitive species including salmonids. USEPA has not developed water quality criteria for protection from direct toxicity to fish or other aquatic-life for nitrate or nitrite, so the SEP relied on literature benchmarks for these constituents. Camargo et al. (2005) reviewed published data on nitrate toxicity to freshwater animals including invertebrates, fish, and amphibians and concluded that levels below 2 mg NO_3-N/L would be protective of the most sensitive species.

Nitrite toxicity occurs to salmonids at lower concentrations than for nitrate; for example, Westin (1974) found that the relative activity of nitrite was approximately 2000 times that of nitrate for Chinook fingerlings. Reviews of nitrite toxicity to fish found that salmonids, particularly *O. mykiss*, appear to be the most sensitive to nitrite toxicity (Lewis and Morris 1986; Smith and Williams 1974). In a series of toxicity tests to various sizes of *O. mykiss*, Russo et al. (1974) found that the nitrite 96-hour LC50's ranged from 0.19 to 0.39 mg NO_2-N/L. However, Smith and Williams (1974) found that even though yearling trout did not die at 0.15 mg/L, they were stresses and had statistically higher levels of methemoglobin than the controls. Westin (1974) suggested 0.12 mg/L nitrite as a maximum allowable concentration (based on 1/10 of 10-day LC10 for Chinook salmon); however, this concentration would likely not provide protection to against the sub-lethal effects observed at 0.15 mg/L in trout. Russo et al. (1974) observed zero mortality in *O. mykiss* exposed to 0.06 mg/L for 10 days. This concentration is likely a good initial safe benchmark for nitrite because they also found that LC50 values remained constant at exposures greater than 8 days.

The toxicity of ammonia, nitrate, and nitrite are highly dependent on other environmental factors. As mentioned earlier, these contaminants reduce the blood's ability to transport oxygen, so environments with lower dissolved oxygen increase the toxicity of these constituents (Lewis and Morris 1986; Thurston et al. 1981). Ammonia toxicity is highly dependent on temperature and pH, and as a result the water quality criterion is calculated using ambient temperature and pH levels (USEPA 2013). Similarly, data suggests that nitrite toxicity is negatively associated to chloride ions (Lewis and Morris 1986). Like the other stressors and environmental conditions considered by the SEP, nutrient toxicity to salmonids must consider multiple environmental factors during the evaluation.

The second category of nutrient environmental objective is ecological use impairments, which would include nutrient imbalances that result in a reduction of beneficial habitat for salmonids. Recent efforts for evaluating environmental impacts from nutrients have moved away from the strict application of a single nutrient concentration criterion across broad landscapes or watersheds (Tetra Tech 2006; USEPA 2000). These efforts were developed, in part, due to the fact that pre-defined nutrient limits may or may not result in eutrophication in all waterbodies. The evaluation of appropriate nutrient levels requires the evaluation of aquatic beneficial uses needing protection, classification of waterbodies by type and trophic status, as well as consideration of other external environmental factors (Tetra Tech 2006; USEPA 2000).

The USEPA (2000) has provided guidance for developing nutrient criteria for rivers and streams. The generalized environmental conditions which define oligotrophic, mesotrophic, and eutrophic lotic systems are displayed in Table C-17. The San Diego Regional Water Quality Control Board adopted water quality objectives for nitrate (10 mg/L), total nitrogen (1.0 mg/L), and total phosphorus (0.1 mg/L), not to be exceeded 10% of the time, as part of a Rainbow Creek nutrient TMDL (SDRWQCB 2006). These objectives are waterbody specific, but they can be used as a general level of nutrients that can cause impairments to aquatic-life beneficial uses. Nutrient concentrations as well as other environmental conditions (e.g., DO and primary productivity metrics) should be assessed in combination to determine ecological support for salmonid life stages.

Table C-17
Suggested Boundaries for Trophic Classifications of Lotic Systems from USEPA (2000)

Variable (Units)	Oligotrophic to Mesotrophic Boundary	Mesotrophic to Eutrophic Boundary
Mean benthic chlorophyll (mg/m^2)	20	70
Maximum benthic chlorophyll (mg/m^2)	60	200
Sestonic chlorophyll (µg/L)	10	30
Total nitrogen (µg/L)	700	1500
Total phosphorus (µg/L)	25	75

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APPENDIX D
ESHE MODEL DESCRIPTION

Pending

APPENDIX E
LONG-TERM STRESSOR PRIORITIES FOR FALL-RUN AND SPRING-RUN CHINOOK SALMON AND STEELHEAD

Appendix E
Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Fall-run Chinook Salmon — Stressor Response Prioritization (Long Term/Coarse Scale)

Life History Stage	Stressor	Score Magnitude	Cert	Total	Priority	Conservation Measure Type
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Compression of the Rearing and Migration Window - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Egg Incubation	Inadequate Incubation Conditions - Multiple Factors	3	4	7	A-2	Priority 2 Action - and associated monitoring
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Multiple Factors	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Lack of suitable spawning habitat - Multiple Factors	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Interactions with hatchery fish and other runs - Multiple Factors	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Multiple Factors	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Holding	Lack of Suitable Habitat - Multiple Factors	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Multiple Factors	2	3	5	A-4	Priority 4 Action - with adaptive management and monitoring
Adult Spawning	Compression of the Spawning window - Multiple Factors	4	2	6	R-1	Priority 1 Research - to inform action design
Adult Holding	Loss of Fecundity - Multiple Factors	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream - Multiple Factors	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Multiple Factors	3	1	4	R-3	Priority 3 Research - to confirm need for action

Fall-run Chinook Salmon — Stressor Response Prioritization (Long Term/Fine Scale)

Life History Stage	Stressor	Score Magnitude	Cert	Total	Priority	Conservation Measure Type
Juvenile Rearing/ Migration	Coarse Sediment Input	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions- Temperature	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Compression of the Rearing and Migration Window - Temperature	4	4	8	A-1	Priority 1 Action - and associated monitoring
Egg Incubation	Inadequate Incubation Conditions - Temperature	3	4	7	A-2	Priority 2 Action - and associated monitoring
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Temperature	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Lack of suitable spawning habitat - Temperature	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Interactions with hatchery fish and other runs - Hatchery	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Interactions with hatchery fish and other runs - Run Segregation	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of fitness/ genetic maladaptation - Hatchery Introgression	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Velocity	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Contaminants/ Toxins	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Temperature	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Holding	Lack of Suitable Habitat - Temperature	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Adult Spawning	Lack of suitable spawning habitat - Spatial Distribution	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring

Appendix E
Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Life History Stage	Stressor	Score Magnitude	Cert	Total	Priority	Conservation Measure Type
Juvenile Rearing/ Migration	Compression of the Rearing and Migration Window - DO	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Depth	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Cover	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Depth	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Contaminants/ Toxins	2	3	5	A-4	Priority 4 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Temperature	2	3	5	A-4	Priority 4 Action - with adaptive management and monitoring
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - DO	4	2	6	R-1	Priority 1 Research - to inform action design
Adult Spawning	Compression of the Spawning window - Temperature	4	2	6	R-1	Priority 1 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Habitat Distribution	4	2	6	R-1	Priority 1 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Temperature	4	2	6	R-1	Priority 1 Research - to inform action design
Adult Holding	Disease	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Holding	Loss of Fecundity - Temperature	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream - Temperature	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream - Contaminants/ Attraction Flows	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream -DO	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Attraction Flow	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Contaminants/ Toxins	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Spawning	Coarse Sediment Input	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Spawning	Lack of suitable spawning habitat - Contaminants	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Disease	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Cover	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Velocity	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Turbidity	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration		3	1	4	R-3	Priority 3 Research - to confirm need for action
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) -Attraction flows	3	1	4	R-3	Priority 3 Research - to confirm need for action
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Prey Density	3	1	4	R-3	Priority 3 Research - to confirm need for action
Juvenile Rearing/ Migration	Predator Density	3	1	4	R-3	Priority 3 Research - to confirm need for action
Adult Holding	Lack of Suitable Habitat - Contaminants	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Lack of Suitable Habitat - Cover	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Loss of Fecundity - Contaminants	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Poaching	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Predator Density	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Spawning	Disease	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Spawning	Poaching	2	2	4	R-3	Priority 3 Research - To inform action design
Egg Incubation	Inadequate Incubation Conditions - Pesticides	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Turbidity	2	2	4	R-3	Priority 3 Research - To inform action design

Appendix E
Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Life History Stage	Stressor	Score Magnitude	Cert	Total	Priority	Conservation Measure Type
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Velocity	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Turbidity	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Velocity	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Passable physical barriers (including low water)	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - DO	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Temperature	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Spawning	Compression of the Spawning window - DO	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Spawning	Lack of suitable spawning habitat -DO	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Egg Incubation	Inadequate Incubation Conditions - Fine Sediments	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Egg Incubation	Inadequate Incubation Conditions - Flow Fluctuation, Redd Scour	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Cover	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Prey Density	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Holding	Lack of Suitable Habitat - Depth	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Lack of Suitable Habitat - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Lack of Suitable Habitat - Velocity	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Loss of Fecundity - Depth	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Loss of Fecundity - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Loss of Fecundity - Velocity	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Lack of suitable spawning habitat - Cover	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Lack of suitable spawning habitat - Depth	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Lack of suitable spawning habitat - Velocity	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Contaminants/ Toxins	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Contaminants/ Toxins	1	1	2	R-5	Priority 5 Research - to understand magnitude
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Poaching	1	1	2	R-5	Priority 5 Research - to understand magnitude
Adult Spawning	Predator Density	1	1	2	R-5	Priority 5 Research - to understand magnitude
Juvenile Rearing/ Migration	Lack of suitable migratory cues - DO	1	1	2	R-5	Priority 5 Research - to understand magnitude
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Depth	1	1	2	R-5	Priority 5 Research - to understand magnitude
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - DO	1	1	2	R-5	Priority 5 Research - to understand magnitude
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Turbidity	1	1	2	R-5	Priority 5 Research - to understand magnitude
Adult Holding	Coarse Sediment Input	1	3	4	T-1	Priority 1 Monitoring (General/ Baseline) - to track magnitude/ ensure no action is warranted

Appendix E
Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Life History Stage	Stressor	Score Magnitude	Cert	Total	Priority	Conservation Measure Type
Egg Incubation	Inadequate Incubation Conditions - Flow Fluctuation, Redd Dewatering	1	3	4	T-1	Priority 1 Monitoring (General/ Baseline) - to track magnitude/ ensure no action is warranted
Egg Incubation	Inadequate Incubation Conditions - Contaminants/ Toxins	1	4	5	T-2	Priority 2 Monitoring (General/ Baseline) -to track magnitude
Egg Incubation	Inadequate Incubation Conditions - DO	1	4	5	T-2	Priority 2 Monitoring (General/ Baseline) -to track magnitude

Spring-run Chinook Salmon – Stressor Response Prioritization (Long Term/Coarse Scale)

Life History Stage	Stressor	Score Magnitude	Certainty	Total	Priority	Conservation Measure Type
Adult Holding	Lack of Suitable Habitat - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Egg Incubation	Inadequate Incubation Conditions - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Adult Spawning	Lack of suitable spawning habitat - Multiple Factors	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Interactions with hatchery fish and other runs - Multiple Factors	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Multiple Factors	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Multiple Factors	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Multiple Factors	4	2	6	R-1	Priority 1 Research - to inform action design
Adult Spawning	Compression of the Spawning window - Multiple Factors	4	2	6	R-1	Priority 1 Research - to inform action design
Adult Holding	Loss of Fecundity - Multiple Factors	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Multiple Factors	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Compression of the Rearing and Migration Window - Multiple Factors	3	2	5	R-2	Priority 2 Research - to inform action design

Spring-run Chinook Salmon – Stressor Response Prioritization (Long Term/Coarse Scale)

Life History Stage	Stressor	Score Magnitude	Certainty	Total	Priority	Conservation Measure Type
Adult Holding	Lack of Suitable Habitat - Temperature	4	4	8	A-1	Priority 1 Action - and associated monitoring
Egg Incubation	Inadequate Incubation Conditions - Temperature	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Coarse Sediment Input	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Velocity	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions- Temperature	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Velocity	4	4	8	A-1	Priority 1 Action - and associated monitoring
Adult Spawning	Coarse Sediment Input	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Lack of suitable spawning habitat - Spatial Distribution	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring

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Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Life History Stage	Stressor	Score Magnitude	Certainty	Total	Priority	Conservation Measure Type
Adult Spawning	Lack of suitable spawning habitat - Temperature	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Interactions with hatchery fish and other runs - Hatchery	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Interactions with hatchery fish and other runs - Run Segregation	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Velocity	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Contaminants/ Toxins	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Temperature	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Compression of the Rearing and Migration Window - Temperature	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of fitness/ genetic maladaptation - Hatchery Introgression	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Depth	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Contaminants/ Toxins	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Cover	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Depth	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Temperature	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Contaminants/ Toxins	2	3	5	A-4	Priority 4 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Temperature	2	3	5	A-4	Priority 4 Action - with adaptive management and monitoring
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Attraction Flow	4	2	6	R-1	Priority 1 Research - to inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Temperature	4	2	6	R-1	Priority 1 Research - to inform action design
Adult Spawning	Compression of the Spawning window - Temperature	4	2	6	R-1	Priority 1 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Habitat Distribution	4	2	6	R-1	Priority 1 Research - to inform action design
Adult Holding	Disease	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Holding	Loss of Fecundity - Contaminants	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Holding	Loss of Fecundity - Temperature	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Holding	Predator Density	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - DO	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Temperature	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) -Attraction flows	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - DO	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Spawning	Lack of suitable spawning habitat - Contaminants	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Disease	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Cover	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Turbidity	3	2	5	R-2	Priority 2 Research - to inform action design

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Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Life History Stage	Stressor	Score Magnitude	Certainty	Total	Priority	Conservation Measure Type
Adult Holding	Lack of Suitable Habitat - Contaminants	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Lack of Suitable Habitat - Cover	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Lack of Suitable Habitat - DO	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Poaching	2	2	4	R-3	Priority 3 Research - To inform action design
Egg Incubation	Inadequate Incubation Conditions - Pesticides	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Turbidity	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Velocity	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Turbidity	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Predator Density	3	1	4	R-3	Priority 3 Research - To inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Contaminants/ Toxins	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Passable physical barriers (including low water)	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Contaminants/ Toxins	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Poaching	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Spawning	Compression of the Spawning window - DO	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Spawning	Lack of suitable spawning habitat -DO	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Egg Incubation	Inadequate Incubation Conditions - Fine Sediments	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Egg Incubation	Inadequate Incubation Conditions - Flow Fluctuation, Redd Scour	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Prey Density	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Cover	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Prey Density	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Holding	Lack of Suitable Habitat - Depth	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Lack of Suitable Habitat - Velocity	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Loss of Fecundity - Depth	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Loss of Fecundity - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Loss of Fecundity - Velocity	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Disease	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Lack of suitable spawning habitat - Cover	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Lack of suitable spawning habitat - Depth	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Lack of suitable spawning habitat - Velocity	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Poaching	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Predator Density	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Juvenile Rearing/ Migration	Compression of the Rearing and Migration Window - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted

Appendix E
Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Life History Stage	Stressor	Score Magnitude	Certainty	Total	Priority	Conservation Measure Type
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Juvenile Rearing/ Migration	Lack of suitable migratory cues - DO	1	1	2	R-5	Priority 5 Research - to understand magnitude
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Depth	1	1	2	R-5	Priority 5 Research - to understand magnitude
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Turbidity	1	1	2	R-5	Priority 5 Research - to understand magnitude
Adult Holding	Coarse Sediment Input	1	3	4	T-1	Priority 1 Monitoring (General/ Baseline) - to track magnitude/ ensure no action is warranted
Egg Incubation	Inadequate Incubation Conditions - Flow Fluctuation, Redd Dewatering	1	3	4	T-1	Priority 1 Monitoring (General/ Baseline) - to track magnitude/ ensure no action is warranted
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - DO	1	3	4	T-1	Priority 1 Monitoring (General/ Baseline) - to track magnitude/ ensure no action is warranted
Egg Incubation	Inadequate Incubation Conditions - Contaminants/ Toxins	1	4	5	T-2	Priority 2 Monitoring (General/ Baseline) -to track magnitude
Egg Incubation	Inadequate Incubation Conditions - DO	1	4	5	T-2	Priority 2 Monitoring (General/ Baseline) -to track magnitude

Appendix E
Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Steelhead – Stressor Response Prioritization (Long Term/Coarse Scale)

Life History Stage	Stressor	Score Mag	Cert	Total	Priority	Conservation Measure Type
Adult Holding	Lack of Suitable Habitat - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Egg Incubation	Inadequate Incubation Conditions - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Multiple Factors	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Multiple Factors	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Spawning	Lack of suitable spawning habitat - Multiple Factors	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Multiple Factors	3	1	4	R-3	Priority 3 Research - To inform action design
Adult Spawning	Compression of the Spawning window - Multiple Factors	3	1	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Compression of the Rearing and Migration Window - Multiple Factors	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Multiple Factors	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Multiple Factors	1	4	5	T-2	Priority 2 Monitoring (General/ Baseline) -to track magnitude

Steelhead – Stressor Response Prioritization (Long Term/Fine Scale)

Life History Stage	Stressor	Score Mag	Cert	Total	Priority	Conservation Measure Type
Adult Holding	Lack of Suitable Habitat - Temperature	4	4	8	A-1	Priority 1 Action - and associated monitoring
Egg Incubation	Inadequate Incubation Conditions - Temperature	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Velocity	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Coarse Sediment Input	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Velocity	4	4	8	A-1	Priority 1 Action - and associated monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Contaminants/ Toxins	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Velocity	4	3	7	A-2	Priority 2 Action - with adaptive management and monitoring
Adult Holding	Coarse Sediment Input	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Adult Spawning	Coarse Sediment Input	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Depth	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Cover	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Depth	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Contaminants/ Toxins	3	3	6	A-3	Priority 3 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions- Temperature	2	4	6	A-3	Priority 3 Action - with associated Monitoring
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Temperature	2	4	6	A-3	Priority 3 Action - with associated Monitoring
Adult Spawning	Lack of suitable spawning habitat -DO	2	3	5	A-4	Priority 4 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Contaminants/ Toxins	2	3	5	A-4	Priority 4 Action - with adaptive management and monitoring
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Temperature	4	2	6	R-1	Priority 1 Research - to inform action design
Adult Holding	Lack of Suitable Habitat - Contaminants	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Spawning	Lack of suitable spawning habitat - Temperature	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Spawning	Lack of suitable spawning habitat - Contaminants	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Spawning	Lack of suitable spawning habitat - Spatial Distribution	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Spawning	Interactions with hatchery fish and other runs - Hatchery	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Predator Density	3	2	5	R-2	Priority 2 Research - to inform action design

Appendix E
Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Life History Stage	Stressor	Score Mag	Cert	Total	Priority	Conservation Measure Type
Juvenile Rearing/ Migration	Disease	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Cover	3	2	5	R-2	Priority 2 Research - to inform action design
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Depth	3	2	5	R-2	Priority 2 Research - to inform action design
Adult Holding	Lack of Suitable Habitat - Cover	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Predator Density	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Disease	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Holding	Poaching	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Temperature	3	1	4	R-3	Priority 3 Research - To inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Contaminants/ Toxins	3	1	4	R-3	Priority 3 Research - To inform action design
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Attraction Flow	3	1	4	R-3	Priority 3 Research - To inform action design
Adult Spawning	Predator Density	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Spawning	Compression of the Spawning window - Temperature	3	1	4	R-3	Priority 3 Research - To inform action design
Egg Incubation	Inadequate Incubation Conditions - Pesticides	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Compression of the Rearing and Migration Window - Temperature	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Compression of the Rearing and Migration Window - DO	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Turbidity	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Turbidity	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Turbidity	2	2	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of suitable migratory cues - Prey Density	3	1	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of fitness/ genetic maladaptation - Hatchery Introgression	3	1	4	R-3	Priority 3 Research - To inform action design
Juvenile Rearing/ Migration	Lack of Suitable Habitat - Prey density	2	2	4	R-3	Priority 3 Research - To inform action design
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Temperature	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - DO	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Attraction flows	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - DO	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Spawning	Disease	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Spawning	Compression of the Spawning window - DO	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Egg Incubation	Inadequate Incubation Conditions - Fine Sediments	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Egg Incubation	Inadequate Incubation Conditions - Flow Fluctuation, Redd Scour	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - Prey Density	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - Prey Density	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Cover	2	1	3	R-4	Priority 4 Research - to evaluate need for action
Adult Holding	Lack of Suitable Habitat - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Lack of Suitable Habitat - Velocity	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Holding	Lack of Suitable Habitat - Depth	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted

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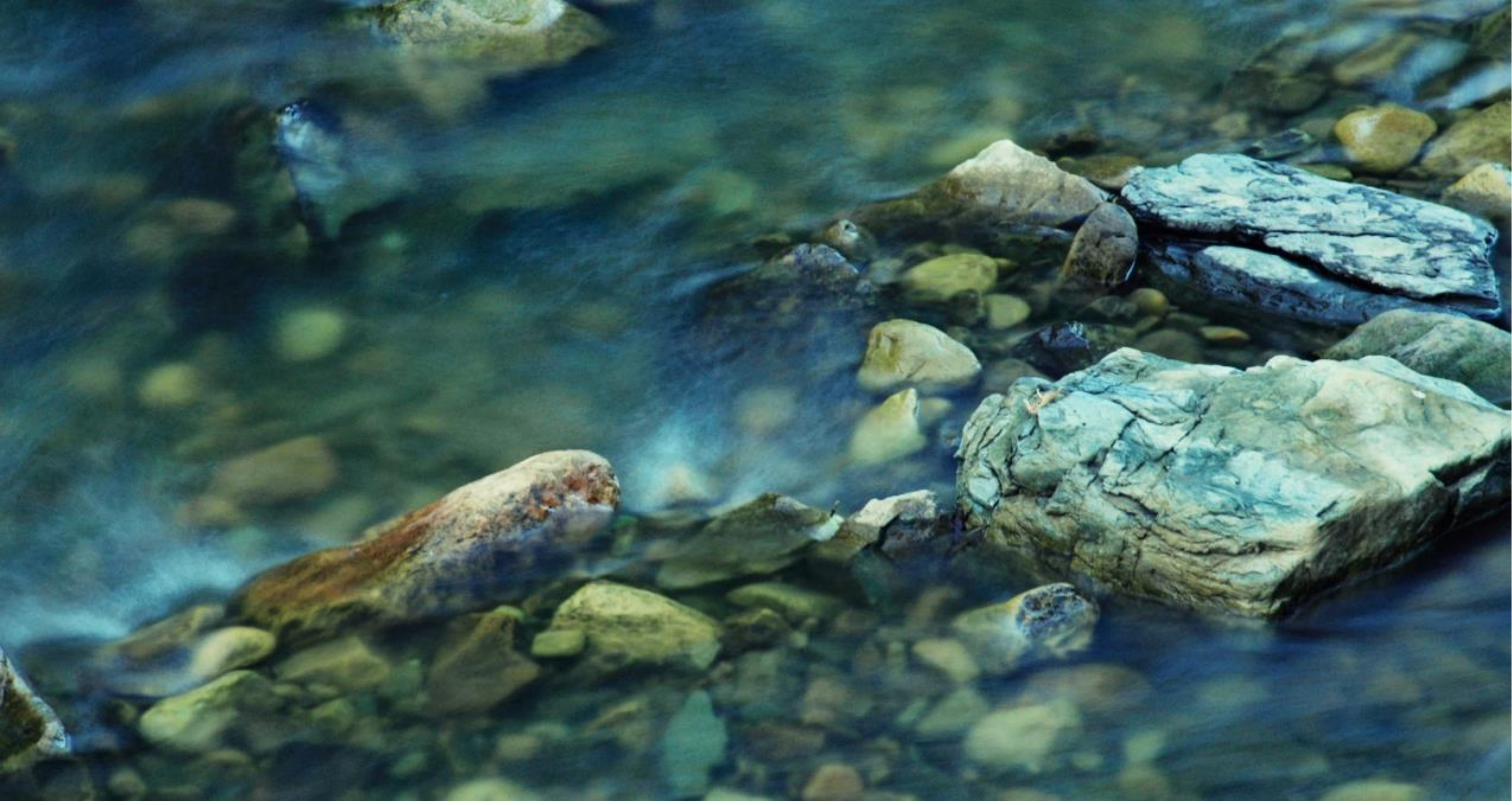
Long-term Stressor Response Priorities for Fall-run and Spring-run Chinook Salmon and Steelhead

Life History Stage	Stressor	Score Mag	Cert	Total	Priority	Conservation Measure Type
Adult Spawning	Lack of suitable spawning habitat - Velocity	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Lack of suitable spawning habitat - Depth	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Lack of suitable spawning habitat - Cover	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Spawning	Poaching	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Juvenile Rearing/ Migration	Lack of Suitable Rearing Habitat - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Juvenile Rearing/ Migration	Lack of suitable migratory conditions - DO	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Velocity	1	2	3	R-5	Priority 5 Research - to confirm that action is not warranted
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Contaminants/ Toxins	1	1	2	R-5	Priority 5 Research - to understand magnitude
Adult Migration	Significant Delay and/or Failure to Reach Natal Stream (direct effects) - Poaching	1	1	2	R-5	Priority 5 Research - to understand magnitude
Juvenile Rearing/ Migration	Lack of suitable migratory cues - DO	1	1	2	R-5	Priority 5 Research - to understand magnitude
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - DO	1	1	2	R-5	Priority 5 Research - to understand magnitude
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Turbidity	1	1	2	R-5	Priority 5 Research - to understand magnitude
Adult Migration	Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease) - Passable physical barriers (including low water)	1	3	4	T-1	Priority 1 Monitoring (General/ Baseline) - to track magnitude/ ensure no action is warranted
Egg Incubation	Inadequate Incubation Conditions - Flow Fluctuation, Redd Dewatering	1	3	4	T-1	Priority 1 Monitoring (General/ Baseline) - to track magnitude/ ensure no action is warranted
Egg Incubation	Inadequate Incubation Conditions - DO	1	4	5	T-2	Priority 2 Monitoring (General/ Baseline) -to track magnitude
Egg Incubation	Inadequate Incubation Conditions - Contaminants/ Toxins	1	4	5	T-2	Priority 2 Monitoring (General/ Baseline) -to track magnitude
Juvenile Rearing/ Migration	Lack of suitable over-summering habitat - Temperature	1	4	5	T-2	Priority 2 Monitoring (General/ Baseline) -to track magnitude



November 2016
SEP Group

Conservation Planning Foundation for Restoring Chinook Salmon (*Oncorhynchus Tshawytscha*) and *O. mykiss* in the Stanislaus River

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November 2016

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ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
7DADM	7-day average of daily maximum temperature
AFRP	Anadromous Fish Restoration Plan
BOD	biological oxygen demand
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
CFR	Code of Federal Regulations
CRR	cohort replacement rate
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
Delta	Sacramento-San Joaquin Delta
DO	dissolved oxygen
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWSC	Deep Water Ship Channel
ELS	early-life stages
ESA	Endangered Species Act
ESHE	Emigrating Salmonid Habitat Estimation
Estuary	San Francisco Bay/Sacramento-San Joaquin Delta Estuary
ESU	evolutionarily significant unit
F&G	California Fish and Game
FL	fork length
FR	Federal Register
ft	foot; feet
ft/s	feet per second
HSI	habitat suitability index
in	inch
IULT	Incipient Upper Lethal Temperatures
m	meter
m/s	meter per second
m^2	square meter

maf	million acre feet
mg/L	milligram per liter
mm	millimeter
NMFS	National Marine Fisheries Service
OPP	Office of Pesticide Programs
pHOS	proportion of hatchery-origin spawners
PIT	passive integrated transponder
Porter-Cologne Act	Porter-Cologne Water Quality Control Act
RBDD	Red Bluff Diversion Dam
RM	river mile
RST	rotary screw trap
S.M.A.R.T.	Specific, Measureable, Achievable, Relevant to overarching goals, and Time-bound
SEP	Scientific Evaluation Process
SJTSP	San Joaquin Tributary Settlement Process
steelhead	California Central Valley Steelhead
SWRCB	State Water Resources Control Board
USDOI	U.S. Department of the Interior
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VSP	viable salmonid population
WDOE	Washington State Department of Ecology
WQC Plan	Bay-Delta Water Quality Control Plan
YOY	young-of-the-year

TECHNICAL SUMMARY

FOREWORD

This document briefly summarizes the *Conservation Planning Foundation for Restoring Chinook Salmon (Oncorhynchus Tshawytscha) and O. mykiss in the Stanislaus River* (report) and highlights the key products and conclusions developed through the Scientific Evaluation Process (SEP). Please refer to the report for more detailed information on the methods, rational, and scientific justification for these products as well as to view the cited literature.

INTRODUCTION

Salmon and steelhead populations in the San Joaquin River basin were once some of the largest in California. Historically, the San Joaquin River and its tributaries supported both spring- and fall-runs of Chinook salmon and Central Valley steelhead. As recently as 1940, spring-run Chinook were the most abundant Chinook run in the San Joaquin system, ascending and occupying the higher elevation streams fed by snowmelt. Over the past century, extensive water storage development throughout the San Joaquin River watershed has resulted in a large proportion of flow being diverted from river channels, thus degrading spawning and rearing habitats and blocking access to historical spawning and rearing reaches. This habitat degradation due to damming, diversions, and levee construction has led to significant declines in Chinook salmon and steelhead populations (Figure TS-1). Spring-run Chinook salmon were considered extirpated from the San Joaquin River basin for decades; however, recently, spring migrating Chinook salmon have been observed in the Stanislaus and Tuolumne rivers.

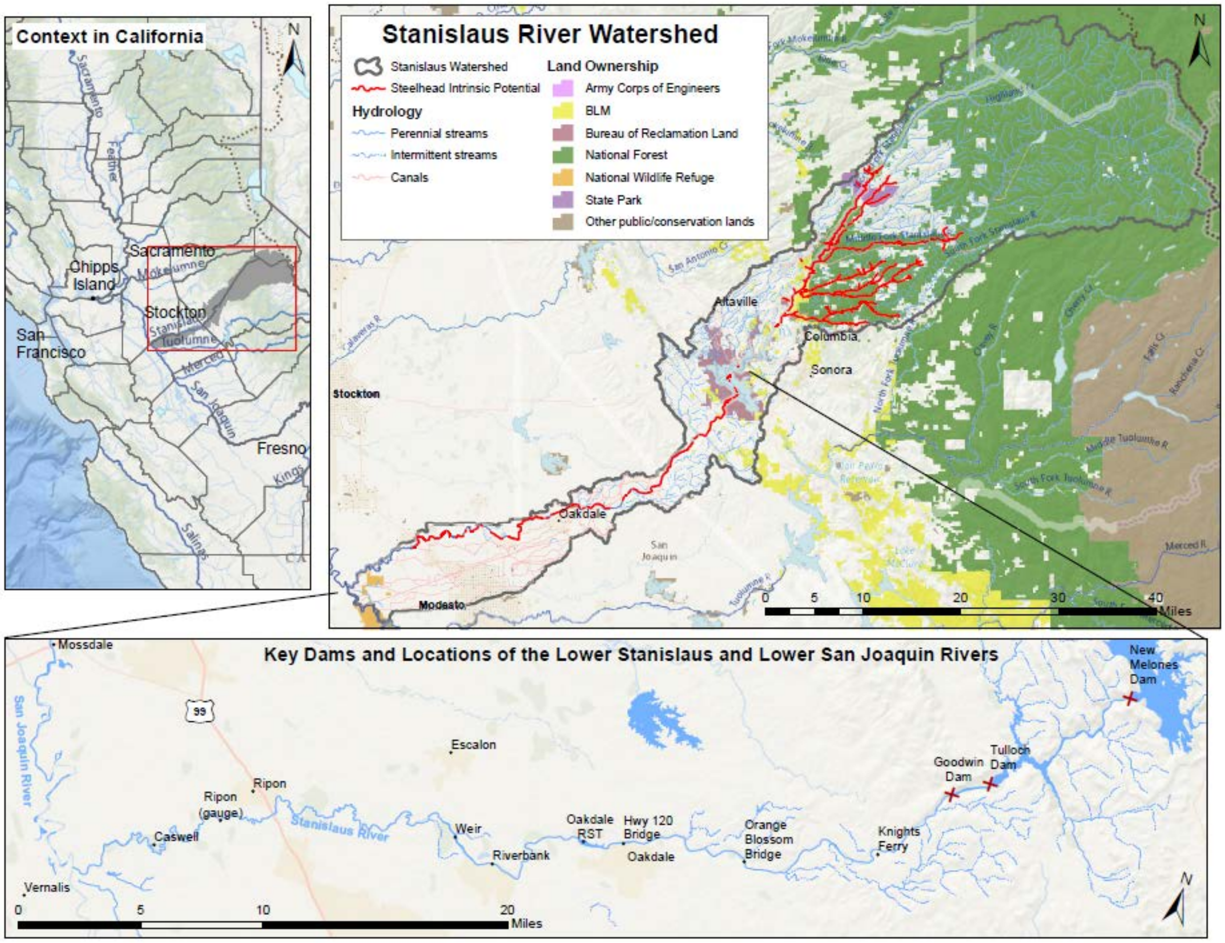

Figure TS-1
Key Dams and Features of the Lower Stanislaus River

Over the past few decades, efforts have been made to reverse and restore the declining health of riverine and estuarine habitats in the Central Valley and, in particular, their anadromous fish fauna. Since at least 1988, with the adoption of Sections 6901 and 6902 of California Fish and Game Code (and arguably back to 1915 with Fish and Game Code Section 5937), numerous policies, laws, and regulations have called for the restoration of anadromous fish populations.

However, the San Joaquin River and its tributaries continue to suffer from declining fish populations, stream health, and overall watershed condition. This is partially attributable to the lack of common vision of conservation success among resource agencies, conservation groups, and water districts. Many policies focus on particular Central Valley salmonid stocks and do not define desired outcomes for other stocks. For example, Central Valley spring-run Chinook salmon and Central Valley steelhead distinct population segments were listed under the Federal Endangered Species Act (ESA) in 1999 and 1998, respectively. The National Marine Fisheries Service determined that listing of fall-run Chinook salmon under the ESA was not warranted, though the species was listed as of special concern in 2004. The doubling of anadromous salmonid populations is required under the State Water Resources Control Board (SWRCB) Bay-Delta Water Quality Control Plan (WQC Plan), the California Fish and Game Code Sections 6900-6924 (by year 2000), and the Central Valley Project Improvement Act (CVPIA; by the year 2002). However, specific restoration targets for the San Joaquin watershed and its tributaries developed under the Anadromous Fish Restoration Plan (AFRP) in 2001 were only for fall-run Chinook salmon and not spring-run or steelhead.

The lack of restoration success in the San Joaquin River and its major tributaries (the Stanislaus, Tuolumne, and Merced rivers) is widely recognized (e.g., proposed update of the WQC Plan, CVPIA progress toward doubling of anadromous fish, National Marine Fisheries Service (NMFS) Recovery Plan for salmon and steelhead). As a result, a large group of stakeholders convened the San Joaquin Tributary Settlement Process (SJTSP) in an effort to explore resolutions to long-standing ecosystem and water management issues. Participants in this process originally discussed a set of actions for the overall system, but, due to the size and complexities of the overall San Joaquin River basin and a lack of shared understanding of the key barriers to restoration success, the stakeholders soon realized that science-based methods should be used to establish desired outcomes (including goals, biological objectives, and environmental objectives) in each of three major tributaries to the San Joaquin River and the lower San Joaquin mainstem. Conservation proposals would then be evaluated in the context of those desired outcomes. The SJTSP stakeholders decided to focus first on the Stanislaus River.

Scientists with appropriate expertise from the California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation, NMFS, American Rivers, The Bay Institute, Trout Unlimited, and The Nature Conservancy participated in collaborative partnership called the SEP. The SEP focused on defining a vision of restoration success for three of the Stanislaus River's native fish populations: fall-run Chinook salmon, spring-run Chinook salmon, and *Oncorhynchus mykiss* (both resident and migratory forms).

The SEP partnership developed a vision of restoration success that expresses and harmonizes the policies listed above into science-based and achievable goals and objectives, and prioritizes barriers (stressors) to these goals and objectives that limit attainment of these desired conditions. This vision of success provides the framework for developing, evaluating, and implementing appropriate strategies for conservation and restoration. Without such a framework, science-based adaptive management cannot be applied to solve complex ecosystem and water management issues in this system. Development of the SEP vision also resulted in a common scientific foundation that will be useful for all parties pursuing a comprehensive approach to restoring native species and habitats in the San Joaquin River basin and in establishing a framework for addressing relevant regulatory processes that include the following:

- The SWRCB's update of the WQC Plan, as called for under both the state Porter-Cologne Water Quality Control Act and the federal Clean Water Act, and
- Federal Energy Regulatory Commission relicensing proceedings.

PURPOSE

The overarching purpose of the SEP effort is to restore conditions in the lower San Joaquin River and its tributaries that will support sustainable native fish populations and other living resources as follows:

- Articulating a clear, scientifically justified expression of policy guidance regarding the desired status of fall-run and spring-run Chinook salmon and *O. mykiss* (both resident (rainbow trout) and anadromous [steelhead] forms) in the Stanislaus River and larger San Joaquin River basin;
- Providing well-documented and transparent technical guidance on the conditions necessary to attain that vision; and
- Providing a foundation for evaluating the effectiveness of proposed actions to achieve the conditions necessary to realize the vision.

APPROACH AND SCOPE

The SEP approach to conservation planning begins by describing a vision of conservation success that integrates and harmonizes a suite of policy goals and objectives, which are described in laws, policies, and plans. This vision is articulated as specific outcomes that are grounded in the best available science. Too often, conservation planning begins with identifying and describing a suite of actions without first defining the problem that the actions are meant to solve. Taking these first important steps of defining goals and objectives provides a transparent basis for evaluating implications of and trade-offs among proposed actions, implementing actions efficiently and within a specific timeframe, and managing actions towards attainment of desired conditions.

The report translates policy guidance regarding desired ecological conditions in the rivers of California's Central Valley into its local expression on the Stanislaus River watershed; the products described in the report reflect biological conditions on the Stanislaus River that are consistent with and supportive of river management and restoration policies for the Central Valley as a whole. Desired outcomes for river restoration and fisheries management were informed by and interpreted through a set of filters that allowed the SEP Group to provide a tangible set of desired biological restoration outcomes. These desired outcomes were used to define quantitative metrics that the group determined to be representative of a restored river ecosystem. As a result, the SEP Group's products do not simply serve one law (e.g., ESA), nor do they merely state CVPIA goals for doubling of anadromous fish populations. Rather, the vision describes conditions on the Stanislaus River that support outcomes that are in line with the range of relevant public policy regarding management of Central Valley fish populations and water quality.

Policy Scope – The first of these filters, the "policy scope," is described as the various laws, regulations, and policy targets that are relevant to ecological management and restoration of Central Valley salmonid populations and water quality. These policies often state desired outcomes in terms that require more complete and specific articulation in order to develop a tangible set of outcomes for the Stanislaus River. For example, while none of these policies describes the need to restore and maintain intra-population life history diversity among salmon, it is well established in the scientific literature that such diversity is essential to achieving any of the desired conditions that are specified in existing policy (e.g., fish in good condition or doubling of anadromous fish populations).

Biological Scope – The biological scope for the report incorporates all salmonids native to the Stanislaus River watershed, including fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss*. Restoration of viable and fishable salmonid populations is a goal of California and national public policy, and many components of the policy scope identify desired outcomes for at least one salmon population or salmon populations in general. However, as described above, the policy scope description of desired conditions for salmonid populations is fragmented. Considering each of the native salmonid populations, both alone and collectively, allowed the SEP Group to develop a unified vision for restoration of the Stanislaus River and synthesize policy imperatives that might otherwise lead to conflicting or counter-productive outcomes. Also, the wealth of available research and monitoring data on these species enabled identification of tangible goals and measureable objectives for salmonid restoration.

For each focal salmonid population, restoration and maintenance of self-sustaining, fishable populations requires attaining adequate levels of several population viability parameters, including abundance, productivity (population growth rates), life history and genetic diversity, and spatial distribution. Collectively these are known as viable salmon population criteria (VSP criteria). Although the VSP criteria point to separate outcomes that are independently measureable, they are interdependent (e.g., acceptable levels of life history and genetic diversity require suitable productivity and abundance in the long term). Different temporal and spatial scales are relevant for each VSP criteria; as a result, the emphasis on particular VSP criteria changes as one considers different geographic scopes and time frames.

When thinking about restoration of the Stanislaus River system, there are some shortcomings to focusing on salmonids. For example, salmon are among the hardiest and most successful fish species in the watersheds they occupy; thus, ecosystem conditions that support restoration of these species may not be protective enough for other sensitive fish and aquatic species (many of which are also covered by elements of the policy scope).

Nevertheless, the SEP Group expects that restoring watersheds for salmonids will provide ancillary benefit to other native species and desirable ecosystem processes.

Geographic Scope – Goals and objectives for these VSP criteria were defined to the extent that these could be addressed in whole or in large part through actions taken within the Stanislaus River watershed. Many elements of the policy scope describe desired outcomes for salmonids of the Central Valley (or California) as a whole. For migratory species like salmon, such outcomes can only be attained if they are supported by environmental conditions across the geographies these fish traverse during their life cycles. For example, adverse conditions in any one habitat could affect the attainment of desired outcomes for abundance identified in elements of the policy scope. The SEP's products articulate these larger policy targets in terms that can be managed by actions on the local scale. Accordingly, the SEP Group focused the planning effort on the San Joaquin watershed and the Stanislaus River, in particular, and described a specific set of conditions that are largely controlled locally and can be modified by local actions.

For the Stanislaus River-specific scope of this effort, the SEP Group described desired outcomes of the VSP criteria that could be controlled by in-river conditions. For example, abundance targets for anadromous populations (fall- and spring-run Chinook salmon and *O. mykiss*) were not specifically defined at the river-specific scale because abundance is not completely controlled by conditions in the Stanislaus River or any one habitat that salmonids occupy during their life cycle. Also, for each focal salmon species, restoring a population on the Stanislaus River would improve Central Valley salmonid viability simply by adding to or strengthening the larger Central Valley spawning population. As a result, no specific objectives for increasing spatial extent outside of the Stanislaus River were included. Rather, the report describes in detail the desired outcomes for the remaining VSP criteria such as productivity (stage-to-stage survival rates in fresh water), juvenile life history diversity (size at and timing of migration), and genetic interactions with other runs and hatchery fish in the Stanislaus River.

This SEP focus on improvements needed in the Stanislaus River and lower San Joaquin River segregates responsibility for achieving overall policy objectives into manageable units. As a result, responsibility for restoration success (attainment of locally relevant goals and specific objectives) can be allocated to parties that can take conservation action on the Stanislaus River. The responsibilities of stakeholders specific to the Stanislaus River environment are independent of the success or failure of restoration/management efforts in the Sacramento-San Joaquin Delta, San Francisco Bay, or the Pacific Ocean. This approach disentangles the improvements needed on the Stanislaus River from those needed elsewhere and thus facilitates local action.

The SEP Group did not develop or evaluate conservation actions that could be taken on the Stanislaus River to improve conditions for native salmonid populations. Rather, the group focused on foundational elements needed to understand the nature and magnitude of challenges to restoring target populations; these elements are also essential to managing restoration activities in an adaptive management context. By developing goals and objectives (biological and environmental) and by ranking and prioritizing the barriers that prevent attainment of those goals and objectives (stressors), the SEP Group sought to provide the design criteria for subsequent conservation planning and the benchmarks against which to prioritize, implement, and adjust conservation actions adaptively.

LOGIC CHAIN

The report follows a structured approach to developing a framework for prioritizing conservation actions that are predicted to achieve measureable outcomes from the VSP criteria. Some restoration programs fail to evaluate the effects of actions on their fundamental objective, in part because they fail to express that objective in specific and measureable terms. To prevent this, the SEP Group initiated a logic chain approach to clearly articulate the linkages between desired outcomes and the specific conditions that are hypothesized to lead to such outcomes. Articulating explicit, quantitative biological objectives provides a framework for the following:

- Evaluating potential conservation measures;
- Measuring the success of conservation measures after implementation; and
- Adjusting the conservation strategy through time to attain desired outcomes based on information gained from implementation and monitoring.

In other words, this approach generates the basic building blocks for any subsequent adaptive management strategies.

The SEP Group addressed the following general questions to establish a logic chain for the development of Stanislaus-specific Biological and Environmental Objectives for Chinook salmon and *O. mykiss* and for identifying, ranking, and prioritizing stressors that prevent attainment of goals and objectives (Figure TS-2):

- What is the problem?
  Define a **Problem Statement**, a concise declaration of the ecological issues that require attention.
- What outcome(s) will solve the problem?
  Determine **Central Valley Goals** that present a vision for species-specific restoration actions across the Central Valley landscape. State desired outcomes that will solve the issue(s) identified in the problem statement.
- What does solving the problem and attaining the goal look like?
  Develop **Central Valley Objectives** that provide a clear standard for measuring progress toward desired outcomes in the larger context of the Central Valley.
- What can efforts in the Stanislaus River contribute to the attainment of Central Valley Objectives?
  Describe **Watershed-specific Goals** that specify the watershed contribution to Central Valley Goals and Objectives. Watershed-specific Goals can be attained within a particular watershed or geographic unit, regardless of actions taken outside the watershed.
- What is the suite of biological outcomes that characterize success?
  Define the specific biological outcomes that characterize success in the geographic area and for the species of interest. **Biological Objectives** are the metrics towards which all conservation actions and adjustments to those actions are directed and will be evaluated.
- What is the suite of physical and ecosystem conditions that characterize success?
  Develop **Environmental Objectives** that define the physical, chemical, and biological conditions that are hypothesized to be necessary to achieve the Biological Objectives. Environmental Objectives quantify the conditions that best available science indicates will lead to attainment of Biological Objectives.

- What are the barriers to achieving Environmental and Biological Objectives? Define the **Stressors** that will need to be alleviated in order to attain the Environmental and Biological Objectives. Prioritize stressors according to the magnitude and certainty of their effect on Environmental and Biological Objectives.

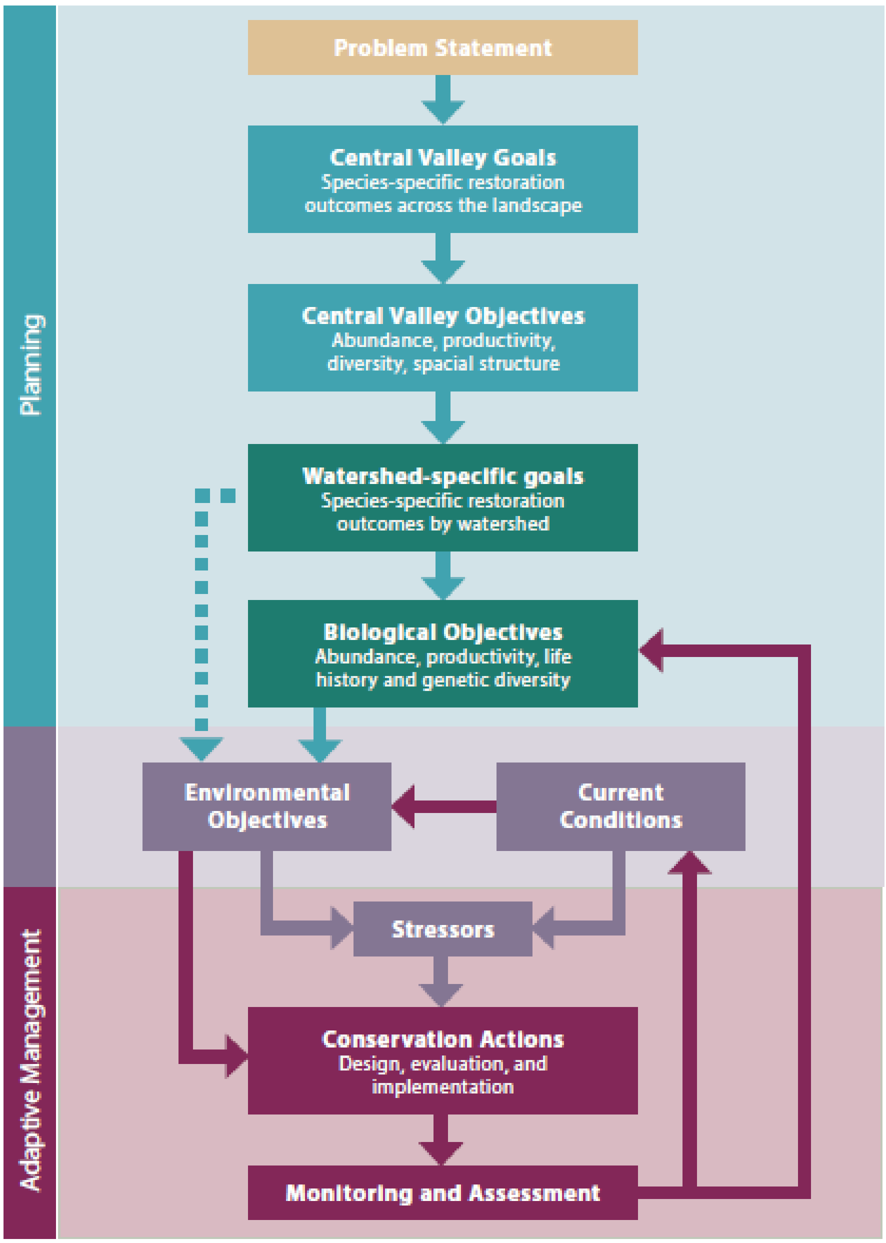

Figure TS-2

Scientific Evaluation Process Logic Chain

The report does not identify or prescribe conservation actions, but rather highlights Environmental Objectives and key stressors that are priorities for management. The SEP Group did not assume any specific method or approach for alleviating stressors and achieving Environmental Objectives. Rather, the group assumed that prioritizing stressors without specifying conservation actions would allow for greater creativity and flexibility in the design of potential actions and solutions to achieve Environmental Objectives and ultimately lead to restoration of salmon and steelhead in the Stanislaus River. Potential conservation actions may include flow prescriptions, habitat restoration, temperature management, fish passage, and others. For example, the section on Environmental Objectives (Section 7) specifies environmental conditions that are necessary to achieve life stage specific outcomes for each species. These conditions include such metrics as the spatial extent of spawning and rearing habitat, optimal water velocity ranges for high quality habitat, and flow variability needed to provide cues for adult and juvenile migration. Attaining these conditions may be addressed through a set of flow prescriptions; however, it is possible that these objectives could also be met through habitat restoration, fish passage, or some combination of actions.

Overall, the SEP approach provides the basis for learning-based management using adaptive decision-making. The SEP products set the stage for generating and evaluating specific proposals for conservation actions and require that such proposals estimate outcomes in terms of Environmental and Biological Objectives. Such impact analyses, combined with analyses of costs to implement the strategy, allow for well-informed, transparent evaluations of trade-offs among proposed approaches.

STRUCTURED AND COLLABORATIVE APPROACH TO DECISION MAKING

Good decisions are defined by the process in which they were generated and by the degree to which they can integrate new information to help minimize uncertainty and improve outcomes. The process of developing the SEP's objectives and stressor evaluations represents a significant advance in the application of science to improve understanding of restoration needs and challenges in the Stanislaus River and throughout the San Joaquin River basin.

The SEP Group produced a consistent and clear description of desired conditions that are embedded in different policies and a strong foundation for adaptive management to attain those outcomes. In addition, collaboration among the participants in the SEP resulted in the alignment of conceptual models of participants with regard to attainable outcomes, system processes, and barriers to achievement of desired conditions. When the SEP began, participating organizations and agencies often had very different definitions of restoration success for the Stanislaus River, and, in most cases, those desired outcomes were not clearly articulated. Similarly, many of the participating scientists entered the SEP with their own internal (but unarticulated) conceptual models of the key problems and limits that prevented attainment of desired biological outcomes. The goals, objectives, and stressor rankings that emerged from this process represent a new scientific consensus around a vision of what the Stanislaus River can be expected to attain with regard to salmonid restoration. The SEP also contextualized how this vision fits into the requirements of existing policy for the Central Valley as a whole and created a science-based, explicit, and agreed-upon conceptual model regarding the numerous barriers to attainment of the vision of success.

The SEP Group recognizes that adaptive management is a critical component of many resource management processes because decisions are always made with some degree of uncertainty. The SEP framework was designed to support an adaptive management framework that could improve decisions and outcomes over time. Managing adaptively requires navigating towards a vision of success that is specifically articulated and widely understood. Thus, the products contained in the report are essential to the practice of adaptive resource management in the Stanislaus River watershed. Indeed, they represent the first step in the adaptive management cycle. For example, the goals and objectives developed by the SEP—and the consensus that these outcomes represent the conditions required under a variety of policies—allow managers to evaluate and implement potential restoration solutions at the appropriate scale. The SEP's analysis of stressors provides a plan of action driven by scientific evidence on the importance of the stress and the appropriate sequence for actions. In other words, the stressor evaluation is expressed in terms of the need and opportunities for adaptive management.

What became clear from developing the vision of success articulated in the report is that there are no silver bullets for restoring populations of fall-run Chinook salmon, spring-run Chinook salmon, or *O. mykiss* on the Stanislaus River. The stressor evaluation presented in Section 8, which is based on comparisons of current conditions to the desired environmental conditions for salmonids as described by the best available science, reveals that a comprehensive conservation strategy is needed. This strategy must include a wide variety of actions to address multiple barriers to success that occur throughout the freshwater life cycle of target salmonid populations. The SEP Group's products provide the essential framework for designing an effective and efficient conservation strategy that can produce desired outcomes on the Stanislaus River (Watershed-specific Goals) and ensure that this watershed can contribute to the attainment of larger laws and policies regarding salmonid restoration throughout the Central Valley (i.e., Central Valley Goals and Objectives). These products will support the prioritization of restoration activities by allowing restoration planners to make good decisions, based on the best available science, and avoid misallocation of limited resources to actions or monitoring that are not part of the critical path to successful restoration outcomes.

A noteworthy realization among participants in the SEP was that restoring viable salmonid populations is indeed possible, but the relationship between restoration effort and abundance is not likely to be linear, at least in the short term. There are numerous environmental thresholds that must be overcome before any biological response will occur. However, if the conditions necessary to support anadromous salmonids are provided, these populations are capable of rapid growth.

In many ways, progress towards restoration has been stifled by policy goals that define success purely in terms of adult salmonid abundance. Because adult abundance results are difficult or impossible to guarantee as a result of modifications to any one environment occupied by anadromous salmon, defining desired outcomes in abundance terms can lead to paralysis because questions such as "where should restoration actions occur?" and "who should be responsible for implementing those actions?" remain unanswered. By focusing desired policy outcomes through the lens of a specific geography and the range of viability parameters that define population viability, the SEP produced attainable definitions of local conditions that can support viable, healthy salmonid populations and an assessment of how local conditions currently impair such populations. As a result of this focus and specificity, the SEP products can facilitate local action and progress.

GOALS AND OBJECTIVES

Central Valley

Central Valley Goals are desired outcomes for Central Valley rivers and their salmonid populations as expressed in the numerous laws and policies that form the policy scope of this effort—they provide guidance and context for all other elements of the logic chain developed herein. Where necessary, the desired outcomes of policies were further defined and articulated by the SEP Group as VSP criteria. For example, many policies call for maintenance or restoration of salmonid populations that are "viable" or "in good condition"; these terms imply a need to achieve acceptable levels in all VSP criteria parameters. Central Valley Goals for each salmonid population considered in the report include the following:

- Increase population size (abundance);
- Increase population growth rates and ability to recover from years of poor recruitment (productivity);
- Increase the number of self-sustaining populations across the landscape (spatial extent);
- Limit genetic influence from hatchery-produced fish and interbreeding of genetically distinct runs (genetic diversity); and
- Support a portfolio of life history types that are typical of each focal population (life history diversity).

In some cases, goals for restoration of rivers and salmonid populations in the Central Valley have been defined more specifically in the report with quantitative objectives. To the extent that they are specific, measureable, achievable, relevant, and time-bound (S.M.A.R.T.), Central Valley Objectives (Table TS-1) serve essential functions in adaptive management as they define goals in a manner that allows planners to scale restoration efforts to an appropriate level, and they facilitate the measurement of progress toward desired outcomes. Therefore, Central Valley Objectives allow effective and transparent evaluation of conservation actions (pre-implementation) and progress, success, and the need to change implementation of conservation actions (post-implementation).

Table TS-1

Central Valley Objectives Relevant to the SEP Scope

Relevant Goal	Target Population(s)	Policies	Objective
Abundance	Fall-run Chinook; Spring-run Chinook; Steelhead	CVPIA/AFRP, Fish and Game Code §6902, 2006 WQC Plan	Double natural production of anadromous fish as compared to their 1967 – 1991 average within 10 years. Specifically: • 750,000 fall-run Chinook salmon per year from the Central Valley as a whole and 22,000 from the Stanislaus River • 68,000 spring-run Chinook salmon per year from Central Valley Rivers as a whole[1] • 13,000 steelhead per year from Central Valley rivers as a whole
Abundance	Spring-run Chinook; Steelhead	ESA, Central Valley Salmonid Recovery Plan	Delisting of both species requires restoration of at least two in the Southern Sierra Diversity Group populations that are at low risk of extinction, which is defined, in part, as a census population size of > 2,500 (833 individuals, on average, for each of the three year classes in one generation) or an effective population size > 500[2].
Productivity	Fall-run Chinook; Spring-run Chinook; Steelhead	CVPIA/AFRP, Fish and Game Code §6902, 2006 WQC Plan	Population growth rate sufficient to double populations within 10 years
Productivity	Spring-run Chinook; Steelhead	ESA, Central Valley Salmonid Recovery Plan	Restoration of viable populations at "low" risk of extinction is defined, in part, by failure to detect productivity declines among populations that meet other recovery criteria.
Spatial Extent	Spring-run Chinook; Steelhead	ESA, Central Valley Salmonid Recovery Plan	Restore at least two viable of spring-run Chinook salmon and anadromous *O. mykiss* populations at low risk of extinction and multiple populations at no greater than moderate risk of extinction in the Southern Sierra Diversity Group
Genetic Diversity	Spring-run Chinook; Steelhead	ESA, Central Valley Salmonid Recovery Plan	Genetic introgression from different ESUs and/or hatchery populations must be no greater than "low" (e.g., < 2%)

Relevant Goal	Target Population(s)	Policies	Objective
Genetic Diversity	Fall-run Chinook salmon	HRSG 2012	Proportion of hatchery-origin spawners less than 20% of adult spawners.

Notes:
1 Production targets for spring-run Chinook salmon and steelhead were not developed by the AFRP for the Stanislaus River. However, natural production from the Stanislaus River would count towards Central Valley-wide Objectives
2 Note that this objective, while specific and measureable, is not time-bound.
ESU = evolutionarily significant unit

Stanislaus River

Central Valley Goals and Objectives for salmonids are the aggregate of biological performance in all the waterbodies critical to Central Valley salmonids. Watershed-specific goals are the expression of local outcomes necessary to support attainment of Central Valley Goals and Objectives. Thus, while goals for the Stanislaus River are not detailed in the policies that define desired outcomes for the Central Valley at-large, it is important to translate these Central Valley-wide outcomes into necessary component outcomes for each relevant waterbody in the Central Valley.

In the context of adaptive management, Watershed-specific Goals serve to provide context and direction for local management efforts. Because Watershed-specific Goals are themselves expressions of existing policy they will change only when and if the overarching policy (Central Valley Goals and Objectives) change. Watershed-specific Goals for the Stanislaus River include the following:

- Increase population size (abundance);
- Increase population growth rates and ability to recover from years of poor recruitment (productivity). For Chinook salmon, population growth rates were targeted to increase in three stages, to support:
    - Rebuilding: a population growth rate that supports increasing populations in a relatively short time,
    - Resilience: achieve a population growth rate that allows the population to rebound in a single generation, after years with poor returns, and
    - Sustainability: achieve freshwater survival rates that are characteristic of salmon in human-modified rivers on the West Coast of North America.
- Maintain genetic integrity of stocks by minimizing hatchery influence and/or introgression with other runs (genetic diversity); and
- Support the fullest expression of life history diversity (as seen within other Central Valley populations and in other rivers that support this phenotype).

There is no Watershed-specific Goal that parallels the Central Valley Goals and Objectives regarding spatial extent (i.e., increase the number of self-sustaining populations across the landscape). This is because restoration of Stanislaus River populations of the focal species (i.e., attaining the other Watershed-specific Goals for each population) will represent the local contribution to the Central Valley Goals and Objectives.

BIOLOGICAL OBJECTIVES

Biological Objectives define Watershed-specific Goals in S.M.A.R.T. terms that define success. These tangible outcomes allow planners and managers to scale solutions appropriately, evaluate proposed actions against a clear baseline, and measure progress in a transparent fashion. Adaptive management requires such clear definitions of success and guidelines for implementing and adjusting actions through time.

The SEP Group made every effort to translate Watershed-specific Goals into Biological Objectives that were S.M.A.R.T. Metrics related to each Biological Objective are either measured currently or measureable using existing technology (see Table TS-2). The Biological Objectives described in the report are believed to be achievable based on performance in other watersheds in the Central Valley or across the focal species' ranges. The determination that an objective was "achievable" did not involve an evaluation of economic or political costs of the action—such an evaluation would be speculative, at best, and premature because a variety of solutions may be proposed to address any barrier to achieving objectives. Also, evaluations of political and economic feasibility were beyond the scope of the SEP efforts. It should be noted that, in many cases, Biological Objectives specified by the SEP Group are already attained in the Stanislaus River in many years; in these cases, the Biological Objectives serve as guidance that will help decision-makers and managers to evaluate and avoid potential negative outcomes of future actions or trends. Biological Objectives may be modified if one of the following is true:

- Relevant Watershed-specific Goals change; this would require changes in the larger policies that these goals represent;
- The specific outcomes are achievable, but not within the specified time-bound; this would require a change in the time-bound associated with the objective; and
- Substantial evidence develops that the objectives are not physically or biologically achievable in the Stanislaus River context; this would require a re-articulation of the Watershed-specific Goal that was both achievable and represented a meaningful

contribution of the Stanislaus River to the relevant desired outcomes for the Central Valley at-large.

Table TS-2

Current and Potential Monitoring that Could be Used to Measure Progress Towards SEP Biological Objectives

Biological Objective Type	Species	Life Stage	Specific Objective	Relevant Current Monitoring (Monitoring Agency)	Relevant Monitoring Needed
Productivity	All	Egg	Egg-emergence to Oakdale RST Survival	Adult escapement at counting weir (USFWS weir – Tri-Dam funds); life history investigations (e.g., escapement and carcass surveys; CDFW); Oakdale RST catch (Tri-Dam – currently not shared)	To be determined
Productivity	All	Egg	Viability	None	Requires incubation chamber (in hatchery or on site) measured by surrogates (e.g., egg trays) and/or as projected by monitoring of temperature, flow, sediment deposition, and scour
Productivity	All	Egg	Incubation success	None	Spawning surveys, redd mapping (superimposition), redd capping
Life History Diversity	Chinook salmon fall-run (FR) and spring-run (SR)	Adult migration	Migration timing	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	To be determined
Productivity	Chinook salmon FR-SR	Adult migration and spawning	Abundance	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	To be determined
Productivity	Chinook salmon FR-SR	Adult migration and holding	Survival	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	Include surveys for SR
Life History Diversity	Chinook salmon FR-SR	Adult migration and spawning	Spawning timing	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	Include surveys for SR
Productivity	Chinook salmon FR-SR	Adult migration and spawning	Prespawn mortality	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	Include surveys for SR
Productivity	Chinook salmon FR-SR	Juvenile emigration	in river (egg to delta) survival	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW); Caswell RST catch (USFWS); Mossdale trawl (CDFW)	Include surveys for SR; Add or modify surveys at Mossdale to more accurately/frequently survey migrating salmonids, and smaller fish in particular; Otolith microchemistry to distinguish juveniles from different natal streams in the lower San Joaquin
Genetic	Chinook salmon FR-SR	Adult migration and spawning	Percentage of hatchery origin spawners	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	Include surveys for SR
Genetic	Chinook salmon FR-SR	Juvenile emigration	Percent introgression (SR-FR)	None	Genetic testing of outmigrating juveniles
Life History Diversity	Chinook salmon FR-SR	Juvenile emigration	Size, timing, and proportion of migrants; number of yearlings	Caswell RST catch (USFWS)	Include surveys for SR; Add or modify surveys at Mossdale to more accurately/frequently survey migrating salmonids, and smaller fish in particular; Otolith microchemistry to distinguish juveniles from different natal streams in the lower San Joaquin

Biological Objective Type	Species	Life Stage	Specific Objective	Relevant Current Monitoring (Monitoring Agency)	Relevant Monitoring Needed
Productivity	*O. mykiss* (steelhead)	Juvenile emigration	Smolt survival down the river and size and proportion of smolt migrants	None	Inclined-screen traps and video cameras, Didson cameras (imaging sonar system), or mark-resight estimates based on PIT tagging (some data from RST)
Productivity	*O. mykiss* (steelhead)	Juvenile emigration	Number of smolts (> 150 mm) per female spawner and total number of smolts per female spawner	Adult escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW); Caswell RST catch (USFWS)	Inclined-screen traps and video cameras, Didson cameras (imaging sonar system), or mark-resight estimates based on PIT tagging (some data from RST)
Productivity	*O. mykiss* (steelhead)	Juvenile rearing	Parr density	Snorkel surveys (USBR)	Electrofishing or other appropriate sampling
Productivity	*O. mykiss* (resident)	Juvenile rearing	Number of smolts (> 150 mm) per female spawner and total number of smolts per female spawner	Adult escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW); Caswell RST catch (USFWS)	Inclined-screen traps and video cameras, Didson cameras (ARIS), or mark-resight estimates based on PIT tagging (some data from RST)
Productivity	*O. mykiss* (resident)	Juvenile rearing	Parr growth rates	None	Growth rates could either be measured by capturing, PIT tagging, and recaptured juvenile *O. mykiss* in the river or estimated by back calculating lengths at age from scales
Life History diversity	*O. mykiss*	Adults	Percentage of anadromous and resident adults	None	Resident: adult snorkel surveys or masks and recapture; Anadromous: weir counts, snorkel surveys, or redd surveys, otolith microchemistry
Life History diversity	*O. mykiss* (steelhead)	Juvenile rearing	Proportion of anadromous mothers	None	Otolith microchemistry
Life History diversity	*O. mykiss* (resident)	Adults	Minimum abundance of resident adults	None	Resident: adult snorkel surveys, mark and recapture, or electrofishing
Life History diversity	*O. mykiss* (steelhead)	Juvenile emigration	Detection of emigrating smolts	Caswell RST catch (USFWS); Oakdale RST catch (Tri-Dam – not currently shared); Mossdale trawl (CDFW)	Modifications to Mossdale trawl (CDFW) to detect juvenile-size ranges

Notes:
ARIS = Didson imaging sonar system
mm = millimeter
PIT = passive integrated transponder
RST = rotary screw trap
USBR = U.S. Bureau of Reclamation

Clearly, political and economic considerations will come into play in the process of determining the best pathway to achieve Biological Objectives. However, political or economic considerations (while important) are not considered valid reasons for modifying Biological Objectives; current evaluations of political or economic feasibility are unlikely to account for potentially innovative solutions to problems that arise as a result of changes in either restoration technology or the socioeconomic backdrop of the Stanislaus River watershed. The Biological Objectives are based in the best available scientific information on the outcomes that a functioning Stanislaus River ecosystem can and should support, given the directives provided by the policy scope. In cases where political or economic considerations are barriers to current attainment of Biological Objectives, it is preferable to make as much progress as possible towards full attainment and simply acknowledge that the Biological Objective in question has not been attained yet.

A variety of Biological Objectives were identified for each focal species. These objectives relate to Watershed-specific Goals for productivity, life history diversity, and genetic diversity of all focal species, and abundance of resident *O. mykiss*. Because abundance Biological Objectives were not developed for anadromous populations, Central Valley Objectives for abundance of the anadromous populations were used to guide Environmental Objectives related to habitat area (e.g., spawning habitat and juvenile rearing habitat). This reflects the understanding that, although conditions on the Stanislaus River are not solely responsible for anadromous fish cohort size, the habitat space available in the river system ultimately defines system-carrying capacity and that carrying capacity must be adequate to support Central Valley Objectives for abundance. Habitat space is the Stanislaus River's "contribution" to the Central Valley Objectives for abundance as defined in the policy scope.

Biological Objectives are reviewed briefly below.

The **productivity** VSP attribute is composed of fecundity and stage-specific survival rates. The SEP Group's Biological Objectives for focal anadromous populations focus on the production of juveniles per adult spawner. Annual estimates of juvenile population size are currently measured at various locations in the Stanislaus and lower San Joaquin rivers; comparing these estimates to adult escapement estimates (which are measured at a counting weir and by redd and carcass surveys) reveals the overall annual productivity of the Stanislaus River for that population.

Biological Objectives for productivity of Stanislaus River salmonids are described in Tables TS-3 to TS-5. For Chinook salmon, productivity objectives tracked the three-staged Watershed-specific Goals for productivity: rebuilding, resilience, and sustainability. Attaining these objectives means that adult-to-juvenile outmigrant survival will increase over a 24-year period. Although adult-to-juvenile outmigrant survival rates are mathematically independent of the number of adult spawners in a given year, the rates apply whether there are 100 spawners or 1,000 spawners; as the population of adults and juveniles reaches the system carrying capacity, actual juvenile survival rates may drop below the objective due to density-dependent mortality. As a result, the Biological Objectives for productivity are only to be measured in years when population abundance is substantially below carrying capacity—such conditions are expected to occur naturally, from time-to-time, regardless of the success of Stanislaus River restoration (e.g., due to poor ocean conditions).

Table TS-3
Chinook Salmon Productivity Objectives

Objective		Productivity[1]												
Life History Stage		Juvenile "rebuilding"			Juvenile "resiliency"			Juvenile "sustainability"			Adult and Egg			
Description	Briefly	Juvenile survival rate consistent with population growth rate of 2x over three generations (Cohort Replacement Rate =1.26)			Juvenile survival rate consistent with population resilience (Cohort Replacement Rate = 2.5)			Juvenile survival rate in freshwater typical of Chinook salmon populations across the Pacific coast (10%)			Survival/reproductive success of adult migrants and indicators of egg incubation success			
	Achieved by When?	Year 10			Year 15			Year 24			Year 9	Year 9	Varies (Year 9, 15, 24; see below)	Varies (Year 9, 15, 24; see below)
	Measure What?	Survival from/to	Survival from/to	Survival total	Survival from/to	Survival from/to	Survival total	Survival from/to	Survival from/to	Survival total	Survival from/to	Egg viability/ deposition	Egg/redd viability	Egg-emergence survival of surrogates
	Measured Where?	Spawning to Caswell [2]	Caswell to Vernalis [2]	Freshwater [3]	Spawning to Caswell [2]	Caswell to Vernalis [2]	Freshwater [3]	Spawning to Caswell [2]	Caswell to Vernalis [2]	Freshwater [4]	Caswell to spawning grounds at onset of spawning [5]	Spawning grounds	Spawning grounds	Spawning grounds
Fall-run	Wet	15.0%			18.0%			35.0%			≥ 90%	a) In hatchery hatching success = 95%; b) < 10% of female carcasses retain ≥ 10% of eggs	a) Environmental conditions consistent with in-hatchery incubation success: ≥ 80% (year 9); ≥ 85% (year 15); ≥ 90% (year 24) b) ≥ 90% redds remain intact through incubation period	Egg to fry survival (at Oakdale RST): ≥ 25% (year 9); ≥ 30% (year 15); ≥ 35% (year 24)
	Median Year	10.8%	69.8%	2.12%	14.3%	74.4%	4.20%	24.8%	80.7%	10.0%				
	Dry	5.0%			9.0%			15.0%						
Spring-run	Wet	15.0%			18.0%			35.0%			Same as above	Same as above	Same as above	Same as above
	Median Year	10.8%	69.8%	2.12%	14.3%	74.4%	4.20%	24.8%	80.7%	10.0%				
	Dry	5.0%			9.0%			15.0%						

Notes:
1 Juvenile productivity and life history objectives refer only to those Chinook that migrate before temperatures in the mainstem San Joaquin reach 25 degrees Celsius (°C) (77 degrees Fahrenheit [°F]).
2 Survival objectives from Spawning to Caswell are premised on attainment of Caswell to Vernalis survival rate. If median Caswell to Vernalis survival rate is unattainable or exceeded, the Spawning to Caswell survival rate objective will be adjusted accordingly.
3 For reference purposes. Includes through-Delta survival. Conditions on the San Joaquin and its tributaries affect Delta survival; however, responsibility of San Joaquin tributaries for through-Delta survival outcomes is yet to be determined. Improvement in freshwater survival rates assume river survival rates and Delta survival rates will improve proportionately from current levels.
4 For reference purposes. Assumes through-Delta survival of 50%. In this case, the improvement in river and Delta environments is no longer proportionate, as adherence to the proportionate improvement standard would require median survival of >50% in the Delta. There was no consensus that survival rates of > 50% in the Delta could be achieved.
5 Currently, adult survival objectives are only developed for spring-run Chinook after they have migrated past Caswell. This reflects desired outcomes in the ability of spring-run to successfully "hold" in the river through the summer. Adult survival objectives may be developed (and potentially for fall-run and steelhead) in the mainstem San Joaquin; however, those objectives would be part of basin-wide planning and may require adult migration monitoring in the lower San Joaquin.

Table TS-4

Resident *O. mykiss* Productivity Objectives

Objective		Productivity	
Life History Stage		**Juvenile Density**	**Juvenile Growth Rate**
Description	**Briefly**	Densities of *O. mykiss* that support desired frequency of anadromy in the population	Average individual growth rates that support desired frequency of anadromy in the population
	Achieved by When?	Year 15	Year 15
	Measure What?	Population density (parr/river km^2)	Average growth rate (mm/day)
	Measured Where?	Upstream of Oakdale, in reaches identified as having high quality *O. mykiss* holding habitat	Upstream of Oakdale, in reaches identified as having high quality *O. mykiss* holding habitat
Resident *O. mykiss*		The minimum density of age-0 *O. mykiss* during the summer equals $1/m^2$ on average	Minimum average growth of both age-0 and age-1 *O. mykiss*, averaged over an entire season, equals 0.60 mm/day

Note:
km^2 = square kilometer
m^2 = square meter
mm = millimeter

Table TS-5

Steelhead Productivity Objectives

<table>
<tr><th colspan="2">Objective</th><th colspan="8">Productivity</th></tr>
<tr><th colspan="2">Life History Stage</th><th colspan="2">Juvenile Smolt Size</th><th colspan="2">Juvenile Smolt Production</th><th colspan="3">Juvenile Smolt Survival</th><th>Adult</th></tr>
<tr><td rowspan="4">Description</td><td>Briefly</td><td colspan="2">Proportion of smolts (Stages 4 and 5 in Table 16 of report) observed should be of a size able to survive the ocean phase and return as anadromous adult</td><td colspan="2">Naturally produced smolts (Stages 4 and 5 in Table 16 of report) per female spawner increase to levels consistent with other healthy steelhead populations…</td><td colspan="3">Smolt survival – smolt (Stages 4 and 5 in Table 16 of report) survival rate consistent with population resilience</td><td>Egg survival consistent with…</td></tr>
<tr><td>Achieved by When?</td><td colspan="2">Year 15</td><td colspan="2">Year 15</td><td colspan="3">Year 15</td><td>Year 15</td></tr>
<tr><td>Measure What?</td><td colspan="2">Fork Length (FL)</td><td colspan="2">Number of smolts per female spawner</td><td colspan="3">Survival through lower Stanislaus River</td><td>Egg survival</td></tr>
<tr><td>Measured Where?</td><td colspan="2">To be determined (Caswell area)</td><td colspan="2">Caswell (or other location prior to confluence with mainstem)</td><td>Lower end of gravel bedded reach</td><td></td><td>Delta entry</td><td></td></tr>
<tr><td colspan="2" rowspan="4">Steelhead</td><td colspan="2">At least 90% of the smolts (Stages 4 and 5) observed should be 150 mm (5.9 inches) FL or greater in length</td><td colspan="2">Naturally produced smolts (Stages 4 and 5) emigrating from the river each year shall increase to at least 165 per female spawner</td><td colspan="3">> 90%</td><td rowspan="4">> 35%</td></tr>
<tr><td>FL</td><td>150 mm (5.9 inches)</td><td rowspan="2">3-year running average</td><td rowspan="2"></td><td colspan="3" rowspan="3"></td></tr>
<tr><td>Percentage</td><td>90%</td></tr>
<tr><td>Year type</td><td>All years</td><td>Minimum</td><td>165</td></tr>
</table>

Biological Objectives for productivity were calculated by comparing current estimated survival rates throughout the salmonid life cycle and asking what survival rates would be needed in freshwater environments in order to achieve the Watershed-specific Goals for population productivity. Ocean mortality estimates were considered to be constant into the future; many of the policies guiding river and salmon restoration in the Central Valley (the policy scope) do not authorize or anticipate further limitation of the ocean salmon fishery. In addition, changes to ocean survival rate would not affect the final stage of improvement in productivity ("sustainability") as the relevant survival objective applies only to the juvenile survival rate of salmon in freshwater environments.

Preliminary analyses of data collected by state and federal agencies revealed that the Watershed-specific Goals for juvenile productivity of Stanislaus River salmon will be difficult or impossible to achieve without improving survival in both the riverine and tidal (Delta) portion of the salmon's freshwater environment. For example, "the sustainability" goal is characterized by survival rates that are typical of other Chinook salmon populations throughout the species' range; however, current survival rates in both the Delta and river environments are well below survival rates that characterize typical productivity of the entire freshwater environment (Table TS-6). Thus, even if there were no mortality in the Delta environment (survival = 100%), survival in the river environment alone is well below that observed in freshwater for most other Chinook salmon populations.

Table TS-6

Survival Rates in Freshwater Environments Necessary to Support Watershed-specific Goal of Rebuilding the Stanislaus River Fall-run Chinook Salmon Population

Reach	Current	River Mile (RM)	Target Survival	Target Survival per RM
Eggs to Vernalis	1.01%	57.0	7.55%	95.57%
Vernalis to Chipps Island	3.75%	54.5	28.06%	97.69%
Chipps Island to Adult[1]	2.83%	-	2.83%	-
Adult to Spawner[1]	60.24%	-	60.24%	-
Recruits per Spawner[2]			**1.26**	

Notes:
1 Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)

2 Recruits per spawner is calculated as product of survival rates (e.g., Eggs to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
– Target survivals assume an equal increase over current survival in Delta and riverine habitats. See report for calculation of survival in different riverine stretches.

Improvements in freshwater survival were applied to river and Delta environments proportionately to the current estimates of survival in these two environments. Riverine survival rates necessary to support the three Watershed-specific Goals for productivity were then further divided into two river segments: one for the Stanislaus River between the spawning grounds and a juvenile salmon monitoring station at Caswell State Park and another for the river reach between Caswell State Park and where the San Joaquin enters the Delta. Because survival is currently estimated to be higher in the Delta than in the river, final estimates of survival rates necessary in the Delta were higher than the survival rates specified by the Biological Objectives for the riverine environment. The SEP Group determined that proportionate improvement in survival in the Delta vs. riverine environment (i.e., increased survival rates as fish grow and age in freshwater) was consistent with natural patterns. However, such proportionate improvement in survival rates eventually led to estimated Delta survival rates that were unrealistically high for juvenile salmon from the Stanislaus River with regard to the final Watershed-specific Goal (sustainability or “typical” Chinook salmon survival rates). Many juvenile salmon emerging from the Stanislaus River are expected to complete freshwater rearing in the Delta (as opposed to salmon migrating from watersheds further upstream that will rear mainly in the river environment), and this extended residence in the Delta will likely cap potential survival improvements in the Delta. The final survival target for Stanislaus River juveniles in the Delta was capped at 50% median annual survival through the Delta. Juvenile survival required in the riverine environment was adjusted to produce overall freshwater survival called for under the final productivity-related Watershed-specific Goal.

Adult-to-juvenile outmigrant productivity in the riverine environment is the product of spawning success of adults that return to the river, egg incubation success, and juvenile survival through the river system. These rates are controlled by conditions in the river system almost exclusively,[1] and, as a result, Biological Objectives for productivity of Stanislaus River salmonids may be attained through modifications of environmental conditions in the Stanislaus River and lower San Joaquin River. In addition to objectives for adult-to-juvenile survival rate, targets were established for adult survival, redd success, egg survival, and adult-fry production. These targets can be used to guide relative conservation efforts focused on improving conditions for each life stage and, by monitoring these component rates, managers can determine where problems are occurring in the event that the overall adult-to-juvenile productivity objectives are not attained.

Biological Objectives for **life history diversity** of Stanislaus River salmonids are described in Tables TS-7 through TS-10. Life history diversity among juvenile salmonids (commonly measured by the timing of and body size at migration) is increasingly recognized as vital to population growth rates (i.e., productivity) and stability of the population through time. Because the timing and quality of conditions in the San Francisco Bay Estuary and marine environments are highly variable, a diverse portfolio of juvenile sizes migrating at different times increases the chances that some fraction of each annual cohort will be able to capitalize on suitable conditions in pelagic environments.

Table TS-7
Fall-run Chinook Salmon Timing of Migration Objectives

Size Class	Caswell RST		Mossdale[1] Trawl	
	Start Week	**End Week**	**Start Week**	**End Week**
Fry (smaller than 55 mm [2.2 in])	Last of January	Second of April	N/A[2]	N/A[2]
Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in])	First of February	Last of May	Second of February	First of June
Smolt (larger than 75 mm [3 in])	Third of February	First of June	February	June

[1] One nuance is that, for each individual female, maximum fecundity is determined by conditions experienced prior to river entry (e.g., in the marine environment); this potential fecundity may then be reduced by poor conditions encountered during the adult migration through freshwater.

Notes:
1 Tributary contribution can be assigned (e.g., by otolith analyses).
2 Mossdale Trawl does not reliably detect fish smaller than 55 mm (2.2 inches).

Table TS-8

Fall-run Chinook Salmon Size at Migratory Objectives

Size Class	Wetter Years	Drier Years
Fry (smaller than 55 mm [2.2 in])	20% minimum	20% minimum
Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in])	20% minimum	30% minimum
Smolt[1] (larger than 75 mm [3 in])	10% minimum	20% minimum

Notes:
1 Includes only juveniles that migrate before daily mean temperatures greater than 25°C (77°F) at Mossdale

Table TS-9

Chinook Salmon Biological Objectives – Life History Diversity Objectives

	Objective	Life History Diversity (Migration Timing) [1]				Life History Diversity (Age-class Distribution Minima) [1]	
Description	Briefly	Support range of juvenile migration dates to maintain life history diversity				Support range of sizes at juvenile migration dates to maintain life history diversity	
	Achieved by When?	Year 10	Year 10	Year 10	Year 10	Year 12	Year 12
	Measure What?	Detection every week no later than…	Detection every week through at least…	Detection every week no later than…	Detection every week through at least…	Minimum % juvenile migrants annually (wetter years)	Minimum % juvenile migrants annually (drier years)
	Measured Where?	Caswell RST	Caswell RST	Mossdale Trawl	Mossdale Trawl	Caswell RST	Caswell RST
Fall-run	Fry	Last week of January	2nd week of April	N/A	N/A	20%	20%
	Parr	1st week of February	Last week of May	2nd week of February	1st week of June	20%	30%
	Smolt	3rd week of February	1st week of June	Last week of February	2nd week of June	10%	20%
Spring-run	Fry	1st week of January	2nd week of April	TBD	TBD	20%	20%
	Parr					20%	30%
	Smolt					10%	20%
	Yearling [2]	Detection in ≥ 50% weeks October to January	Detection in ≥ 50% weeks February to April	TBD	TBD	≥ 1.5 yearlings per 1,000 female spawners	

Notes:

1 Juvenile productivity and life history objectives refer only to those fish that migrate before temperatures in the mainstem San Joaquin reach 25°C (77°F).

2 The yearling life history strategy is associated with spring-running adults (fall-run adults may produce yearlings as well, but it is considered to be extremely rare). Production of some yearlings is expected whenever spring-run Chinook reproduce successfully; however, detection of yearlings is only required when sufficient numbers of spring-run salmon reproduce.
N/A = not applicable
TBD = to be determined

Table TS-10
Spring-run Chinook Salmon Timing of Migration Objectives at Caswell Rotary Screw Trap

Size/Life History Type	Frequency	Start	Fall-run Start	End (Both Runs)
Yearling (to be measured two calendar years following parent cohort return [escapement])	a) Detection in at least 50% of weeks between the second week of October to January, and b) 50% of weeks February to April (The division between time periods is intentional and meant to ensure that some yearlings migrate in each of the time periods)	October	No Applicable Objective	April
YOY (Fry, Parr, and Smolt)[1]	Every week	First week of January	Last week of January	First week of June

Note:
1 See Table TS-8 for definitions of fry, parr, and smolt size classes.
YOY = young-of-the-year

For Chinook salmon, life history diversity objectives took two forms: minimum standards for both the temporal distribution of migration and for the distribution of fish among three body size categories. Targets were not intended to be overly prescriptive in either of these categories, as life history diversity parameters should vary from year to year in response to environmental conditions. Rather, the life history diversity objectives were designed to identify minimum levels of diversity, below which the SEP Group would be concerned that the overall population was overly homogenous. It is worth noting that the existing fall-run Chinook salmon population on the Stanislaus River already meets many of the life history diversity Biological Objectives in many years (e.g., timing of juvenile migration), and other objectives, such as body size distribution, should be easily met following establishment of adequate rearing conditions on the Stanislaus River.

Life history diversity objectives for the Stanislaus River *O. mykiss* population were complicated by the extremely variable nature of *O. mykiss* life histories. Because factors like the proportion of anadromy (production of steelhead) are so dynamic within and among *O. mykiss* populations, there are few objective baselines against which to establish expectations for a healthy *O. mykiss* population. However, to support the attainment of

Central Valley Objectives, life history diversity objectives were developed to ensure the expression of both resident and anadromous *O. mykiss* in the Stanislaus River (Table TS-11). Essentially, the Stanislaus River is expected to provide the environmental conditions to support the production of steelhead by supporting the appropriate *O. mykiss* growth rates, smolt survival, etc.

Table TS-11

***O. mykiss* Life History Diversity Objectives**

Objective		Life History Diversity (Anadromy)					
Life History Stage		Juvenile				Adult	
Description	Briefly	Smolts produced per female spawner indicative of healthy spawner		Supports anadromy via a sufficient proportion of juveniles with anadromous *O. mykiss* mothers	Supports a range of outmigration dates for life history diversity	Support viable levels of both life history types	Support viable levels of both life history types
Description	Achieved by When?	Year 15		Year 15	Year 15	Year 15	Year 15
Description	Measure What?	Smolts/ female spawner		Proportion of age-0 juveniles with anadromous maternal origin in otolith	Smolt (Stages 4 and 5; at least 150 mm [5.9 in] FL) Detection	Proportion of adult *O. mykiss*	Resident adult abundance
Description	Measured Where?	Spawning reach		Age-0 *O. mykiss* collected in rearing areas	Caswell RST		Reach just downstream of Goodwin Dam
O. mykiss		This shall be tracked on a brood year basis					Age 1+ fish superpopulation > 1,492 to 7,873
O. mykiss		Annual hydrology > 50% exceedance	> 300	> 45%	Minimum of 4 months of the year	> 25% resident – Summer	3 to 9 age 1+ fish per 100 m^2 (1,076 ft^2)
O. mykiss		Annual hydrology ≤ 50% exceedance	> 150			> 20% anadromous – immigrating adults	

Note:
ft^2 = square feet

Genetic diversity objectives were intended to limit interbreeding between naturally spawned and hatchery-spawned individuals and among the different runs of Chinook salmon. Both phenomena are detrimental to the development of viable runs that are specifically adapted to local ecological conditions. Furthermore, both of these threats to genetic diversity are high priority management problems in the Central Valley. The prevalence of hatchery-origin fish returning to spawn in Central Valley rivers is a significant problem in managing wild stocks, and interbreeding among genetically distinct fall and spring-run Chinook salmon poses numerous threats to both populations.

Genetic diversity objectives are listed in Table TS-12.

Table TS-12
Genetic Objectives

Objective		Genetic	
Life History Stage		Adult	Egg/Juvenile
Description	Briefly	Maintain wild run genetic integrity	
	Achieved by When?	Year 9	Whenever spring-running fish are present
	Measure What?	Percentage hatchery origin spawners	Introgression
	Measured Where?	Spawning grounds	Spawning grounds
Fall-run	Wet	pHOS < 20% of spawners	< 2% hatchery influence
	Median Year		
	Dry		
Spring-run	Wet	N/A	< 2% inter-run mating
	Median Year		
	Dry		

Note:
pHOS = proportion of hatchery-origin spawners

Abundance objectives were developed for the resident *O. mykiss* only because, like for Chinook, the abundance of the anadromous form is not controlled solely by conditions in the freshwater environment (see Environmental Objectives below). Maintaining a viable population of resident *O. mykiss* is believed to be necessary in order to support: 1) increased frequency of the anadromous phenotype; 2) resilience of *O. mykiss* populations to prolonged natural occurrence of conditions that render anadromy a poor strategy; and 3) local recreational fisheries. The abundance objective for *O. mykiss* is in the term of parr density (i.e., one age-0 *O. mykiss* per square meter during the summer in specified reaches). Parr density, in conjunction with *O. mykiss* productivity objectives and associated Environmental Objectives, are believed to represent conditions in the Stanislaus River that will promote and protect the life history diversity of both resident and anadromous *O. mykiss.* The density and growth objectives for *O. mykiss* are described in Table TS-4.

ENVIRONMENTAL OBJECTIVES

Environmental Objectives represent the design criteria for the restored river. They are, in some sense, hypotheses about what is required to attain the Biological Objectives. Using the desired outcomes described above, as well as published literature and available models, the SEP Group defined a suite of environmental conditions that would support attainment of the Watershed-specific Goals and Biological Objectives. Where possible, these were expressed in ranges that the literature indicated would represent "Detrimental," "Sub-Optimal," and "Optimal" conditions for salmonids. Detrimental conditions for any one variable are those that will result in failure of the affected cohort to attain the Biological Objectives that are specific to that life stage. Conversely, attainment of Optima environmental conditions across the suite of Environmental Objectives is consistent with attainment of the Biological Objectives; in other words, all of the Biological Objectives are well within the known capacities of Chinook salmon and *O. mykiss* populations when environmental conditions are in the optimal range. Optimal conditions will not always occur for any one variable; the severity, duration, frequency, and number of other conditions that are sub-optimal will determine whether a given population attains its Biological Objectives. As a general rule, the more conditions that are sub-optimal and the longer or more frequently they are sub-optimal, the less likely it is that Biological Objectives will be attained.

Environmental Objectives were established for each life stage of each focal population. Variables addressed included temperature, dissolved oxygen (DO), contaminant concentrations, physical habitat space (e.g., gravel for spawning, shallow habitat for rearing), and others. To the extent possible, Environmental Objectives are not expressed as volumes of flow required to produce these optimal conditions, although flow volumes can be determined that will meet a particular suite of Environmental Objectives (e.g., depth and velocity of water to maintain desired temperatures or DO levels in spawning gravel).

The Environmental Objectives represent the hypothetical environmental conditions (based on best available science) that are necessary to attain the Biological Objectives in the Stanislaus River. It is possible that Biological Objectives can be attained even though the full suites of Environmental Objectives are not being met. This is grounded on the uncertainty around our scientific knowledge, natural variability, physical and biological interfaces, etc. As restoration proceeds on the Stanislaus River and the range of environmental conditions that approach their respective Environmental Objectives increases, the likelihood of attaining the Biological Objectives increases as well. When Biological Objectives are attained, the Environmental Objectives may be reassessed in an adaptive management context. Similarly, Environmental Objectives will need to be reassessed in the unlikely event that optimal conditions are attained for all Environmental Objectives but the Biological Objectives are not attained.

STRESSORS

Stressors (also known as limiting factors) are conditions (physical, biological, or ecological) within the system that limit or inhibit the attainment, existence, maintenance, or potential for desired conditions as characterized by the Biological and Environmental Objectives. Because different objectives are already being achieved to different degrees under existing conditions, identification of stressors is critical in order to:

- Highlight components of desired conditions that are not being achieved; and
- Identify the specific obstacles (i.e., stressor[s]) inhibiting desired conditions.

As a complement to the identification of stressors, ranking stressors:

- Enables the development of specific actions to achieve desired conditions by resolving stressors; and
- Facilitates the prioritization and sequencing of those actions to maximize benefit by addressing the most significant stressors first.

In this way, when combined with the Biological and Environmental Objectives, the stressor analysis provides the basis for the following:

- Prioritizing conservation measures, including habitat enhancement actions and research, for maximum biological benefit;
- Understanding the full range and extent of conservation measures necessary to support population recovery; and
- Setting expectations related to the extent of conservation measures required to see progress towards the Biological Objectives for a given life history stage by virtue of the extent of the stress to that life history stage that has been resolved.

Stressor Identification, Ranking, and Prioritization

The process for identifying and ranking stressors includes the following four key steps:

1. **Identification of the range of stressors affecting each life history stage**. Potential stressors were identified based on a combination of expert opinion elicitation and review of published literature as well as other available data related to current and projected future conditions. Stressors identified were framed in terms of parameters specified in environmental objectives to characterize desired conditions (e.g., temperature and DO) and factors that are not specifically addressed in the objectives but which affect the potential for the Biological or Environmental Objectives to be achieved (e.g., predation).
2. **Assignment of stressors, for each life history stage, as relevant to: 1) current population and conditions; 2) target population and conditions; or 3) both.**
   - In the first case, the stressor affects the species or ecosystem under current conditions and/or at the current species population levels.
   - In the second case, the stressor, although not currently impacting populations or ecosystem conditions, is predicted to become impactful once populations approach recovery; when ecosystem conditions progress towards desired conditions; or as a function of some other trend, transition, or tipping point occurring in the future.
   - In the third case, a stressor is currently having an impact on the species, and it is also expected that the magnitude or nature (e.g., scale and predictability) of that impact will change as populations increase, progress towards environmental objectives is made, or some other future condition occurs.

3. **Scoring of stressors by life history stage for current conditions and target of future conditions, as applicable.** Based on existing information, stressors were assigned a score of 1 to 4 points (1 being lowest and 4 being highest) in two categories—magnitude and certainty—using a scoring approach adapted from the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). Magnitude scores were based on the scale and severity of the impact to populations from the stress. Certainty scores were based on the understanding of a stressor's related impact as a function of the available information base as well as the predictability of that impact. In combination, magnitude and certainty scores generate an overall score, guide stressor ranking, and provide indication about the appropriate stressor response.
4. **Stressor ranking and prioritization across life history stages.** Once scored, stressors for individual life history stages were combined for each of the three species (fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss*). Stressors were then sorted and ranked based on their magnitude and certainty scores and assigned a stressor response type. In addition to the severity of the stress, a high magnitude score indicates the potential need for a major action, depending on certainty. A low magnitude score, depending on certainty, suggests either a need for monitoring to ensure the magnitude does not increase or research to confirm the low magnitude score and potentially inform adaptive management. In order to facilitate the application of the stressor analysis to development and sequencing of conservation measures to alleviate stressors, the stressors were grouped and prioritized according to stressor responses in the following broad categories: Actions, Research, and Monitoring.

Stressor priorities are presented summarized across life history stages for fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss*. All stressors identified in the analyses for the different species/life history stages are considered significant and in need of being addressed in order for Environmental and Biological Objectives to be achieved. However, the analysis specifically identifies stressors with both a high magnitude and certainty as the highest priority for response in the form of conservation action(s) that will resolve the stressors and support attainment of the Environmental Objectives. The analysis further defines lower priority actions as those with a lower magnitude, but also with a high degree of certainty. Stressors with a high magnitude, but a lower degree of certainty, are considered the highest priority for research, with other research priorities falling in below based on their relative magnitude scores. Low magnitude stressors are prioritized under baseline monitoring needs, where higher certainty indicates a priority for trend monitoring to ensure that the magnitude does not increase.

The report includes an analysis and summary of both coarse scale stressors (e.g., lack of suitable rearing habitat) and single variable fine scale stressors (e.g., lack of suitable rearing habitat as a function of temperature) for each of the species over both the near- and long-term. The results are summarized in a total of four matrices—1) coarse and 2) fine scale priorities for both 3) near-term and 4) long-term populations—and are presented for each of the three focal species (near term Figures TS-3 through TS-5; long term in Appendix E).

Results of Stressor Analysis

The following matrices summarize a portion of the stressor prioritization results for each of the three target species. For the purposes of this technical summary, only the highest and high priority coarse scale stressors for each of the three target species are included in order to provide a sense of the most biologically pressing needs for action or research in the near term.

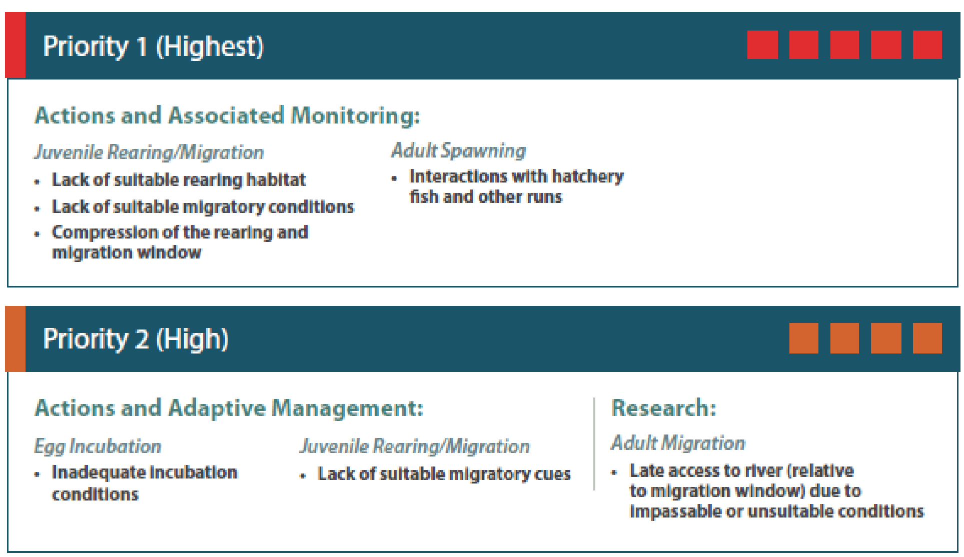

Figure TS-3

Fall Run Chinook Salmon – Stressor Response Prioritization (Near Term/Coarse Scale)

Priority 1 (Highest)

Actions and Associated Monitoring:

Adult Spawning
- Interactions with hatchery fish and other runs

Egg Incubation
- Inadequate incubation conditions

Juvenile Rearing/Migration
- Lack of suitable rearing habitat
- Lack of suitable migratory conditions

Priority 2 (High)

Actions and Associated Monitoring:

Adult Holding
- Lack of suitable habitat

Actions and Adaptive Management:

Juvenile Rearing/Migration
- Lack of suitable migratory cues

Research:

Adult Holding
- Loss of fecundity

Adult Spawning
- Compression of the spawning window

Adult Migration
- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease)

Juvenile Rearing/Migration
- Compression of the rearing and migration window

Figure TS-4

Spring Run Chinook Salmon – Stressor Response Prioritization (Near Term/Coarse Scale)

Priority 1 (Highest)

Actions and Associated Monitoring:

Egg Incubation
- Inadequate incubation conditions

Juvenile Rearing/Migration
- Lack of suitable rearing habitat
- Lack of suitable migratory conditions

Priority 2 (High)

Actions and Associated Monitoring:

Adult Holding
- Lack of suitable habitat

Actions and Adaptive Management:

Juvenile Rearing/Migration
- Lack of suitable migratory cues

Figure TS-5

Steelhead – Stressor Response Prioritization (Near Term/Coarse Scale)

Stressors, as explained above, are the obstacles to achieving the desired conditions (i.e., Environmental Objectives) necessary for the species to attain the target population conditions (i.e., Biological Objectives). For this reason, for any given life history stage, progress towards the Biological Objectives can only be expected once the high priority stressors have been addressed and Environmental Objectives largely achieved. The efficacy of conservation measures designed to reduce stressors should therefore be measured based on the extent that those measures advance or achieve Environmental Objectives or Biological Objectives.

Once Environmental Objectives have been significantly advanced, or achieved via the resolution of priority stressors, Biological Objectives become metrics to measure species response to the actions and conditions quantified in the Environmental Objectives. In addition, Biological Objectives can serve as triggers for adaptive management actions in cases where Biological Objectives are not being achieved despite Environmental Objectives having been met and stressors resolved.

Although Environmental Objectives and stressors do not have a one-to-one relationship with Biological Objectives, there are several core relationships among them that can serve to guide expectations around biological response to the attainment of Environmental Objectives, including the following:

- **Habitat Quality → Survival**
  Given the carrying capacity associated with a given spatial area of habitat, fish condition and survival is largely linked with habitat quality as defined by Environmental Objectives and stressors for a given life stage.
- **Habitat Spatial Extent → Abundance**
  Given habitat quality and suitability (as quantified by the Environmental Objectives) and associated survival rates, increased spatial extent of suitable habitat increases carrying capacity for that life history stage.
- **Habitat Temporal Extent → Diversity and Resilience**
  Given sufficient habitat quality and spatial extent, the temporal extent and availability of habitat increases the potential for a given life history stage to express diversity.

Even when the primary stressors for a given life history stage have been addressed, certain Biological Objectives (e.g., population growth and abundance) require success across multiple or all life history stages. It therefore becomes necessary for the high priority stressors to be addressed, and Environmental Objectives achieved for all life history stages, in order to see meaningful progress towards the full suite of Biological Objectives.

In general, native species in the Stanislaus River are impacted by changes to river flow (e.g., reduced mean annual flow and an altered hydrograph), habitat alteration (e.g., dams and legacy mining), and biological modification (e.g., non-native species and hatchery-origin fish). In addition, changes to river flow and habitat alteration can influence biological modifications. Thus, the vast majority of stressors can be addressed through water management, habitat, or a combination of the two. For example, one of the highest priority stressors for juvenile fall-run Chinook salmon is the lack of rearing habitat. To alleviate this stressor, conservation actions would have to include a combination of habitat restoration and flow regimes to adequately inundate the restored habitat for an appropriate duration to support juvenile growth. Flow and habitat are both critical elements of river function and emergent themes necessary for river restoration. Although the SEP Group has not outlined specific actions necessary to alleviate stressors and meet Environmental and Biological Objectives, it is clear that modifications to both current habitat and current flow regimes will be necessary to achieve the objectives for the Stanislaus River.

ADDRESSING UNCERTAINTY

Each component of the SEP framework is essential to adaptively managing a comprehensive salmonid restoration strategy. Biological Objectives represent the minimum conditions necessary to achieve Watershed-specific Goals for the Stanislaus River and its contribution to Central Valley Goals and Objectives for anadromous fish restoration. Management activities must be oriented toward attainment of the Biological Objectives and modified over time, as necessary, to achieve those objectives. This means that, prior to selection and implementation of conservation actions, proposed actions must be evaluated based on their ability to support the Biological Objectives and, following implementation, monitoring will be needed to assess whether the actions' expected benefits materialize. Because it is difficult to measure the direct effect of individual actions on the Biological Objectives, the Environmental Objectives provide the physical design criteria against which conservation actions (individually and collectively) can be evaluated. Environmental Objectives represent hypotheses of the environmental conditions needed to achieve the Biological Objectives. Stressors, and their relative magnitude and certainty scores, represent hypotheses regarding the existing and expected future barriers to attainment of Environmental and/or Biological

Objectives. Finally, conservation actions will represent hypotheses about the best way to ameliorate Stressors and to attain Environmental and Biological Objectives.

An adaptive management framework is necessary to:

- Evaluate conservation measures for the hypothesized relationships between proposed actions, Environmental Objectives, and biological outcomes;
- Predict trade-offs between alternative sets of proposed conservation measures and to select the conservation measures with the best predicted outcomes;
- Monitor the response of environmental and biological metrics to implemented conservation measures and predicted outcomes; and
- Update hypotheses, stressor evaluations, and Environmental Objectives over time in response to monitoring and new information.

NEXT STEPS FOR THE STANISLAUS RIVER

The next steps in developing a comprehensive conservation strategy for salmonids in the Stanislaus River will be the design of a suite of specific conservation actions (a comprehensive conservation strategy), including the monitoring elements needed to evaluate the performance of actions individually and collectively. Such actions can and should be evaluated based on their ability to alleviate the priority Stressors, and to attain the Environmental and Biological Objectives identified here. Stakeholders, resource managers, and decision-makers can employ the SEP group's goals, objectives, and stressor evaluations to assess the specific contributions of different Conservation Actions (alone and together) to the Biological and Environmental Objectives. Following implementation of Conservation Actions, information developed through monitoring can be synthesized to allow measurement of an action's effects, in terms of the environmental conditions (Stressors and Environmental Objectives) it was intended to modify. This adaptive management approach enables efficient adjustment of Conservation Actions and the conservation strategy, as needed. If monitoring indicates that Conservation Actions are not performing as intended, then changes to the actions, or additional actions, will be implemented to ensure that Environmental Objectives and Biological Objectives are reached.

The SEP's logic chain framework (Figure TS-2) also facilitates design of efficient and powerful monitoring plans. Implementation of the conservation actions will require various levels of monitoring, including site-specific monitoring to document compliance and performance of specific measures as well as system-wide monitoring to evaluate overall effectiveness. Monitoring activities will need to produce data that are relevant to assessing progress at all levels of the logic chain structure; monitoring results should inform managers whether progress is being made towards the following:

1. Intended performance of individual conservation actions
2. Stressor reduction/elimination
3. Environmental Objectives
4. Biological Objectives

The SEP's goals, objectives, and stressors also encourage targeted and efficient monitoring of individual conservation actions. When conservation actions are developed, their projected effect on relevant stressors and, in particular, their expected contribution towards attainment of Environmental Objectives must be described. Clearly, monitoring needed to assess performance of conservation actions can only be determined after the conservation strategy is described in detail. However, the monitoring needed to evaluate progress towards larger desired outcomes (items 2 through 4 in the list above) has been defined by the performance metrics presented in this report. In certain cases, the stressors addressed by a conservation action may transcend the effect of any particular physical/chemical environmental condition; actions that are designed to reduce predation pressure fall into this category. In such cases, monitoring plans that accompany the proposed action should be specific with regard to the way in which the action is expected to reduce the stress, so that the effect of the action can be tracked by relevant monitoring.

The SEP Group is prepared to evaluate conservation plan proposals for the Stanislaus River to determine how likely they are to produce the Environmental and Biological Objectives. Such an evaluation will be limited to SEP group members that did not participate in development of proposed conservations strategies. Evaluations will be conducted using a systematic and transparent process to document likely effects, uncertainties, and potential unintended negative consequences of actions. To be evaluated, a conservation strategy will need to:

- Be comprehensive (i.e., address desired outcomes throughout the riverine life history of the focal populations)
- Be specific in terms of the scale and timing of actions
- Document its projected effect on Stressors and the attainment of objectives

BEYOND THE STANISLAUS RIVER

In addition to assisting with the evaluation of conservation plans that emerge for the Stanislaus River, the SEP Group intends to develop goals and objectives for the Tuolumne, Merced, and lower San Joaquin rivers. In addition, the SEP Group will evaluate the stressors in each of those environments and how they affect relevant life history stages of the focal populations. This process will culminate in the integration of a basin-wide vision.

Integration of goals and objectives for different waterbodies may require adjustment for the sake of consistency. Additionally, some desired outcomes can only be articulated in the context of goals and objectives for all three San Joaquin River tributaries. For instance, management of adult salmonid straying is a basin-wide issue that will require improved conditions on each of the tributaries and hatchery management objectives. Similarly, identification of effects on one life stage that are driven by changes in the previous life stage (e.g., bigger, healthier juvenile outmigrants contribute to better survival through Delta and less stressful adult migration through Delta/lower river leads to higher spawning success/fecundity upstream) will require a basin-wide approach.

Having created the template with the Stanislaus River process, the application of the SEP approach to other waterways in the San Joaquin Basin can happen much more quickly, provided there is adequate facilitation and technical support. The beauty of the SEP approach is that work towards desired conditions on the Stanislaus River can begin immediately. For example, while Delta restoration is essential to attaining desired conditions for the Central Valley's salmonid populations, there is no need to delay the process of attaining Stanislaus-specific Biological Objectives while required outcomes for the Delta are further defined. The SEP's Watershed-specific Goals and Biological Objectives are local in scope and achievable. The time to begin moving towards this vision is now.

1 INTRODUCTION

Over the past few decades, efforts have been made to reverse and restore the declining health of riverine and estuarine habitats in the Central Valley and, in particular, their anadromous fish fauna. Yet, these habitats and key populations continue to be at risk of further degradation and decline. This is partially attributable to the lack of a common vision of conservation success among resource agencies, conservation groups, and water districts. A vision of conservation success must include appropriate targets of success and prioritized actions based on their ability to attain overarching goals and objectives. In addition, a vision of conservation success provides the framework for developing, evaluating, and implementing appropriate strategies for conservation and restoration. Without such a framework, science-based adaptive management cannot be applied to solve complex ecosystem and water management issues.

The lack of conservation success is recognized in multiple regulatory processes associated with the lower reaches of the San Joaquin River and its major tributaries, the Stanislaus, Tuolumne, and Merced rivers. Because these regulatory processes may affect change in fisheries and the operations of various water and resource management agencies, a large group of stakeholders interested in resolving long-standing ecosystem and water management issues convened to work on a process to negotiate a settlement for these various regulatory processes. This settlement negotiation process, called the San Joaquin Tributary Settlement Process (SJTSP), originally discussed a set of goals for the San Joaquin River system, but the stakeholders soon realized that science-based methods should be used to establish desired outcomes (including goals, biological objectives, and environmental objectives) for the river and to evaluate conservation proposals in the context of those desired outcomes. The SJTSP stakeholders decided to focus first on one major San Joaquin River tributary—the Stanislaus River—due to the size and complexities of the overall San Joaquin River basin.

Scientists with appropriate expertise were identified by the various parties to participate in an effort to identify a new pathway for improving the status of Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley rainbow trout and steelhead (*O. mykiss*) populations in the San Joaquin River basin. The collaboration involved experts from the

California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation, National Marine Fisheries Service (NMFS), American Rivers, The Bay Institute, Trout Unlimited, and The Nature Conservancy. The process was open to all stakeholders. This collaborative group pursued a Scientific Evaluation Process (SEP) and identified itself as the SEP Group.

The SEP Group focused on defining desired outcomes for three fish populations: spring- and fall-runs of Chinook salmon and *O. mykiss* (both resident and migratory forms). This focus was motivated by the following:

- The understanding that restoring conditions that support these populations would provide significant benefits to other ecosystem attributes and functions in the lower Stanislaus River watershed; and
- The availability of data on salmonids relative to other aquatic biological resources in the Stanislaus River.

The SEP Group developed goals and specific objectives for the salmonid populations of the Stanislaus River that incorporated and harmonized numerous federal and state policies, programs, and plans, including the Anadromous Fish Restoration Program (USFWS 2001), Bay-Delta Water Quality Control Plan (WQC Plan), Endangered Species Act (ESA) recovery plans, and relevant CDFW code sections. The programs and plans that the SEP Group considered as part of this framework are discussed in detail in Section 2.3.1.

The SEP is intended to help provide a common scientific foundation of fact for all parties engaged in developing a comprehensive approach to solving San Joaquin River basin aquatic resource management issues as well as parties engaged in relevant regulatory processes, including specifically:

- The State Water Resources Control Board (SWRCB) update of the WQC Plan, as called for under the state Porter-Cologne Water Quality Control Act (Porter-Cologne Act) and the federal Clean Water Act; and
- Federal Energy Regulatory Commission relicensing proceedings.

The purpose of the SEP is three-fold, as follows:

1. Develop a clear, scientifically justified vision for the desired status of fall-run and spring-run Chinook salmon and resident (rainbow trout) and migratory (steelhead) forms of *O. mykiss* in the Stanislaus River and larger San Joaquin River basin;
2. Provide well documented and transparent technical guidance on the conditions necessary to attain that vision; and
3. Provide a foundation for evaluating the effectiveness of proposed actions to achieve the conditions necessary to realize the vision.

This report explicitly addresses the first two purposes, and its development supports the third purpose as it relates to the Stanislaus River. The vision and technical guidance developed here will inform similar products for other major San Joaquin River tributaries (the Tuolumne and Merced rivers) and for the mainstem San Joaquin River downstream of its confluence with the Merced to the Sacramento-San Joaquin Delta (Delta). The SEP Group envisions that the strategies proposed to achieve the conditions necessary to restore salmonid populations to the Stanislaus River and throughout the San Joaquin River basin would be developed through discussions and multi-party negotiations among resource agencies, conservation groups, and water districts. Proposed strategies (suites of Conservation Actions) would then be reviewed using a systematic process (e.g., the methodology described for the Delta Regional Ecosystem Restoration Implementation Program that was developed by state and federal agencies). The overarching purpose of these efforts and strategies is to restore the San Joaquin River and its tributaries to support sustainable native fish populations and other living resources.

2 SCOPE, CONTEXT, AND CONSIDERATIONS

2.1 Historical Context

San Joaquin River basin salmonid populations were once some of the largest in California's Central Valley (CDFG 1990). Historically, the San Joaquin River and its tributaries supported spring- and fall-runs of Chinook salmon and steelhead (Yoshiyama et al. 2001; Moyle 2002). As recently as the 1940s, spring-run Chinook salmon were the dominant salmon run in the San Joaquin River basin (Fry 1961).

From the 1940s to the 1980s, extensive water storage development occurred throughout the San Joaquin River watershed, resulting in a large proportion of flow being diverted from river channels. In addition, spawning and rearing habitats were degraded, and access to historical spawning and rearing reaches was blocked by dams. This habitat degradation and loss caused by construction and operation of dams, along with habitat degradation caused by gravel mining, channelization, and other human actions, has led to significant declines in spring- and fall-run Chinook salmon and steelhead populations. For decades, spring-run Chinook salmon were considered to be extirpated from the San Joaquin River basin (Fisher 1994); however, more recently, "spring-running" Chinook salmon have been observed in the Stanislaus and Tuolumne rivers (Franks 2012).

2.2 Considerations for Biological and Environmental Objectives

The SEP Group expressed its vision for the desired status of Stanislaus River salmonid populations in the form of "Biological Objectives" (Section 6). They developed "Environmental Objectives" (Section 7) to provide technical guidance on the conditions necessary to attain the Biological Objectives. Objectives were developed using the following considerations:

1. Objectives are "Specific, Measureable, Achievable, Relevant to overarching goals, and Time-bound" (S.M.A.R.T.).
2. Biological and Environmental Objectives for the Stanislaus River are specific to conditions that can be controlled or greatly influenced by actions in the Stanislaus River. In cases where setting Stanislaus River-specific objectives require making assumptions regarding outcomes in other parts of the salmonid life cycle,

those assumptions are stated.

- For example, productivity (juvenile survival) objectives for the Stanislaus River assume and reflect anticipated improvements in survival through the Delta because it is not possible to restore adequate salmonid productivity unless conditions improve throughout the freshwater environments used by these fish.

3. Biological and Environmental Objectives provide a framework for evaluating proposed actions. Actions necessary to achieve these objectives are not proposed or evaluated in this document.
4. Biological and Environmental Objectives for the Stanislaus River are intended to serve Central Valley Goals and Objectives.

   - For example, Central Valley Goals and Objectives that set expectations for abundance of salmonids produced by or returning to the Stanislaus River have already been identified (e.g., the Anadromous Fish Restoration Plan [AFRP] identifies a target of natural production of 22,000 harvestable size fall-run Chinook salmon; USFWS 2001) or were derived with reference to policy guidance and outcomes on similar systems in the Central Valley. These expectations were used to inform development of Biological and Environmental Objectives for the Stanislaus River. However, the SEP Group did not identify adult abundance objectives for the Stanislaus River because the group recognized that abundance is related to conditions throughout the salmonid life cycle and cannot be tied solely to conditions in the Stanislaus River.

5. Levels of four viability parameters—abundance, productivity, diversity, and spatial structure—determine if salmonid populations are viable, healthy, and in good condition and to what level of risk they are exposed (McElhany et al. 2000). These parameters influence each other directly and indirectly. For any population, failure to achieve threshold levels for any one of these parameters represents a threat. Therefore, the SEP Group specifically addresses these four parameters for each population through life stage-specific Biological Objectives.
6. While the specific Biological and Environmental Objectives reported here have been developed for the Stanislaus River, they are intended to be applied in concert with analogous targets specific to all rivers in the San Joaquin River basin. Thus, creating ecological conditions in the Stanislaus River necessary to support Biological

Objectives for the target salmonid populations is only one component of a broader strategy for supporting vibrant and diverse populations of Chinook salmon and *O. mykiss* throughout the San Joaquin River basin.

7. In addition to tributary-specific objectives, San Joaquin River basin-wide objectives will need to be established in some cases.
   - For example, the production of juvenile salmonids from all San Joaquin River tributaries will affect the quantity and quality of rearing and migration habitats needed in the lower San Joaquin River to support the combined outmigration. Additional objectives, to which the Stanislaus will need to contribute but which depend on the relative contributions of other San Joaquin tributaries, will be developed after the SEP Group develops biological goals and objectives for the Tuolumne and Merced rivers.
8. The objectives discussed in this report focus on salmonid species; however, their cumulative effect is intended to benefit numerous native species and habitat types throughout the Stanislaus River watershed, the San Joaquin River corridor, and into the Delta. Because salmonids are a relatively resilient and hardy species, attainment of objectives designed to restore these populations may not represent the level of restoration of the Stanislaus River, lower San Joaquin River, or Delta required by other species or downstream ecosystems.
9. All objectives identified here are believed to be measureable using existing technology, and existing monitoring is adequate to monitor attainment of some objectives. However, additional monitoring may be necessary to evaluate the attainment of some of the S.M.A.R.T. objectives identified in this report.
10. Successfully restoring the sustainability and resiliency of anadromous fish populations in the San Joaquin River basin may require restoring access to habitats in watersheds above dams. All major rivers in the San Joaquin River basin are identified by NMFS (2014) as candidates for building fish passage for access to upstream habitats. The SEP Group makes no assumptions that specific measures would occur in the future. Rather, the conservation measures to be developed through future discussions and negotiations are expected to respond to and serve the Biological and Environmental Objectives identified in this report and will be evaluated as to how well they support attainment of the objectives.

2.3 Scope

The SEP Group developed Biological and Environmental Objectives for the Stanislaus River in the context of policy, geographical, and biological considerations.

2.3.1 Policy Considerations

Numerous laws, programs, and plans at the state and federal level call for restoring healthy anadromous salmonid populations in the Central Valley and the San Joaquin River. The SEP Group's Biological and Environmental Objectives for restoring salmonids of the Stanislaus River incorporated and attempted to convey technical guidance within a framework that is consistent with and harmonizes the requirements of these laws, plans, and programs (listed below).

Many policies, laws, and regulations call for the restoration of anadromous fish populations in the Central Valley and the San Joaquin River's watershed, but these policies do not necessarily apply consistently to different populations as illustrated in the examples below:

- Central Valley spring-run Chinook salmon and steelhead are listed under ESA, but fall-run Chinook salmon are not listed.
- Doubling of Chinook salmon runs is required under the WQC Plan, California Fish and Game (F&G) Code, and Central Valley Project Improvement Act (CVPIA) and doubling of steelhead is required under the F&G Code and CVPIA. However, specific restoration targets for the San Joaquin watershed and its tributaries were developed under the AFRP only for fall-run Chinook salmon, not spring-run or steelhead.

The Biological and Environmental Objectives developed by the SEP Group for the Stanislaus River were designed to support outcomes consistent with, and goals derived from, application of the laws, policies, and programs described below.

California Fish and Game Code Sections 2760-2765

The purpose of the Keene-Nielsen Fisheries Restoration Act of 1985 is to prevent further declines in fish and wildlife; restore fish and wildlife to historical levels where possible; and enhance fish resources through the protection of, and an increase in, the naturally spawning salmon and steelhead resources of the state.

California Fish and Game Code Section 5937

This section of the F&G Code is intended to balance the needs of California's native fish and the construction and operations of dams by requiring dam operators to release enough water to maintain fish populations below the dam "in good condition" (Börk et al. 2012). This section of the F&G code was enacted in 1915 and has rarely been implemented. However, one notable instance where the code was used was a decision by the Court of Appeals on suit brought by California Trout concerning Mono Lake tributaries (California Trout, Inc. v. State Water Resources Control Board 1989 ["CalTrout I"]).

California Fish and Game Code Sections 6900-6924

The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act declares that it is the policy of the State to significantly increase the natural production of salmon and steelhead by the year 2000, and it directs the CDFW to develop a plan that strives to double the current natural production of salmon and steelhead resources. This is the same narrative (i.e., a doubling goal) as in the CVPIA.

Central Valley Project Improvement Act

In 1992, the CVPIA (Public Law 102-575) revised the goals of the federal Central Valley Project; Title 34 makes protection, restoration, and enhancement of fish and wildlife a goal of the Central Valley Project on par with its water delivery goal. Specifically, Section 3406(b)(1) of Title 34 requires that the secretary of the U.S. Department of the Interior (USDOI) develop and implement a program that makes all reasonable efforts to ensure that, by the year 2002, natural production[2] (i.e., the abundance of fish available for harvest in the ocean fishery excluding fish originating from hatcheries) of anadromous fish in Central Valley rivers and streams will be sustainable on a long-term basis at levels not less than twice the average levels attained during the 1967 through 1991 period. On

[2] Production refers to the abundance of fish available to the ocean fishery and should not be confused with escapement, which refers to the number of adult fish that return to freshwater habitats to spawn.

January 9, 2001, the USFWS released the Final Restoration Plan for the Anadromous Fish Restoration Program to comply with this narrative requirement, which is referred to as the “doubling goal.” The AFRP calculates an annual natural production target of almost 1 million Chinook salmon (including 750,000 fall-run, 68,000 spring-run, 110,000 winter-run, and 68,000 late-fall-run Chinook salmon). Production targets consistent with attainment of the overall “doubling goal” are established for most Central Valley rivers, including the Stanislaus; however, there are gaps in the river-specific targets of the AFRP. For example, the AFRP established a target of 13,000 naturally produced steelhead at the Red Bluff Diversion Dam (RBDD), but no steelhead targets have been established for the remainder of the Central Valley watershed, which would be much larger than the current (partial) target. Similarly, the AFRP does not establish targets for restoration of spring-run Chinook salmon in San Joaquin tributaries, even though the San Joaquin basin was once their stronghold in the Central Valley.

Federal Endangered Species Act Determinations and Plans

In 1998, NMFS listed the distinct population segment of steelhead in the Central Valley as threatened under ESA (63 Federal Register [FR] 13347); steelhead are present in the Stanislaus River. In 1999, the NMFS listed the Central Valley spring-run Chinook salmon evolutionarily significant unit (ESU) as threatened under ESA (64 FR 50394). Spring-run were believed to have been extirpated from the San Joaquin basin. The final NMFS recovery plan for endangered salmon of the Central Valley calls for reestablishment of at least two viable spring-run populations to the San Joaquin basin as a critical step in delisting this species (NMFS 2014). Recent status reviews conducted by NMFS resulted in no changes being made to the status of spring-run Chinook salmon or steelhead under ESA (NMFS 2011a, 2011b). In 1999, NMFS considered information about the Central Valley fall-run and late fall-run Chinook salmon ESU and determined that listing was not warranted. However, NMFS considered the fall-run and late fall-run Chinook salmon ESU to be a candidate species for listing in the future, so they are managed as a species of concern (NMFS 2009a).

San Joaquin River Restoration Program

After the completion of Friant Dam by the federal government in the 1940s, nearly 95% of the river's flow below the dam was diverted. As a result, 60 miles of the river ran dry, the second largest salmon population in the state was lost, and local fish and wildlife populations declined. Decreased water flows and water quality degradation impacted downstream farms and communities. Since 2009, the U.S. Bureau of Reclamation, USFWS, NMFS, CDFW, and the California Department of Water Resources have been working together to implement the San Joaquin River Restoration Program (resulting from a 2006 legal settlement between environmental groups, the Friant Water Users Authority and the federal government, and subsequent federal legislation) to restore spring-and fall-run Chinook salmon to the mainstem San Joaquin River downstream of Friant Dam. In the long term, this program intends to restore annual runs of up to 30,000 spring-run Chinook salmon and 10,000 fall-run Chinook salmon.

State Water Resources Control Board's 2006 Water Quality Control Plan

The WQC Plan contains the current requirements under federal Clean Water Act Section 303(c)(33 U.S.C., § 1313(c)) and Section 13240 of the state Porter-Cologne Act to protect the beneficial uses of the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Estuary). Specifically, it identifies beneficial uses of water in the Estuary, including its watershed, water quality objectives to protect those beneficial uses, and a program of implementation for achieving the water quality objectives. In the 2006 WQC Plan, the narrative objective for salmon protection states "Water quality conditions shall be maintained, together with other measures in the watershed, sufficient to achieve a doubling of natural production of Chinook salmon from the average production of 1967 to 1991, consistent with the provisions of state and federal law" (SWRCB 2006). The SWRCB is currently engaged in updating the WQC Plan and is proposing new flow standards on the lower San Joaquin River and its three eastside tributaries for the protection of fish and wildlife beneficial uses.

The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988

The California Advisory Committee on Salmon and Steelhead Trout was created in 1983 to develop a strategy for the conservation and restoration of salmon and steelhead resources in California. The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 was signed by the governor of California to implement the advisory committee's recommendations, which included doubling the natural production of Central Valley salmon and steelhead.

2.3.2 Geographical Considerations

The SEP Group focused on the Stanislaus River as a first step toward developing a transparent framework for identifying desired outcomes for salmonids in the San Joaquin River basin and the environmental conditions needed to support those outcomes (Figure 1). This focus was justified by the following:

- Current habitat conditions and potential for restoration of the Stanislaus River;
- The relatively large amount of information available on the Stanislaus River compared to others in the San Joaquin River basin; and
- The high level of interest by the SWRCB and other stakeholders in the WQC Plan process:
  - They are expected to issue new flow standards for the Stanislaus River and the two other main tributaries (the Merced and Tuolumne rivers) to the lower San Joaquin River.

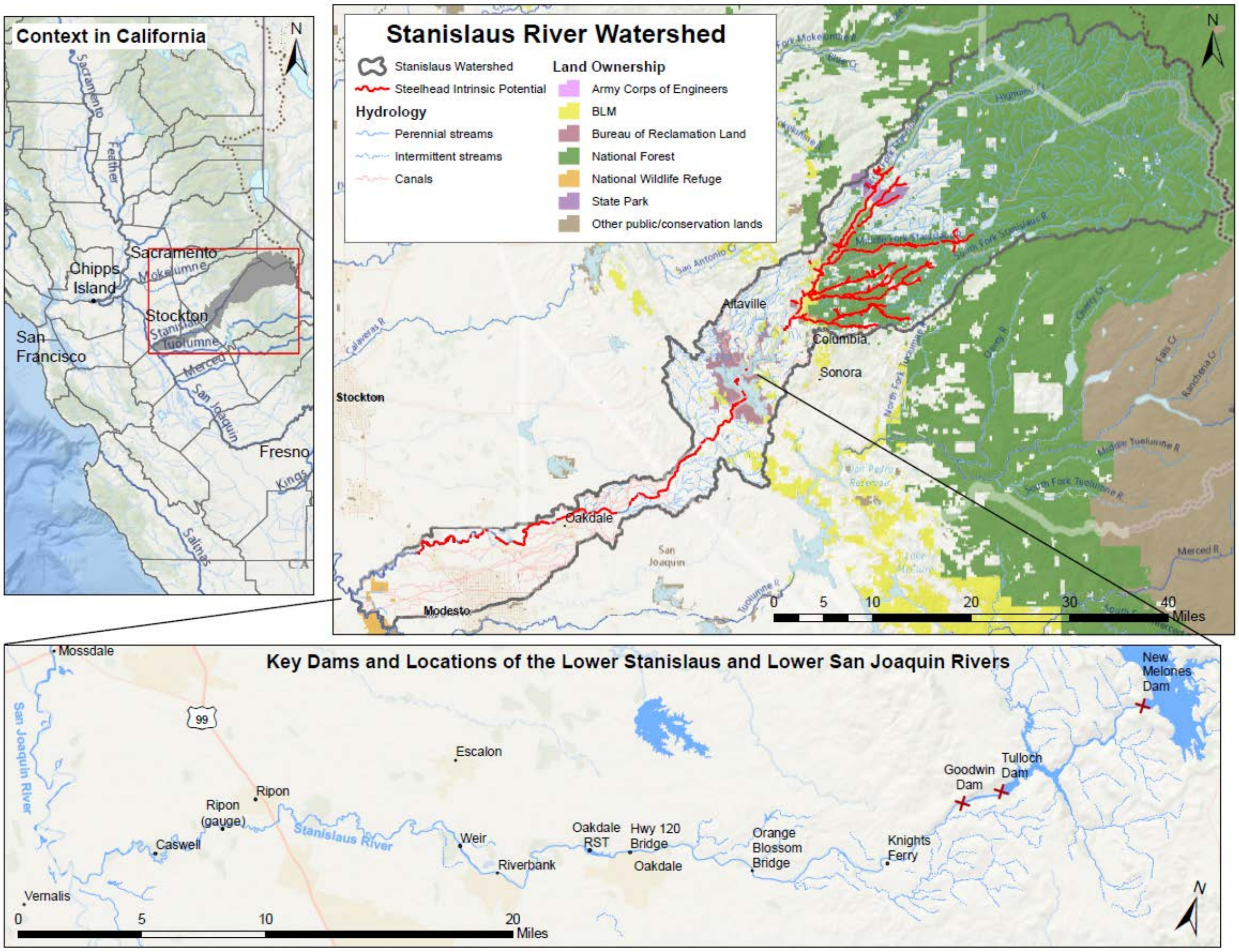

Figure 1
Key Dams and Features of the Lower Stanislaus River

Focusing on the Stanislaus River meant articulating desired outcomes for its salmonid populations and defining the suite of environmental conditions on the river that are necessary to attain those outcomes. Plan Goals and Biological and Environmental Objectives are specific to outcomes that can be attained by actions on the Stanislaus River; they represent conditions on and outcomes from the Stanislaus River that are consistent with laws, policies, and programs related to restoration of salmonids throughout the Central Valley. Additionally, the SEP Group recognized that the Stanislaus River must contribute to conditions in the lower San Joaquin River and southern Delta, but, in many cases, it is not possible to completely define that contribution without performing a similar evaluation of goals and objectives for the other rivers in the San Joaquin River basin. The SEP Group's intent is that the template developed for the Stanislaus River will be used to develop similar sets of Biological and Environmental Objectives for the Tuolumne and Merced rivers and the lower mainstem San Joaquin River (the area of the watershed downstream of the confluence of the San Joaquin and Merced rivers and upstream of the Delta).

The spatial scope of this initial effort to develop Biological and Environmental Objectives for the Stanislaus River includes the Stanislaus River from Goodwin Dam to its confluence with the San Joaquin River (Figure 1). While the Biological and Environmental Objectives are specific to reaches within the Stanislaus River, the SEP Group recognizes that establishing Biological Objectives for Chinook salmon and *O. mykiss* in the Stanislaus River and identifying the ecological conditions required to support them does not end at the Stanislaus River. Suitable habitat conditions in the lower San Joaquin River are necessary for the successful restoration of Chinook salmon and *O. mykiss* populations in the Stanislaus River. The SEP Group estimates that current survival of fall-run Chinook salmon through the Stanislaus River to the San Joaquin's entry into the Delta is extremely low (less than 1%; Section 6.2.1 and Appendix A).

Biological Objectives for the Estuary and Pacific Ocean were not addressed because these ecosystems respond to ecological drivers and human actions that are beyond the geographic scope identified for the SEP Group's consideration. However, in some cases (e.g., juvenile survival targets), assumptions regarding future conditions in the Estuary and Pacific Ocean were necessary in order to estimate the Stanislaus River's contribution to attaining larger, Central Valley-wide Goals. When assumptions about future conditions beyond the Stanislaus River were necessary in order to establish targets for the Stanislaus River, the assumptions and the rationale behind them were described in detail.

2.3.3 Biological Considerations

The overarching intent of the SEP is to restore native salmonids and associated habitat and ecosystem processes in the Stanislaus River and throughout the San Joaquin River basin. Salmonids are the focus of many policies regarding environmental and water management in the Central Valley, and they are among the best-monitored and studied organisms in this area. Achievement of all Biological Objectives for a given population is intended to result in a population that is viable, healthy, and sustainable. Achievement of all Environmental Objectives is hypothesized to achieve the Biological Objectives for salmonids and support other native river-dependent species. The Biological Objectives developed by the SEP Group focused on the following species/runs:

- Fall-run Chinook salmon,
- Spring-run Chinook salmon, and
- *O. mykiss*.

Attaining the Biological and Environmental Objectives for these salmonids may not be adequate to restore all of the important ecological and physical functions of the Stanislaus River. In addition, establishing conditions necessary to attain Biological Objectives for salmonids in the San Joaquin River basin's tributaries may not result in conditions necessary for achieving sustainable benefits in the Delta and Estuary. Thus, protecting and restoring other aquatic resources in the San Joaquin River basin, the Delta, or the Estuary may require contributions from the Stanislaus River in addition to those described in this report.

2.4 Developing Foundational Elements Necessary for Conservation Planning ("Logic Chain")

Too often, conservation planning begins with identifying and describing a suite of actions, without first defining the problem that the actions are meant to solve and explicitly defining a set of objectives that can be used to measure success. Taking these first important steps of defining goals and objectives provides a transparent basis for evaluating implications and trade-offs among proposed actions, implementing actions efficiently and within certain time-bounds, and managing actions towards attainment of desired conditions.

The SEP Group did not develop or evaluate Conservation Actions that should be taken on the Stanislaus River in order to improve conditions for native salmonid populations. Rather, the group focused on foundational elements needed to understand the nature and magnitude of challenges to restoring target populations; these elements are also essential to managing restoration activities in an adaptive management context. By developing goals and objectives and by ranking and prioritizing the barriers that prevent attainment of those goals and objectives, the SEP Group sought to provide the "design criteria" for subsequent conservation planning and the benchmarks against which to prioritize, implement, and adjust Conservation Actions adaptively.

The SEP Group addressed the following questions to establish a logic chain for development of the Biological and Environmental Objectives for Chinook salmon and *O. mykiss* in the Stanislaus River and for identifying, ranking, and prioritizing stressors that prevent attainment of goals and objectives (Figure 2).

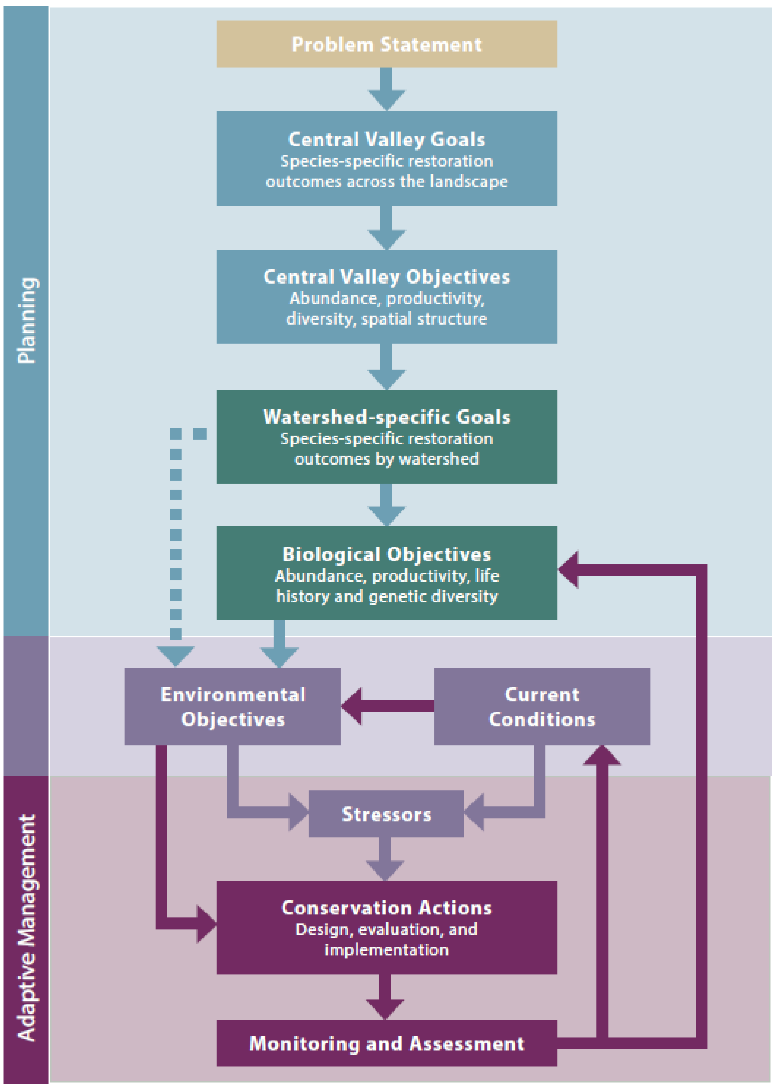

Figure 2

Scientific Evaluation Process Logic Chain

What is the problem?

For each target species and for the ecosystem as a whole, **problem statements** provide a concise declaration of the ecological issues that require attention. Problem statements are general and factual descriptions of the problem(s) and do not assume particular causes of, or solutions to, those problems. For target species, a problem statement would address, at a minimum, each attribute of viability for which the species is deficient. For example:
Central Valley spring-run Chinook salmon populations are imperiled because abundance is well below desired levels, survival rates are inadequate to achieve population growth, populations are severely constrained geographically, and the populations express only a narrow range of the life history variants that are typical of this species.

What outcome(s) will solve the problem?

Central Valley Goals present a vision for species-specific restoration actions across the Central Valley landscape and state desired outcomes that will solve the issue(s) identified in the problem statement. The Central Valley Goals describe outcomes that may be beyond the scope of this or other conservation planning efforts, but they are important for creating a context for any conservation strategy. For example, one Central Valley Goal for spring-run Chinook salmon is to:
Increase the spatial diversity of independent, viable spawning populations of Spring-run Chinook salmon, including establishment of populations in the Southern Sierra Diversity group.

What does solving the problem and attaining the goal look like?

Central Valley Objectives provide specificity to a related Central Valley Goal. Objectives are S.M.A.R.T. statements that indicate what level of restoration constitutes attainment of the goal. Central Valley Objectives provide a clear standard for measuring progress toward a desired outcome in the larger context of the Central Valley. The function of Central Valley Objectives is to define a magnitude of the problem and set a context for planning so that investment in conservation activities on the local scale (e.g., in the Stanislaus River Basin) is appropriately scaled to the larger conservation challenge.

What can efforts in the Stanislaus River contribute to the attainment of Central Valley Objectives?

To identify relevant targets for a specific plan, Central Valley-wide Goals and Objectives are filtered through the biological, geographic, and policy lenses that constrain the current planning effort. Consideration of the scope (i.e., geographic, policy, biological) for the planning effort enables identification of **Watershed-specific Goals** that can be addressed within that scope. Watershed-specific Goals are a subset of the Central Valley Goals and are tailored to support attainment of Central Valley Goals and Objectives. Watershed-specific Goals describe the contribution to Central Valley Goals and Objectives that can be attained within a particular watershed or geographic unit. For example, one watershed-specific goal for the Stanislaus River is to:

> Achieve freshwater survival rates for fall-run Chinook salmon that are typical of other self-sustaining populations of ocean-type Chinook salmon.

What is the suite of biological outcomes that characterize success?

Biological Objectives define Watershed-specific Goals in S.M.A.R.T. terms—they are the biological outcomes that define success in the area and for the species, and they harmonize the policies proscribed by the scope. For example:

> Freshwater survival rates (egg-smolt) for fall-run Chinook salmon spawned on the Stanislaus River will be XX% by year XXXX of the plan.

Biological Objectives related to focal species or populations are S.M.A.R.T. targets that must be attained within the plan's scope in order to realize Watershed-specific Goals and thereby support Central Valley Goals and Objectives (i.e., what species-specific conditions must be achieved or exist in the Stanislaus River in order to be consistent with the Central Valley Objectives?).

In the context of adaptive management, Biological Objectives are the metrics towards which all Conservation Actions and adjustments to those actions are directed. Until Biological Objectives have been attained, Conservation Actions must be implemented or improved; attainment of the Biological Objectives indicates that conservation efforts have been successful in attaining their related Watershed-specific Goals.

What is the suite of physical and ecosystem conditions that characterize success?

Environmental Objectives define the physical, chemical, and biological conditions that the SEP Group hypothesized are needed to attain the Biological Objectives. These values are specific to different species, life stages, and habitats and are derived from published literature (e.g., temperature and dissolved oxygen [DO] limits), conceptual and quantitative conceptual models (e.g., area of inundated floodplain), and professional judgment. Like other objectives, these values are specific, measureable, and achievable. They are intended to provide specific guidance for design and prioritization of Conservation Actions to achieve relevant Biological Objectives; their time bounds are defined by the Biological Objectives that they support.

Environmental Objectives are targets that support the attainment of Biological Objectives and Watershed-specific Goals. More specifically, Environmental Objectives quantify the conditions that best available science indicates will lead to the attainment of Biological Objectives. In an adaptive management context, Environmental Objectives should be thought of as hypotheses regarding conditions necessary to attain desired biological outcomes that should be evaluated through research and monitoring and adjusted as necessary to support the Biological Objectives. In the absence of new evidence, the working assumption is that until Environmental Objectives are attained, it is unlikely that Biological Objectives will be attained. Producing these conditions is believed to be necessary, but not a substitute for, attainment of the Biological Objectives. Environmental Objectives provide specific guidance and transparent linkages between the Biological Objectives and the design of Conservation Actions. Similarly, Environmental Objectives inform the design of monitoring activities because monitoring must be capable of detecting progress towards Environmental Objectives that result from Conservation Actions as well as progress towards Biological Objectives as a function of improvements in environmental conditions. If Biological Objectives are attained on a sustained basis prior to full attainment of Environmental Objectives, that would suggest the need to modify the Environmental Objectives in the light of this new evidence. Conversely, failure to attain Biological Objectives despite success in achieving Environmental Objectives is strong evidence that other stresses are impairing attainment of desired biological outcomes. This failure should trigger the following actions:

- New or enhanced management actions to improve environmental conditions and address additional stressors, and
- Refinement of the Environmental Objectives and analysis of stressors to capture those additional conditions critical achieving Biological Objectives.

What are the barriers to achieving Environmental and Biological Objectives?

Restoration of salmonid populations in the Stanislaus River will require substantial improvements in a variety of environmental conditions. In order to address the barriers to attaining those objectives (referred to in this report as "stressors") in the most efficient manner, the SEP Group characterized, documented, and scored stressors according to the magnitude and certainty of their effect. Magnitude and certainty scores reflected a comparison of current conditions (e.g., as documented in published peer-reviewed literature, grey literature, monitoring data) with relevant Environmental Objectives. Professional judgement of those most familiar with current conditions on the Stanislaus River was also incorporated into scoring of Stressors, but certainty scores were not high when professional judgement was the only source of information on current conditions. Stressor magnitude and certainty scores were then used to prioritize the need for Conservation Actions (e.g., those that would increase rearing habitat; or actions to reduce thermal stress) to eliminate the stress in the near term (when populations are low) and in the long term (assuming populations increase and anticipated changes to the regional climate materialize). Stressor magnitude and certainty scores were also used to characterize the type of response—conservation action, research, or improved monitoring—that would be appropriate for a conservation plan.

Stressors describe the current environmental conditions that prevent attainment of both Environmental Objectives and (both by extension and directly) Biological Objectives. Stresses to Environmental Objectives are generally measured quantitatively. Stressor scoring reflects a combination of the known and hypothesized magnitude of a given stressors effect on the attainment of Biological Objectives as well as the degree of scientific certainty regarding how resolving a stressor will support attainment of Environmental and Biological Objectives. As Conservation Actions are implemented, the relative ranking of Stressors should change as either 1) their effect is ameliorated, 2) scientific understanding of their effect changes, or 3) both of the above. Monitoring is necessary to determine whether Stressors are being ameliorated or becoming worse and whether biological outcomes are responding as expected to any changes in the stressor. Thus, while conservation planning and implementation will focus on attainment of Environmental Objectives and Biological Objectives, adaptive management will address stressors frequently and directly.

What actions can be taken to achieve the Environmental and Biological Objectives?
As described above, development and evaluation of Conservation Actions does not occur in this report. This report provides the basis for focusing, prioritizing, and evaluating Conservation Actions that will be proposed by others to relieve stress on target salmonid populations and lead to attainment of Environmental Objectives, Biological Objectives, and Watershed-specific Goals. These actions may include flow regime modifications and non-flow measures. Certain Conservation Actions may address Biological Objectives directly without addressing a specific Environmental Objective. For example, a conservation measure intended to reduce juvenile mortality rates (e.g., by directly manipulating competitor or predator populations) would be evaluated by its contribution to attainment of Biological Objectives for productivity.

Conservation Actions are intended to produce beneficial effects. These effects must clearly relate to reduction of high-priority Stressors and progress towards Environmental and Biological Objectives. Monitoring should be designed to detect whether actions are having their intended effects and whether they are having unintended negative effects relative to objectives. Adaptive management will apply monitoring results to adjust Conservation Actions to maximize the intended effect and eliminate or minimize undesirable effects.

For each run of Chinook salmon and the life history types of *O. mykiss* discussed in this report, development of the Biological Objectives centered on achieving the following generalized Watershed-specific Goals:

- Support the fullest natural expression of life history diversity as needed to increase population stability, resilience, and productivity;
- Support productivity (survival) rates characterizing a viable population that are necessary to attain Central Valley abundance and productivity objectives; and
- Maintain genetic integrity of wild stocks to avoid deleterious or undesirable effects to wild populations from introgression and hatchery influence.

Based on these goals, the SEP Group developed the following:

- Biological objectives related to life history, productivity, and genetic attributes of viability;

- Environmental Objectives needed to support the Biological Objectives; and
- Description and prioritization of stressors that prevent attainment of Biological Objectives now and in the future.

3 VIABLE SALMONID POPULATION ATTRIBUTES

The SEP Group's approach to defining Watershed-specific Goals and Biological Objectives for the Stanislaus River was based on four key attributes of viable populations—abundance, life history and genetic diversity, productivity, and spatial structure (McElhany et al. 2000; Lindley et al. 2007; NMFS 2014). These four attributes are referred to as the viable salmonid population (VSP) parameters. Criteria for VSPs (a concept developed by the NMFS [McElhany et al. 2000]) inform the ecosystem and habitat conditions needed to restore Chinook salmon and steelhead. By defining distinct attributes of a viable population in a measureable form, the VSP approach allows for a comprehensive, measureable description of a healthy population and for prioritization of threats to a population's health. The VSP approach is useful for describing a vision for restored salmonid populations because it clearly acknowledges that healthy populations cannot be characterized by any one population attribute (e.g., abundance); rather, all the VSPs must reach acceptable levels before a population can be deemed "healthy."

The Biological Objectives described in this report reflect the distinct outcomes required for salmonid populations in the Stanislaus River and acknowledge that these VSP criteria are inter-related and mutually supportive. For example, natural levels of intra-population diversity and productivity are necessary in order for a population to display an abundance associated with restoration on a sustainable, long-term basis. The scope of this effort (the Stanislaus River) necessitated a different degree of emphasis on each of the VSP parameters. For example, spatial structure (described in detail below) refers to the number and distribution of spawning populations, but the Stanislaus River will only support one spawning population of each of the target salmonids. In other words, spatial structure is most relevant at the species scale and it is outside of this effort's scope, which is focused on the populations within the Stanislaus River.

3.1 Abundance

Abundance, or the number of organisms in a population, is a common species conservation and management metric. Populations or species with low abundance are generally less viable and at higher risk of extinction than large populations for reasons that include increased susceptibility to environmental variation, demographic stochasticity, loss of genetic diversity, and interruption of mating systems. Abundance correlates with, and contributes to, other viability parameters, including spatial structure (i.e., distribution and extent), diversity, and productivity. Simply increasing the abundance of organisms (or any other single viability parameter) is not sufficient to guarantee viability into the future. In other words, population viability depends on maintaining acceptable levels of each attribute of viability.

Abundance is also a key metric for determining acceptable levels of harvest for commercially and recreationally valuable species like Chinook salmon. As a result, population abundance targets for this species must exceed the minimum necessary to insulate the population from extinction threats. Production targets (i.e., abundance measured as the number of fish that reach the age where they are targeted by the ocean fishery) for different populations of Chinook salmon and steelhead have been set for many Central Valley rivers; these are incorporated into numerous state and federal policies and regulations such as the AFRP (USFWS 2001) and the WQC Plan (SWRCB 2006).

Abundance is the product of fecundity and survival rates that occur throughout the salmonid life cycle. At the Stanislaus River's carrying capacity, available habitat will constrain abundance; the river's carrying capacity can be adjusted to be consistent with Central Valley Goals and Objectives for the Stanislaus River (e.g., by expanding spawning or rearing habitat availability). However, because abundance is not controlled solely by conditions on the Stanislaus River (i.e., many factors controlling abundance are beyond the geographical scope of this process), the SEP Group did not establish Biological Objectives for abundance of focal salmon populations.

3.2 Life History and Genetic Diversity

Genetic diversity and life history diversity are interrelated components. With respect to genetic diversity, the ability of Chinook salmon and steelhead to navigate and spawn in the rivers where they were born contributes to the highly variable life history patterns and genetic diversity characteristics by facilitating local adaptation (Taylor 1991; Waples 1991). Genetic differences among the different ESUs of Chinook salmon are maintained because many of the life history traits, such as season of adult migration, are genetically inherited

(Banks et al. 2000; Carlson and Seamons 2008). Individuals within an ESU may have locally adapted gene complexes that improve the survival of their offspring in that habitat (Waples 1991). Introgression among the ESUs or between hatchery and natural-origin salmon can disrupt these gene complexes, thereby changing life history traits and potentially reducing the success of offspring (Ford 2002; Araki et al. 2007). Therefore, to maintain the diversity and productivity of Chinook salmon in the Central Valley and allow ESUs to adapt to local conditions, it is important to create conditions that encourage successful reproduction within locally adapted gene pools and that limit gene flow among ESUs or with hatchery-origin populations.

Life history diversity is often cited as a crucial component of salmonid population resiliency. This is based on theoretical and empirical evidence that the maintenance of multiple and diverse salmon stocks fluctuating independently of each other reduces extinction risk and long-term variation in regional abundances (Roff 1992; Hanski 1998; Hilborn et al. 2003; Schindler et al. 2010). This "portfolio effect" of spreading risk across stocks can also act at the within-population scale (Greene et al. 2009; Bolnick et al. 2011). For example, juvenile Chinook salmon leave their natal rivers at different sizes, ages, and times of the year, and this life history variation is believed to contribute to population resilience (Beechie et al. 2006; Miller et al. 2010; Satterthwaite et al. 2014). Thus, preserving and restoring life history diversity is an integral goal of many salmonid conservation programs (Ruckelshaus et al. 2002). Finally, it is increasingly recognized that strengthening a salmon population's resilience to environmental variability (including climate change) will require expanding habitat opportunities to allow a population to express and maintain its full suite of life history strategies (Bottom et al. 2011).

As with Chinook salmon, life history diversity is critical to the success of *O. mykiss* populations. The native range of *O. mykiss* is widespread, in part, because of its diverse portfolio of life history patterns. *O. mykiss* have the ability to exist as anadromous or adfluvial forms; rear in high elevation headwater streams or coastal estuaries; and reside in lakes. In addition to the genetic component of life history diversity, some phenotypic diversity appears to be driven by individual condition and as a response to prevailing environmental conditions. Studies have shown that juvenile steelhead need to reach a minimum smolt size of approximately 140 millimeter (mm; 5.5 inches [in]) fork length (FL) to survive to maturity (Ward et al. 1989; Bond et al. 2008). As river systems vary widely in productivity (e.g., availability of food for juvenile fish), steelhead parr can take anywhere from 1 to 3 or more years to reach this size, so smolt ages vary depending on parr growth rates (Seelbach 1993). Age at first maturity can range from 1 to 4 years in the ocean, with jacks spending just 1 year and most adults spending 2 or 3 years in marine environments before sexually maturing. Unlike Pacific salmon, adult steelhead have the ability to spawn several times in their lifespan. This repeat spawning helps compensate for the relatively small run sizes relative to salmon and periodic inaccessibility or unsuitability of natal streams. A steelhead population's spawning timing can last several months (typically December to April), and emigration of smolts can span several months (typically February to June). Variability in smolt age, age at first maturity, spawning timing, and smolt emigration combine to produce a species that is highly adaptable to a wide range of stream environments, enabling it to succeed in many types of aquatic habitats—from Alaska's large, glacial fed rivers to small coastal streams in southern California.

An important property of wild steelhead that emerges from this variation is that there are usually not distinct cohorts of adults (Kendall et al. 2014). Wild adult steelhead in a river are typically a mix of many cohorts, with fish that smolted at 1 to 3 years of age, matured after 1 to 3 years at sea, with some on their second or third spawning run. Total ages of the adults can range from 2 to 7 or more years. The loss of one cohort to a poor year is not as critical to the viability of the population as it would be if the entire population were based on one or two strong cohorts.

Within the Central Valley, the extensive loss of historical habitat due to dams and the poor quality of the remaining spawning, rearing, and migratory habitats have led to a drastically reduced overall abundance of *O. mykiss* and the near-loss of the steelhead (i.e., anadromous) form in many watersheds. The steelhead form is especially sensitive to habitat loss because its persistence requires high quality fluvial spawning and rearing areas, migratory corridors with high survival, and reasonable ocean survival and productivity. Currently, many rivers in the Central Valley are dominated by one form of *O. mykiss*, the freshwater fluvial, or resident, form. The steelhead form is now largely dominated by hatchery fish, all of which are released as age-1 smolts, and increasingly mature after only 1 year in the ocean. Reversing the loss of life history diversity in *O. mykiss* and establishing conditions that favor the anadromous form to be expressed will require extensive habitat improvements in the rivers and the Delta.

Certain components of genetic and life history diversity are controllable by actions taken in the Stanislaus River basin, whereas others will require actions across the larger San Joaquin River basin watershed or larger geographic areas. For example, the diversity of juvenile ages and sizes at outmigration reflects conditions during the rearing and migration phases that occur in the river. The SEP Group established Biological Objectives for life history diversity of each focal population related to the distribution of size and timing of juvenile migration. On the other hand, limiting the influence of hatchery production on the genetic diversity of local populations may require both watershed-specific and region-wide actions. The SEP developed Biological Objectives related to genetic diversity and the stressors that prevent attainment of those objectives now and in the future. Local, watershed-specific solutions may result in progress towards those objectives, although full-attainment of the objectives may require a region-wide approach (i.e., as part of integrating desired outcomes for the Stanislaus with those to be developed for the Merced and Tuolumne rivers).

3.3 Productivity

Productivity represents the ability for populations to grow when conditions are suitable, which is essential to conservation success. Species or populations that display persistent negative population growth, as well as populations with limited ability to respond positively to favorable environmental conditions, are less viable and are at higher risk of extinction. The productivity parameters used in developing Biological Objectives for the Stanislaus River are expressed as population rates (e.g., survival, offspring per adult female). In the absence of density-dependent factors, the productivity parameters measure the ability of salmon to survive to reproduce and reproductive success (McElhany et al. 2000).

Desirable population growth rates are commonly determined by identifying an abundance target and a future date by which that abundance should be attained (e.g., NMFS 2012a). The population growth rate is then calculated as the minimum average population growth needed to achieve the desired abundance in the predetermined timeframe. However, this approach does not always result in productivity estimates that reflect healthy populations.

An example of this would be if the abundance target could be achieved in less time by a population displaying growth rates typical of the species as a whole.

While population growth rates vary depending on environmental conditions, population demography, and how abundance relates to local habitat carrying capacity, species are often characterized as having "intrinsic" population growth rates that reflect their life history and demographic characteristics (e.g., age at first reproduction, fecundity, survival, and sex ratio). The reproductive success rates and life stage-specific survival rates observed in VSPs are valid reference points for determining adequate productivity goals and targets for managed populations in the absence of density-dependent limitations.

Stage-specific productivity (e.g., egg to smolt survival) can be affected by creating suitable conditions within the habitat used by each life stage. The SEP Group developed Biological Objectives for productivity (survival rates) of salmonid life stages that utilize the Stanislaus River. The SEP Group recognizes that these survival rates may not be achieved when abundance levels approach the carrying capacity of the habitat; thus, the SEP Group's Biological Objectives for juvenile survival are intended to be measured when population abundance is not near estimated carrying capacity (McElhany et al. 2000). In addition, SEP Environmental Objectives specify the extent of habitat creation needed to expand carrying capacity of the Stanislaus River going forward.

3.4 Spatial Structure

Spatial structure refers to the geographic distribution of populations or individuals in a population. McElhany et al. (2000) suggest that a population's spatial structure is made up of the geographic distribution of individuals in the population and the processes that generate that distribution. The structure of a population depends on the quality of habitat available to the population, how the habitat is configured spatially, the dynamics of the habitat, and the dispersal characteristics of individuals in the population (McElhany et al. 2000).

Fresh et al. (2009) point out that spatial structure helps contribute to population persistence by the following:

- Reducing the chance of a catastrophic loss because groups of individuals are widely distributed spatially;

- Increasing the chance that locally extirpated or dwindling groups will be rescued by recolonization; and
- Providing more opportunity for long-term demographic processes to buffer a population from future environmental changes.

In addition, there is evidence that broader geographic extent may decrease extinction risk of North American fishes (Rosenfield 2002). Restoring areas that support source populations can increase the overall stability of metapopulations by increasing the number of individuals available to support nearby populations (Fullerton et al. 2011).

The SEP Group did not develop Biological Objectives for spatial structure because this parameter is typically evaluated at the species scale (e.g., number and distribution of populations throughout the Central Valley), and the geographic scope of this effort was limited to the Stanislaus River. Restoring spring-run Chinook salmon spawning population to the Stanislaus River (i.e., attaining the Watershed-specific Goals and Biological Objectives identified in this report) serves Central Valley Goals and Objectives regarding salmonid spatial extent because the Stanislaus River would represent an entirely new (restored) spawning population for this ESU in the Central Valley, as a whole, and the Southern Sierra Diversity Group, in particular (NMFS 2014). In addition, attaining Biological Objectives for fall-run Chinook salmon and *O. mykiss* will allow these populations to serve as vibrant source populations within their respective San Joaquin River basin metapopulations. Therefore, attaining desired biological outcomes on the Stanislaus River contributes to the system-wide spatial structure objectives for Chinook salmon and steelhead throughout the Central Valley (NMFS 2014).

4 CURRENT STATUS OF CHINOOK SALMON AND *O. MYKISS* IN THE SAN JOAQUIN RIVER BASIN

A general overview of the current status relative to historical status is described for each species below.

4.1 Fall-run Chinook Salmon

Historical records made by Spanish explorers in the early 1800s and later that century by John Muir, Livingston Stone, and others suggest that fall-run Chinook salmon were historically abundant throughout the San Joaquin River basin (Yoshiyama et al. 1996). As European settlement occurred in the area, salmon runs diminished due to habitat degradation and loss. According to a report by the Stanislaus River Fish Group, hydraulic mining and the dams associated with that practice likely caused the initial decline of Chinook salmon and steelhead runs in the Stanislaus River (SRFG et al. 2003). These early dams were small, temporary, and only partial impediments to movement.

While spring-run Chinook salmon were believed to be the primary salmon run in the Stanislaus River, fall-run Chinook salmon also historically inhabited the river and became dominant following construction of Goodwin Dam in 1912, which blocked upstream migration (Yoshiyama et al. 1996). Today, though not a state- or federally- listed species, fall-run Chinook salmon populations across the Central Valley are also severely impacted and vulnerable to extinction (Katz et al. 2012).

Production of fall-run Chinook salmon in the San Joaquin River basin often falls to very low levels (USFWS 2001). Fall-run Chinook salmon production in the Stanislaus River was estimated to average 10,868 fish from 1967 to 1991 (SFWO 2014). This estimate was used to generate the Central Valley Objective (AFRP target derived from the CVPIA "doubling goal") of natural production of 22,000 fish. Adult fall-run Chinook salmon escapement into the Stanislaus River averaged 3,087 fish from 2003 to 2013 (Gutierrez 2014). Escapement (which includes post-harvest mortality) is always less than production (which measures abundance prior to harvest) in a given year; still, these low levels of escapement indicate failure to achieve the CVPIA/AFRP production targets.

Fall-run Chinook salmon life history diversity is believed to be constrained in the Stanislaus River (Sturrock et al. 2015). For example, based on fall-run Chinook salmon size and date-at-migration from the Caswell rotary screw trap (RST; Figure 1 and Table 8), half of the smolt phenotype migrates within a period of less than 3 weeks in many years. Moreover, some smolt migrants are detected when temperatures or other conditions in the lower San Joaquin River may be inhospitable (e.g., after early June). Similarly, 50% of parr-sized fish pass Caswell in a period that is usually less than 1 month (Tables 6 and 8). Furthermore, in several years a small percentage of juvenile migrants are parr- or smolt-sized fish, whereas in other years (years when juvenile production is low), larger-sized migrants represent the vast majority of all juveniles detected at Caswell (Johnson 2014, pers. comm.). This constriction means that juvenile migrants do not exhibit the life history diversity that may be needed to capitalize on optimal conditions in the lower San Joaquin River, Delta, Estuary, and/or nearshore ocean environments. Fall-run Chinook salmon exhibit high inter-annual variation in size at migration on the Stanislaus River that is related to annual hydrology (Sturrock et al. 2015), which may be exacerbated by lack of adequate rearing habitat. Comparison of adult returns with subsequent juvenile outmigrant counts suggests density-dependent limitation on the Stanislaus River salmon population during dry years (Figure 3; Sturrock and Johnson 2016, pers. comm.).

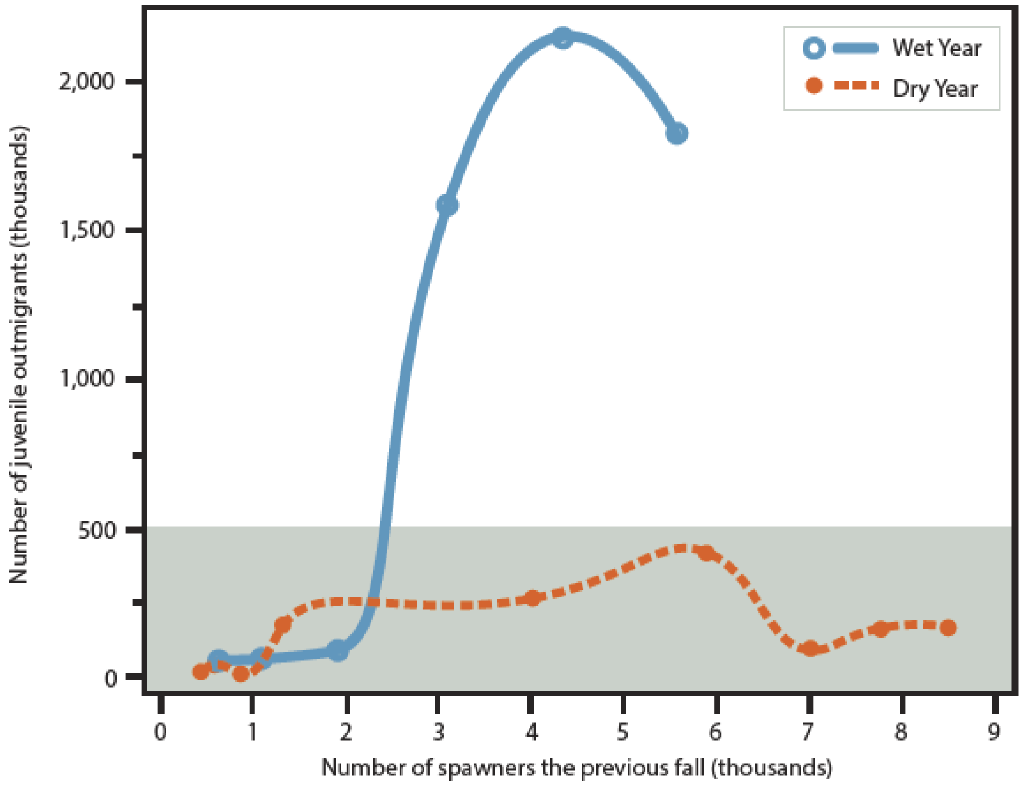

Figure 3
Relationship of Spawners to Subsequent Juvenile Production

Notes:
As measured at Caswell RST on the Stanislaus River. Wet versus dry year type distinction based on actual river flows. (Modified from Sturrock and Johnson 2016, unpublished data)

4.2 Spring-run Chinook Salmon

Historically, spring-run Chinook salmon occurred in the headwaters of all major river systems in the Central Valley, where natural barriers to migration were absent (NMFS 2014). This habitat was estimated to have supported runs as large as 500,000 fish between the late 1880s and 1940s (CDFG 1990: Yoshiyama et al. 2001). Although spring-run Chinook salmon were probably the most abundant salmonid in the Central Valley under historical conditions, large dams eliminated access to almost all historical habitat (Figure 4), and the run has suffered the most severe declines of any of the four Chinook salmon runs in the Sacramento River basin (Fisher 1994). Dams currently block access to the vast majority of historical spawning and rearing habitat of spring-run Chinook salmon and steelhead in the Central

Valley. Figure 4 depicts the loss of historical spawning habitat for steelhead, which is also generally representative of spring-run Chinook salmon habitat loss.

Before the construction of Friant Dam, 200,000 to 500,000 adult spring-run Chinook salmon were estimated in the San Joaquin River (Yoshiyama et al. 2001). For decades, spring-run Chinook salmon were considered extirpated from the San Joaquin River basin (Fisher 1994). More recently, there have been reports of "spring-running" Chinook salmon in San Joaquin tributaries, including the Stanislaus and Tuolumne rivers (NMFS 2013a), which suggests there is existing potential for spring-run Chinook salmon to recolonize and persist in the Stanislaus River. In addition, in 2014, a reintroduction program was initiated as part of the San Joaquin River Restoration Program, and 54,000 juvenile spring-run Chinook salmon were released into the river.

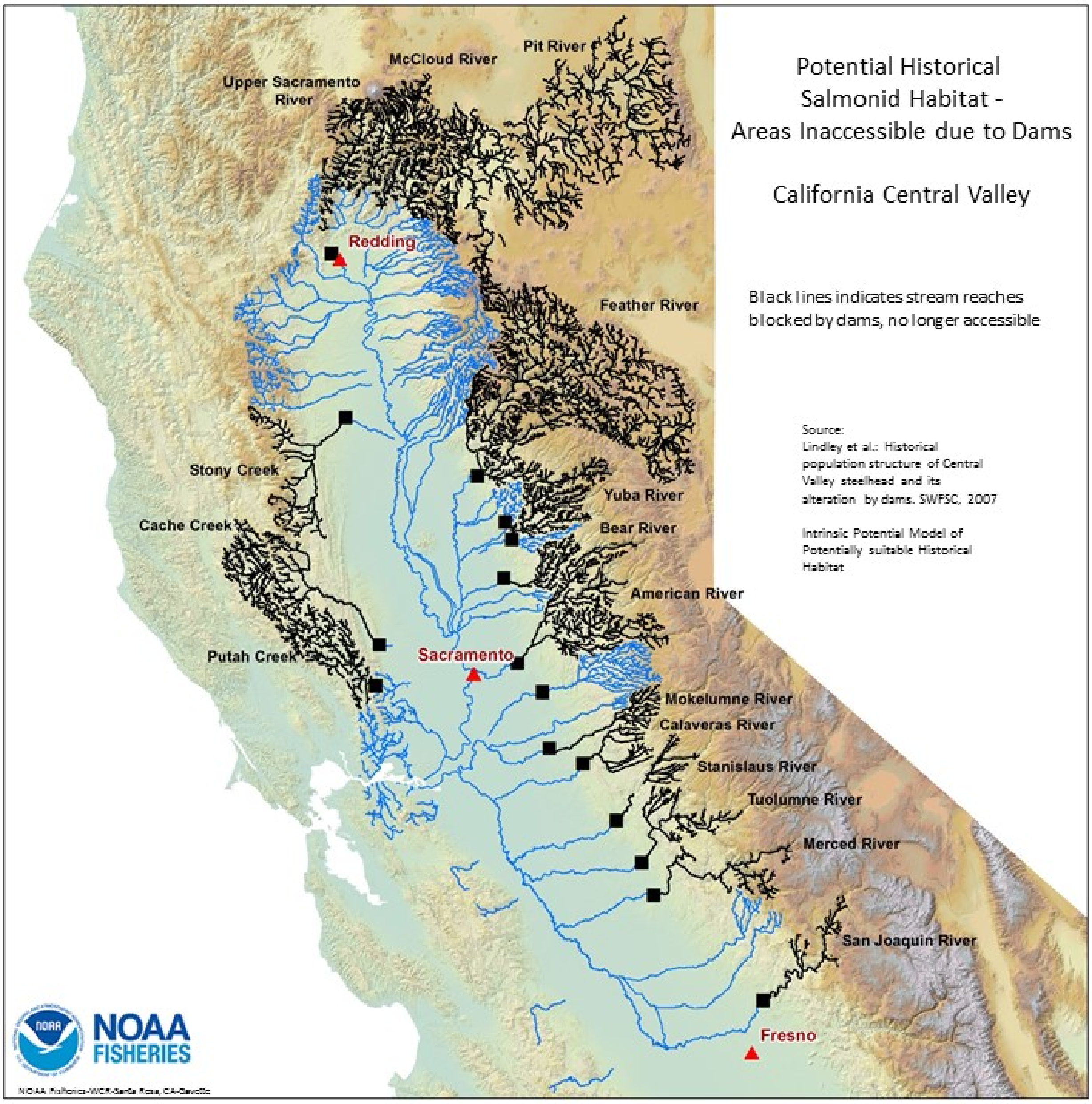

Figure 4

Dams that Currently Block Access to Historical Spawning and Rearing Habitat of Chinook Salmon and Steelhead in the Central Valley

4.3 *O. mykiss* (Steelhead and Resident Rainbow Trout)

Historically, steelhead were found from the upper Sacramento and Pit rivers south to the Kings River and possibly the Kern River systems and in east- and west-side Sacramento River tributaries (Yoshiyama et al. 1996). Lindley et al. (2006) estimated at least 81 steelhead populations were distributed throughout the tributaries of the Sacramento and San Joaquin rivers. Presently, dams block access to 80% of historically available habitat and all spawning habitat for about 38% of historical populations (Figure 4; Lindley et al. 2006).

In the San Joaquin River basin today, steelhead are rare and were once thought to be extirpated (McEwan 2001). However, Zimmerman et al. (2008) found evidence for steelhead presence in all three San Joaquin River tributaries, but their methods could not provide estimates of abundance. Monitoring has also detected small populations of non-hatchery origin steelhead in the Stanislaus River and other streams previously thought to be devoid of steelhead (McEwan 2001). In essence, steelhead are found in most Central Valley watersheds where people have made a concerted effort to look for them. A total of 23 *O. mykiss* larger than 406 mm (16 in) in length returned to the Stanislaus River from 2003 to 2011 based on weir count data distributed regularly by FISHBIO, although no sampling was conducted during spring for 2 years during this period (2006 and 2008).

An issue associated with estimating steelhead abundance is the difficulty in distinguishing anadromous fish from the resident form of *O. mykiss* that have matured in the river. In addition, due to their large size and strong swimming abilities, juvenile steelhead are rarely captured in RSTs such as the one located at river mile (RM) 8 near Caswell State Park. It is unclear at this time whether this lack of catch is due to the scarcity of smolts produced in the river, the known poor efficiency of RSTs at catching large juvenile steelhead, steelhead outmigration timing being outside the RST monitoring period, or some combination of these factors.

The resident *O. mykiss* population of the lower Stanislaus River is relatively abundant compared to the rare anadromous form. These stream-maturing and permanent river residents are most abundant in the cold, gravel-bedded reach from Goodwin Dam to Oakdale, and support a popular sport fishery. They are typically found in areas with high to moderate water velocity and some type of structure or cover such as boulders or cobble, large wood, or aquatic vegetation. Demographic information on the population, such as total abundance, age structure, and productivity, are largely unknown. One recent study by Bergman et al. (2014) estimated the total population of *O. mykiss* in the reach extending from the base of Goodwin Dam to 200 meters (m) downstream at about 3,400 fish. Captures of *O. mykiss* labeled as adults in the Oakdale RST show fish in this stage ranging from 300 mm FL to 475 mm FL. Records of *O. mykiss* caught at the weir have identified residents up to 550 mm FL, though most are in the 300- to 500-mm FL range.

4.4 Late Fall-run Chinook Salmon

Recent adult salmon weir counts in the Stanislaus River have documented small numbers of Chinook salmon migrating upstream in January, February, and March. Yoshiyama et al. (1996) mention that late fall-run Chinook salmon possibly occurred in the San Joaquin River (based on CDFW reports of late-fall-run fish).

Although the SEP Group did not develop Watershed-specific Goals or Biological Objectives for late fall-run Chinook salmon in the Stanislaus River, it recognized the importance and potential value of diversity in timing of adult migrations that would be provided by such a population, especially in light of the potential effects of projected climate change on environmental conditions. Restoration of this run to the Stanislaus River may be worth considering in the future.

5 STANISLAUS WATERSHED DESCRIPTION

The Stanislaus River is a major tributary of the San Joaquin River, approximately 113 miles in length, with a watershed covering approximately 1,075 square miles (USFWS 2008; Figure 1). The Stanislaus River originates as the north, middle, and south forks in the western slopes of the Sierra Nevada, mainly in the Stanislaus National Forest. Land uses in the upper and lower watersheds are distinctive. Approximately 90% of the upper watershed (above Goodwin Dam) is forest and 10% is agriculture. While the upper watershed (approximately 940 square miles) remains relatively undeveloped, the lower watershed has been extensively developed to provide water, hydroelectric power, gravel, and conversion of floodplain habitat for agricultural and residential uses (SRFG et al. 2003), with 61% of the land area in agricultural production, 34% in urban development, and 5% is undeveloped.

The Stanislaus River is extensively dammed and diverted. The 32 dams within the Stanislaus River watershed have a total capacity of about 2.85 million acre-feet (maf), or 237% of the average unimpaired runoff (SRFG et al. 2003). On the mainstem, New Melones Dam (RM 68) blocks the river downstream of the confluence of the south, middle, and north forks of the Stanislaus River. New Melones Dam was completed by the U.S. Army Corps of Engineers in 1979; the reservoir is now the largest storage reservoir in the basin, with a storage capacity of 2.4 maf. New Melones Dam and New Melones Lake were designed to control floods up to the 100-year-flood (Kondolf et al. 2001). Downstream from New Melones Lake is Tulloch Dam (RM 60), which forms Tulloch Reservoir. Approximately 1.5 miles downstream of Tulloch Dam is Goodwin Dam (RM 58), which is the main water diversion point on the Stanislaus River. Goodwin Dam blocks passage to the upper watershed for returning anadromous fish.

The average unimpaired runoff in the watershed is about 1.2 maf (Reclamation 2008). The median historical unimpaired runoff is 1.1 maf per year, with a range of between 0.2 and 3.0 maf (USFWS 1995). Snowmelt contributes the largest portion of the flows in the Stanislaus River, with the highest runoff occurring in the months of April, May, and June (Reclamation 2008). Agricultural water supply development in the Stanislaus River watershed began in the 1850s, significantly altering the basin's hydrologic conditions. The current hydrograph differs greatly from unimpaired flow conditions. Spring and summer flows are capped at 1,500 cubic feet per second (barring flood releases), while summer flows are increased to maintain downstream water quality. The river section below Goodwin Dam has been identified on the U.S. Environmental Protection Agency (USEPA) Clean Water Act Section 303(d) list for not meeting water quality standards for diazinon, chlorpyrifos, Class A pesticides, unknown toxicity, mercury, and temperature (USEPA 2011).

Historically, 113 miles of the Stanislaus River were anadromous fish habitat (USFWS 2008), but currently only the lower 58 RMs are accessible to anadromous fish, with access terminating at Goodwin Dam (KDH Environmental Services 2008). Compared to historical conditions, the area of suitable salmonid spawning and rearing habitats has been substantially reduced due to anthropogenic influences.

6 DEVELOPMENT OF GOALS AND OBJECTIVES SPECIFIC TO THE STANISLAUS RIVER

6.1 Overall Approach

The SEP Group developed Watershed-specific Goals and Biological Objectives to reflect improvements that could be attained within the geographic and policy scope (Section 2.3) for the salmon VSP criteria (Section 3). Watershed-specific Goals and Biological Objectives were developed for population productivity as well as genetic and life history diversity. Because establishment and maintenance of viable and healthy populations of Chinook salmon and *O. mykiss* in the Stanislaus River contribute to the Central Valley Goal of improving spatial structure for each species addressed in this report, there was no need to set Watershed-specific Goals and Biological Objectives for spatial structure. Establishing populations that met the criteria for other VSPs, as described in the Biological Objectives, would also support the Central Valley Goal of improving spatial structure for these populations. In addition, S.M.A.R.T. Biological Objectives were not defined for abundance of any of the focal populations, though many previous policies define Central Valley Goals and Objectives for Chinook salmon and *O. mykiss* in terms of target abundances (Section 2.3.1). One of the Watershed-specific Goals for each focal population is increased abundance. However, many factors limit abundance in each life stage throughout the entire life cycle of Chinook salmon and *O. mykiss*. Many of the factors that affect overall abundance occur outside of the spawning and rearing habitat of the Stanislaus River. Thus, actions and actors on the Stanislaus River have only partial control over salmonid abundance in any give year, and Biological Objectives for abundance are inappropriate given the geographical scope of this effort. The Watershed-specific Goals and Biological Objectives are intended to contribute to all of the Central Valley Goals and Objectives, including abundance, though target abundances were not incorporated into Biological Objectives for the Stanislaus River.

The SEP Group developed Watershed-specific Goals for each of the species and runs that would improve and maintain the VSP parameters of genetic and life history diversity and productivity (i.e., population growth rates as affected by survival rates). One of the Biological Goals identified was to support the fullest expression of Chinook salmon and *O.*

mykiss life history diversity to increase population stability, resilience, and productivity. For Chinook salmon populations, productivity goals were described in three phases:

1. Attain juvenile survival rates that allow for population growth;
2. Attain juvenile survival rates that allow for rapid reattainment of Central Valley Objectives after years with low escapement; and
3. Attain juvenile survival rates that reflect those typical among other Chinook salmon populations across the West Coast.

The specific Biological and Environmental Objectives developed to help achieve the Watershed-specific Goals varied among the species and runs. They were designed to be measurable and monitored over time. In Section 6, the specific metrics associated with each Biological Objective needed to achieve the Central Valley Goals and Objectives are defined, and the rationale and approach for each metric are described.

6.2 Fall-run Chinook Salmon

6.2.1 What is the Problem?

Central Valley fall-run Chinook salmon populations are a species of special management concern because natural production is well below desired levels, survival rates are inadequate to achieve population growth and maintain population resilience, the populations express only a narrow range of the life history variants that are typical of this species, and hatchery influence on wild stocks compounds all of these problems.

The production[3] of San Joaquin fall-run Chinook salmon often falls to very low levels, with generally low spawning escapements across years. Escapement is related to hydrology, with very low escapement following drought conditions and higher (but still sub-par) escapement generally following years with high spring runoff (USFWS 1995; Sturrock et al. 2015). Abundance has generally declined since the 1967 through 1991 period used to set AFRP ocean production objectives. Actual fall-run Chinook salmon counts (escapement) in the

[3] As used here, "production" means the number (abundance) of fish available to the ocean fishery: 2-year-old salmon in the ocean. This term should not be confused with "productivity," which refers to population growth rates and/or the population vital rates (e.g., survival, fecundity) that determine population growth rate.

Stanislaus River are variable, averaging 3,087 fish from 2003 to 2013 (Gutierrez 2014). Similarly, productivity (measured as juveniles per spawner) appears to be constrained by hydrology, with more juveniles produced for a given number of spawners in years when river flows are high (Figure 3). Juvenile survival rates are generally low for this population (AFRP 2005). Life history diversity of the fall-run Chinook salmon population is constrained throughout the Central Valley (Lindley et al. 2009; Miller et al. 2010; Carlson and Satterthwaite 2011) and in the Stanislaus River, in particular. The influence of hatchery-produced spawners on the Stanislaus River fall-run Chinook salmon population (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013) is well above limits indicative of healthy populations, suggesting that population viability is compromised by hatchery stocks (Araki et al. 2007; Lindley et al. 2007; Johnson et al. 2012). The spatial diversity of fall-run Chinook salmon spawning habitats within the San Joaquin River basin is not a primary concern, as fall-run Chinook salmon spawn in each of the San Joaquin River's main tributaries and are being restored to the San Joaquin mainstem.

6.2.2 What Outcome(s) (Central Valley Goals) will Solve the Problem?

Where applicable, the SEP Group used existing laws, policies, and programs to identify Central Valley Goals. In some cases, the expression of desired conditions in existing laws, policies, and programs was quite general (e.g., to maintain "fish in good condition"), and the SEP Group needed to translate the policy intent into more specific language that would be relevant to planning and management.

Abundance

Increasing abundance of fall-run Chinook salmon is a Goal of state and federal law for the Central Valley, including the San Joaquin River and its three salmon-bearing tributaries. The CVPIA (Section 3406 of the CVPIA, Title 34 of Public Law 102-575) calls for naturally spawning populations of anadromous fish that are double the 1967 to 1991 baseline within 10 years. State law (F&G Code § 6902(a)) and water quality regulations (SWRCB 2006) express the same target.

Productivity and Life History Diversity

Improvements in fall-run Chinook salmon productivity (measured as juvenile survival and adult migration success in freshwater) and increased life history diversity (i.e., size at and timing of juvenile migration) are necessary to achieve desired conditions. These desired conditions are described in several relevant policies, including abundance targets for fall-run Chinook salmon in the Central Valley (USFWS 2001), maintaining fish "in good condition" (F&G Code § 5937), and achieving acceptable levels of the criteria NMFS uses to evaluate salmonid population viability (Lindley et al. 2007). The goals of improving productivity and life history diversity among Central Valley salmonids are also consistent with all known fisheries-related management policies in this area.

Genetic Diversity

For fall-run Chinook salmon, concerns about the level of genetic diversity needed to support a healthy and viable population revolve around the influence of hatchery production and management (Williams 2006). A high occurrence of straying of fall-run Chinook salmon occurs between the San Joaquin and Sacramento basins (Johnson et al. 2012; Kormos et al. 2012), potentially due to the relative river flows across various Central Valley tributaries during the return migration as well as hatchery release practices (Marston et al. 2012). In 2010, the U.S. Congress established and funded a hatchery review process in California due to concern that the genetic resources required to support a sustainable salmon fishery and recover at-risk runs of salmon were not being adequately managed using traditional hatchery practices (HSRG 2012). The need to reform the hatchery practices system-wide has been identified by scientists and policymakers based on growing concerns and scientific findings about the potential effects of hatcheries on the viability of salmon and steelhead in their natural habitats (HSRG 2012). In addition, eliminating genetic introgression with spring-run Chinook salmon, or reducing it to a very low level, is a major goal for the maintenance and restoration of fall-run Chinook salmon in the Central Valley (Lindley et al. 2006; HSRG 2014). Thus, providing opportunities for fall-run reproductive isolation is particularly important for the maintenance of fall-run populations in rivers with dams that cause spring-run and fall-run Chinook salmon to spawn in the same area.

6.2.3 What Does Solving the Problem Look Like (Central Valley Objectives)?

Where applicable, the SEP Group used existing laws, policies, and programs to identify Central Valley Objectives. Central Valley Objectives are presented below to provide context for Watershed-specific Goals and Biological Objectives on the Stanislaus River.

Abundance

Fall-run Chinook salmon production levels for each Central Valley river that would be consistent with the Central Valley-wide Goals of the CVPIA were calculated by the AFRP. The AFRP objective for ocean production of fall-run Chinook salmon for the three salmon-bearing tributaries in the San Joaquin River basin is 78,000, which is divided among the Stanislaus (22,000), Tuolumne (38,000), and Merced (18,000) rivers. Achievement of these targets was intended to occur within a decade after the passage of the CVPIA (USFWS 2001).

Productivity

Laws, policies, and programs that provide guidance for Central Valley Objectives generally do not provide explicit targets for salmonid productivity. However, the AFRP and CVPIA provide insight into the desired rate of population growth for fall-run Chinook salmon—doubling from a baseline within roughly three Chinook salmon generations. Furthermore, the AFRP and CVPIA targets imply that population growth rates will be sufficient to make populations resilient against periodic cohort failures (Johnson et al. 2010). Populations may fluctuate above and below the production target, but they should be resilient such that periodic years of low production, due to any cause, do not prohibit reattainment of an abundance target in the next generation.

These two elements of the AFRP and CVPIA goals for Central Valley production (rebuilding a population over three generations and resilience of the population to short-term declines) were used to develop Watershed-specific Goals and Biological Objectives for productivity (i.e., survival) rates in the Stanislaus River. Furthermore, the SEP Group looked to other viable populations of Chinook salmon to gauge freshwater survival rates that would characterize a Chinook salmon population as being in good condition. It determined that freshwater survival rates needed to support doubling the population growth rate in 9 years and survival rates required to produce a resilient population were lower than is typical of Chinook salmon. Thus, a third Central Valley Objective was established—achieve freshwater survival rates typical of Chinook salmon within 24 years (approximately eight salmon generations).

Life History Diversity

No policies speak directly to Central Valley Objectives for necessary improvements in the life history diversity of fall-run Chinook salmon. However, there is increasing evidence that habitat loss and simplification have constrained fall-run Chinook salmon life history strategies, and improvements will be necessary to attain the other Central Valley Goals for this run of Chinook salmon (Ruckelshaus et al. 2002; Lindley et al. 2009; Miller et al. 2010; Schindler et al. 2010; Carlson and Satterthwaite 2011; Satterthwaite et al. 2014).

Genetic Diversity

Benchmark metrics have been established based on genetic models to reduce the proportion of hatchery-origin spawners (pHOS) in Central Valley rivers to less than 20% of adult spawners, and preferably less than 5% (even when the hatchery of origin is a conservation-orientated facility using best management practices). A high proportion of hatchery-origin spawners has the potential to increase competition for spawning habitat, reduce reproductive success, and erode mechanisms required for local adaptation of salmon to their environment—ultimately putting them at a high risk of extinction (Araki et al. 2007; Lindley et al. 2007). Specific gene-flow criteria (less than 2% introgression) between ESUs have been proposed to achieve long-term genetic integrity and maintain a low extinction risk for natural populations in the Central Valley (Lindley et al. 2007; HSRG 2014).

6.2.4 How Will this Effort Contribute to Attainment of Central Valley Objectives (Watershed-specific Goals)?

As described, the scope of the SEP Group's current effort is the Stanislaus River through the lower San Joaquin River to the Delta. Specific goals and objectives for the Stanislaus and lower San Joaquin rivers were developed to support the system-wide goals identified.

Abundance

Increased abundance of fall-run Chinook salmon on the Stanislaus River is a Watershed-specific Goal that supports Central Valley Goals and Objectives. Because abundance is the product of fecundity and survival rates throughout the life cycle (and is therefore controlled in many locations, including the Stanislaus River), there is no S.M.A.R.T. Biological Objective for abundance to accompany this Goal (i.e., no Biological Objective for the Stanislaus River).

There is evidence that salmon abundance and productivity on the Stanislaus River are constrained by limited carrying capacity. Specifically, in years when winter-spring flow rates on the Stanislaus River are low, the number of juveniles produced does not increase as spawning escapement increases. However, juvenile production does increase with spawning escapement under high flow conditions (Figure 3).

The SEP Group used the Central Valley Objective of average annual natural production of 22,000 fall-run Chinook salmon within three salmon generations to set a context for determining Environmental Objectives (e.g., physical, chemical, and biological conditions necessary to support and achieve Biological Objectives) for the Stanislaus River. The purpose of this was to ensure that the Environmental Objectives—especially those related to spatial extent of habitat—included sufficient carrying capacity to attain and support Watershed-specific Goals and the Central Valley Goals and Objectives for Chinook salmon.

Productivity

Adult escapement and ocean production reflect previous spawning stock, female fecundity, and survival through different life stages and Chinook salmon habitats. Juvenile survival rate is the relevant metric that can be controlled at the local spatial scale to affect attainment of Central Valley Goals and Objectives for abundance. Furthermore, productivity is an important attribute of population viability beyond its contribution to abundance (McElhaney et al. 2000). Egg-outmigrant survival rates calculated for the Stanislaus River (Appendix A) reveal that productivity is too low to maintain population viability; survival rates appear to respond positively when winter-spring flow rates are elevated (Figure 3).

As described, the Central Valley Goals and Objectives were used to guide development of Watershed-specific Goals for productivity (freshwater survival rates). Watershed-specific Goals for freshwater survival become progressively more protective over time and describe freshwater survival rates sufficient to generate the following:

- Rebuilding: achieve a population growth rate that supports increasing populations in a relatively short time span (i.e., doubling the population in three generations);
- Resilience: achieve a population growth rate that allows the population to rebound after years with poor returns (i.e., increasing the population up to 2.5-fold in one generation); and

- Sustainability: achieve freshwater survival rates that are characteristic of salmon in human-modified rivers on the West Coast of North America (i.e., outmigrating smolt represent at least 10% survival from eggs to smolt).

Life History Diversity

Life history diversity must be maintained at a level that allows Chinook salmon populations to respond to varying climatic, hydrologic, and oceanic conditions over time (Beechie et al. 2006; Miller et al. 2010; Spence and Hall 2010; Satterthwaite et al. 2014). There is strong evidence that life history diversity among juvenile Chinook salmon originating from the Stanislaus River is severely constrained and limited diversity impairs population growth, resilience, and viability (Zeug et al. 2014; Sturrock et al. 2015). The SEP Group identified Watershed-specific Goals for life history diversity that must be met to achieve a self-sustaining population of naturally produced fall-run Chinook salmon in the Stanislaus River. For this application, life history diversity objectives were characterized in terms of the size distribution and time distribution of juveniles leaving the river system. The Watershed-specific Goal for fall-run Chinook salmon life history diversity is to:

> **Support the fullest expression of fall-run Chinook salmon life history diversity (as seen in other Central Valley populations and in other rivers that support this phenotype) in order to increase and maintain population stability, resilience, and productivity.**

Genetic Diversity

In addition, the SEP Group adopted a Watershed-specific Goal for genetic diversity to mirror the Central Valley Goal:

> **Maintain genetic integrity of wild fall-run Chinook salmon stocks by minimizing hatchery influence**

To achieve this goal, river conditions that support restoration of a self-sustaining, fall-run Chinook salmon phenotype must be established on the Stanislaus River. Establishing and maintaining such a distinct population requires that gene flow between distinct life history types be limited. It also requires that Environmental Objectives support the fall-running phenotype during all life history stages. In addition, the impact of hatchery-origin spawning fish has a large influence on the genetic diversity of natural-origin Chinook salmon population on the Stanislaus River. Hatchery management is a San Joaquin River basin-wide and Central Valley-wide issue in that there are no hatcheries on the Stanislaus River. The SEP Group believed it was important to include the goal within the Stanislaus River scope, to the extent practical, or that attaining this Central Valley Goal relies on actions taken and conditions established within the Stanislaus and lower San Joaquin rivers.

6.2.5 What Suite of Species-specific Outcomes (Biological Objectives) Characterize Success?

Fall-run Chinook salmon abundance continues to decline in the Stanislaus River, indicating that current population biological attributes are not sufficient to maintain a self-sustaining, viable population, much less to attain the SEP Group's goals and objectives. The objectives below were developed to achieve the SEP Group's Watershed-specific Goals for fall-run Chinook salmon on the Stanislaus River.

6.2.5.1 Rationale for Productivity Objectives

In many cases, the desired survival rate of salmonids in any life stage has been calculated based on the desire to attain a given abundance target within a predetermined period. However, survival rates calculated by this method are not necessarily the survival rates that reflect healthy productivity of a Chinook salmon population. Indeed, Pacific salmon populations are characterized by high intrinsic rates of growth (Healey 1991; Quinn 2005) that arise from a strategy of placing eggs in low-productivity riverine environments where incubation and juvenile success rates are relatively high. The capacity to quickly colonize new habitats and rapidly rebound from periods of poor recruitment explain, in part, the widespread and long-term success of Pacific salmon. Furthermore, historical accounts from across the Pacific coast of abundant spawning runs of Chinook salmon attest to the fact that these populations were often limited only by competition for mates and suitable spawning habitats, not survival rates during freshwater juvenile or marine life stages.

Three reviews of Chinook salmon survival in freshwater across their range were assessed by the SEP Group (Healey 1991; Bradford 1995; Quinn 2005). Each study synthesized results of numerous other studies to produce average egg to smolt survival. In some cases, the same rivers were studied, but the time series used appeared to differ. Members of the SEP Group contacted the authors of these studies to understand the methodologies that were used and to confirm that the populations studied represented “typical” (i.e., not pristine) conditions across the Chinook salmon range. Using this approach, freshwater survival of 10% was determined to be representative of Chinook salmon in human-modified rivers on the West Coast of North America.

By analyzing current survival rate estimates for Stanislaus River salmon, the SEP Group also learned that it would be extremely difficult or impossible to achieve freshwater survival targets without improvement in the river and Delta environments (Appendix A). No historical data are available from this system to establish the appropriate balance between in-river and through-Delta survival, and no analogous salmon-bearing river systems with such a large inland estuary exist elsewhere. The SEP Group found no reason that survival rates in-river should be greater than or equal to through-Delta survival. Calculated improvements necessary in overall freshwater survival were therefore distributed proportionately across riverine and estuarine habitats. The same approach to allocating responsibility for improved freshwater survival rates was employed by NMFS (2012a).

At higher levels of survival required to attain the Watershed-specific Goals of resilience and sustainability, the approach of generating “equal improvement” for in-river and through-Delta relative survival rates produced survival rate targets in the Delta that may be unachievable (i.e., they would not meet S.M.A.R.T. criteria). Through-Delta survival rates were capped at 50%, and in-river survival rates were adjusted accordingly to attain desired freshwater survival rates.

Freshwater survival rates for rebuilding and resilience assume current post-Delta survival rates through the Estuary and Pacific Ocean. If survival rates in the bay or ocean change substantially, the freshwater survival rate objectives may be adjusted. However, freshwater survival rates for sustainability are typical of Chinook salmon populations across their range (i.e., they reflect typical “productivity” of Chinook salmon populations).

Survival rates in freshwater may be impacted by density-dependent factors when populations approach local carrying capacity. Freshwater survival rate objectives produced by the SEP Group apply only to situations where the spawner population is lower than the system's targeted carrying capacity (i.e., in years when there should be little effect on overall survival rates of density-dependent competition). As spawner populations increase, the SEP Group may refine productivity objectives to apply to years where the spawner and juvenile cohorts approach intended carrying capacity (i.e., Environmental Objectives for habitat area) for the system. Thus, attainment of current survival objectives should be measured only when the spawning population is below a certain threshold (McElhany et al. 2000); that threshold has not been determined.

In-river productivity rates are also affected by conditions that influence adult migration, holding, and spawning success among adults. Unsuitable conditions (including high temperatures, low DO concentrations, or other migration barriers) during adult migration and holding may result in sub-lethal impacts that reduce productivity between escapement and subsequent juvenile outmigration. Thus, objectives for desired adult migration, holding, and spawning success were developed. Because the holding period for adult fall-run Chinook salmon is abbreviated compared to that observed among spring-run Chinook salmon, a detailed description of the rationale and approach for adult productivity objectives for spring-run Chinook salmon is provided in Section 6.3.5.1.

6.2.5.2 Methods for Productivity Objectives

The SEP Group created a spreadsheet-based life cycle model to investigate which changes to current survival rates in different life stages are necessary to attain Watershed-specific Goals for population growth rates (Appendix A). The purposes of this model are as follows:

- Estimate and evaluate relative survival rates of juvenile Chinook salmon emigrating from the Stanislaus River through the lower San Joaquin River and the Delta, and
- Serve as a tool for the following:
  - Development of specific freshwater juvenile survival (productivity) objectives for Chinook salmon, and
  - Allocation of improvements in survival rates systematically across different reaches of juvenile freshwater habitat at discrete times in the future.

The spreadsheet model is based on a set of survival rate estimates for freshwater and marine environments generated from data sources used by resource managers. Despite natural variance and measurement uncertainty associated with these data, they represent the best available data. The spreadsheet model can be used to estimate relative differences in survival rates across different habitats and the magnitude of improvement required to meet Biological Objectives for salmon in the Stanislaus River and lower San Joaquin River.

Survival rates for various life stages of San Joaquin River basin Chinook salmon were collected from previous reports and existing data sources (Table 1). Where estimates differed among reports, the SEP Group determined which estimates were most likely to reflect actual conditions; these estimates were referred to as the "Consensus Estimate" in Table 1. Previous studies did not account for mortality between the lowest sampling station in the Stanislaus River (the RST at Caswell) and the Delta, which begins at Vernalis on the San Joaquin River (Figure 1). Survival in this 10.5-RM stretch was estimated from the per-RM average of survival rates upstream of the stretch between Oakdale and Caswell and through the Delta.

Table 1

Calculated Recruits per Spawner Based on Survival Consensus Estimates

<table>
<tr><th>Reach</th><th>USDOI (2011)</th><th>NMFS (2012)</th><th>Consensus Estimates</th><th>RM</th><th>Survival per RM</th></tr>
<tr><td>Eggs to Caswell</td><td>6.64%</td><td rowspan="4">5.64%</td><td>1.87%</td><td>46.5</td><td>91.79%</td></tr>
<tr><td>Eggs to Oakdale</td><td></td><td>10.62%</td><td>14.4</td><td>85.58%</td></tr>
<tr><td>Oakdale to Caswell</td><td></td><td>16.02%</td><td>32.1</td><td>94.46%</td></tr>
<tr><td>Caswell to Vernalis[1]</td><td></td><td>54.09%</td><td>10.5</td><td>94.32%</td></tr>
<tr><td>Vernalis to Chipps Island</td><td>5%</td><td>3.75%[2]</td><td>3.75%</td><td>54.5</td><td>94.15%</td></tr>
<tr><td>Chipps Island to Adult[3]</td><td>-</td><td>-</td><td>2.83%[5]</td><td>-</td><td>-</td></tr>
<tr><td>Adult to Spawner[3]</td><td>50%</td><td>70%</td><td>60.24%</td><td>-</td><td>-</td></tr>
<tr><td>Recruits per Spawner[4]</td><td></td><td></td><td>0.02</td><td></td><td></td></tr>
</table>

Notes:

1 No existing data were available to estimate survival in the reach between Caswell and the Delta boundary. Survival in this reach was estimated as a function of the average per-RM survival from Oakdale to Caswell and from Vernalis to Chipps Island.

2 Vernalis to Chipps Island survival (3.75%; Brandes, pers. comm.)

3 Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)

4 Recruits per spawner is calculated as product of survival rates (e.g., Eggs to Caswell × Caswell to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
5 NMFS 2009b
– Estimated juvenile survival rates in different segments of the migration corridor for Stanislaus River Chinook salmon, including survival from egg stage to the RST at Caswell ("Eggs to Caswell"); Eggs To Oakdale RST ("Eggs to Oakdale"); Caswell RST to the Delta ("Caswell to Vernalis"); through the Delta ("Vernalis to Chipps Island"); Delta exit to age-2 fish in the ocean ("Chipps Island to Adult"); and ocean harvest and other adult mortality prior to escapement ("Adult to Spawner"). Consensus estimate is based on calculations from data collected at the RSTs located Oakdale and Caswell, as reported by USFWS, and survival estimates in each segment of fall-run Chinook salmon migration beyond the Caswell RST that the SEP Group considered to be the most accurate. See Section 6.2.5.2 for a description of the Stanislaus River Survival Model (Appendix A).

The model is based on estimated egg deposition (i.e., run size × estimated sex ratio × measured average fecundity) and life stage survival estimates. The conceptual diagram for the spreadsheet model is depicted in Figure 5. Survival estimates were developed for the following:

- Two reaches of the Stanislaus River (i.e., survival from egg deposition to the RSTs at Oakdale (Stanislaus reach 1) and survival from Oakdale to the RSTs at Caswell (Stanislaus reach 2);
- A reach including the lower Stanislaus and San Joaquin rivers from Caswell to Vernalis (San Joaquin River reach);
- The Sacramento San Joaquin Delta from Vernalis to Chipps Island (Delta reach);
- The marine environment prior to harvest; and
- Losses from maturity to spawning escapement.

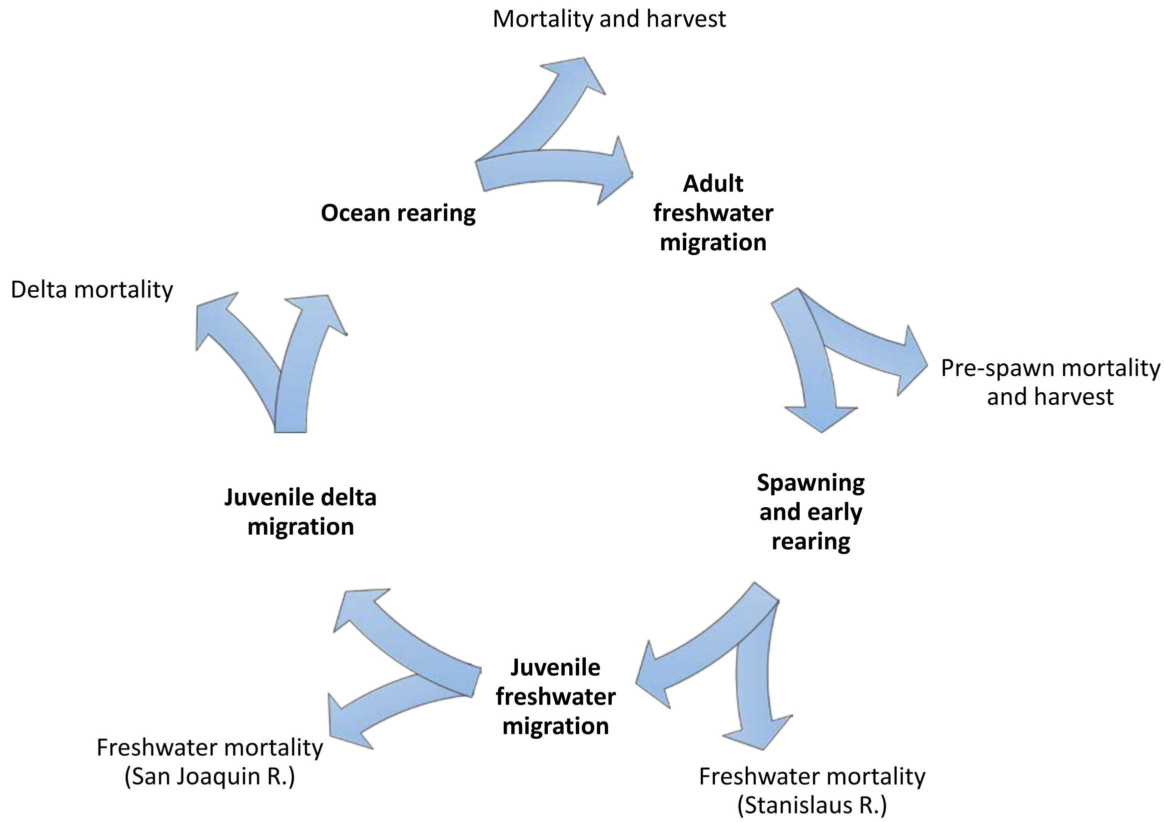

Figure 5

Life Cycle Diagram and Potential Sources of Mortality used in the Stanislaus Survival Model

6.2.5.2.1 Data Sources and Derived Metrics

The following data and derived metrics were represented in the spreadsheet-based Stanislaus Survival Model provided in Appendix A. Derived variables are based on the best available information.

Year

This represents the calendar year when data were recorded. Note that calculation of survival from eggs to subsequent enumeration of juveniles uses data from two different calendar years: the year in which escapement/spawning occurs (year x) and the year in which juvenile outmigrants are caught by RSTs (year x+1).

Water Year Index

Water years extend from October 1 of one year to September 30 of the next year (e.g., the 2010 water year is from October 1, 2009, to September 20, 2010) to capture the typical wet season in California. The water year index represents hydrology in 1 of 5 categories of water year type (wet, above normal, below normal, dry, critical). Data for the workbook were obtained from California Department of Water Resources.

Oakdale RST Expanded Passage

This is the estimated number of Stanislaus River-origin juvenile Chinook salmon passing Oakdale derived from RST estimates (Cramer Fish Sciences 2013).

Caswell RST Expanded Passage

This is the estimated number of Stanislaus River-origin juvenile Chinook salmon passing Caswell derived from RST estimates (Cramer Fish Sciences 2013).

Adult Production

This is the estimated number of Stanislaus River-origin adult Chinook salmon in a given year-class in the ocean prior to harvest (CHINOOKPROD, USFWS 2013).

Ocean Harvest

This is the estimated number of Stanislaus River-origin adult Chinook salmon in a given year-class harvested by an ocean fishery (CHINOOKPROD, USFWS 2013).

Freshwater Harvest

This is the estimated number of adult Stanislaus River-origin Chinook salmon in a given year-class harvested by a freshwater fishery (CHINOOKPROD, USFWS 2013).

Total Harvest

This is the estimated number of adult Stanislaus River-origin Chinook salmon migrating to the basin harvested by either ocean or freshwater fishery (CHINOOKPROD, USFWS 2013).

Grandtab Escapement

This is the estimated number of adult Chinook salmon returning to the Stanislaus River each year (Grandtab, USFWS 2013).

Weir Escapement

This is the estimated number of adults migrating upriver after harvest derived from resistance board weir counts (Fuller 2013). These numbers differ from Grandtab escapement because the sampling methodology differs. Results between the two escapement estimates are not systematically different (i.e., one is not consistently higher than the other), and the Grandtab dataset is longer than the Weir Escapement dataset. Thus, weir escapement is provided for reference in the data sheets with model inputs (Appendix A), but weir escapement is not used in the model calculations.

Median % Females

The median proportion of females is calculated from fish surveyed on the Stanislaus River from 1995 to 2013 as 60% of the spawning population of Chinook salmon (see tab titled "Stan sex ratio + fecundity" in Appendix A; Swank, pers. comm.).

Median Fecundity

This is estimated from fish surveyed by CDFW on the Stanislaus River from 1995 to 2013 using a length-fecundity relationship for San Joaquin fall-run Chinook salmon developed by Loudermilk et al. (1990)—median value of 5,813 eggs per female adult Chinook salmon (see tab titled "Stan sex ratio + fecundity" in Appendix A; Swank, pers. comm.).

Vernalis to Chipps Island Survival

The Vernalis to Chipps Island survival is 3.75% based on regionally accepted evaluations (NMFS 2012; Swank, pers. comm.).

Chipps Island to Adult Survival

The Chipps Island to Adult survival is 2.83% (NMFS 2009).

Ocean to Spawning Escapement

Ocean to Spawning escapement is calculated annually as the ratio of Grandtab spawning escapement and adult production. The geometric mean of annual values is used to parameterize the survival model.

Estimated Egg Deposition

Estimated egg deposition is calculated annually as the product of Grandtab spawning escapement, median proportion of females, and median fecundity.

Eggs to Oakdale Survival

Eggs to Oakdale survival is calculated annually as the ratio of Oakdale RST passage in year x+1 and estimated egg deposition in year x. Geometric mean of annual values is used to parameterize the survival model.

Eggs to Caswell Survival

Eggs to Caswell survival is calculated annually as the ratio of Caswell RST passage in year x+1 and egg deposition in year x. Geometric mean of annual values is used to parameterize the survival model.

Oakdale to Caswell Survival

Oakdale to Caswell survival is calculated annually as the ratio of Caswell RST passage in year x and Oakdale RST passage in year x. The ratio between survival from Eggs to Oakdale and survival from Oakdale to Caswell has been used to develop sub-objectives for egg to fry productivity. Note that the time series for Eggs to Caswell survival and Eggs to Oakdale or Oakdale to Caswell survival are not equal (because of differences in the number of years for which an expanded passage estimate at Oakdale RST has been calculated).

Calculated Caswell to Vernalis Survival

This is calculated annually based on Oakdale to Caswell survival and Vernalis to Chipps Island survival. Survival per RM is first calculated for Oakdale to Caswell and Vernalis to Chipps Island by taking the root equal to the number of RMs. For example, Vernalis to Chipps Island survival is calculated as:

$$Survival\ per\ RM = 0.0375^{\frac{1}{54.5}} = 0.9415$$

Caswell to Vernalis survival per RM is calculated as the weighted average of estimated Oakdale to Caswell survival per RM and Vernalis to Chipps Island survival per RM. Caswell to Vernalis survival for the reach is calculated by taking survival per RM multiplied to the power equal to the number of RMs. The geometric mean of annual values is used to parameterize the survival model.

Eggs to Vernalis Survival

Eggs to Vernalis survival is calculated annually as the product of Eggs to Caswell survival and Caswell to Vernalis survival.

Target population growth rates (i.e., cohort replacement rates [CRR]) were calculated for each productivity goal (rebuilding, resilience, and sustainability) using the exponential growth equation (equation 2.2 in Haddon 2001):

$$e = (N_t/N_0)^{1/t}$$

where:

e	=	growth rate
t	=	number of generations
N_t	=	population at generation t
N_0	=	population at generation 0 (initial population)

Freshwater survival rates (Eggs to Chipps Island) necessary to achieve the desired growth rate for each productivity goal were calculated by assuming that current population sex ratio, fecundity, and post-Delta survival rates (including ocean harvest rates) were fixed. Following the approach taken by NMFS (2012a), the SEP Group apportioned the necessary increase in freshwater survival equally to two reaches: riverine (Eggs to Vernalis) and estuarine (Vernalis to Chipps Island). Survival necessary to achieve each productivity goal in each reach (riverine and Delta) was calculated by multiplying current survival rates in those two habitats by the same multiplier. For each productivity goal, the multiplier for Delta and riverine reaches represented the square root of the quotient of target total freshwater survival rate (those needed to achieve each of the productivity goals) divided by current estimated survival rate through freshwater (e.g., "Consensus Estimate" of current survival rate from Eggs to Caswell × Caswell to Vernalis × Vernalis to Chipps Island* in Table 1).

Within the riverine reach, the target survival rate was further divided into target survival for Eggs to Oakdale, Oakdale to Caswell, and Caswell to Vernalis. The reach from Caswell to Vernalis was calculated as a weighted average of per-mile survival rates in the Delta (Vernalis to Chipps Island) and the Stanislaus River (Eggs to Vernalis). Once the 10.5-mile Caswell to Vernalis survival rate was calculated, it was possible to solve for the remaining stretch of river (Eggs to Caswell) by dividing the river-wide survival rate by the Caswell to Vernalis reach. The Eggs to Caswell survival rate is the Stanislaus-specific survival rate Biological Objective for each of the three juvenile productivity goals, and it is accompanied by the Caswell to Vernalis survival rate that will be affected by conditions (e.g., flows, water temperatures) contributed by the Stanislaus River and other San Joaquin tributaries.

Although several population metrics in the above equations were fixed mean values (proportion of females, fecundity, current Vernalis to Chipps Island survival, and Chipps Island to Adult survival), some parameters were based on annual observed data (Eggs to Vernalis survival and Ocean to Spawning survival; Appendix A). The SEP Group calculated 95% confidence intervals for target freshwater survival rates based on the observed variation in the annual estimates for these two parameters. Using Program R, the SEP Group simulated target freshwater survival using observed data (100,000 iterations) using the logit function to ensure target survival rates were constrained between 0 and 1.

An upper limit was imposed on target freshwater survival rates for Stanislaus River and Delta reaches at 50%. This upper limit assumes that survival rates greater than 50% in either the riverine or the estuarine portion of the freshwater life cycle would be unrealistic. The 50% survival rate limit only affected Biological Objectives for the Delta reach, as current Delta survival is greater than survival in-river, and only for the final increment of improvement in productivity (e.g., freshwater survival rates consistent with "sustainability").

6.2.5.3 Current Productivity

The SEP Group summarized annual survival estimates for different portions of the freshwater life cycle of fall-run Chinook salmon originating in the Stanislaus River using values found in agency reports and monitoring data (Table 1). Group consensus of SEP members was used to determine the best survival estimate for a given reach based on available information (i.e., the “consensus estimate”). The consensus estimate of survival per reach and survival per RM within each freshwater reach were derived from the following (in order of priority):

1. Annual observed data;
2. Mean values derived from observed data and reported in agency documents; then
3. Estimated survival based on the mean per-RM survival rate immediately upstream and downstream.

Consensus estimates are based on the geometric mean of annual estimates where annual data are available. Overall, the estimated median recruits per spawner of the fall-run Chinook salmon population in the Stanislaus River is 0.02. This growth rate is much lower than the value of 1.0 necessary for a stable population; thus, the current population on the Stanislaus River is in decline. The number of juvenile outmigrants per spawner is strongly and positively correlated with winter-spring flow conditions in the Stanislaus River (Figure 3 and Appendix A), and the spawning cohort in one year is strongly correlated with San Joaquin River flows in the year that that cohort migrated to the ocean (Sturrock et al. 2015).

6.2.5.3.1 Rebuilding: Recruits per Spawner Equal 1.26

The initial Biological Objective for productivity, intended to support the goal of rebuilding the Stanislaus River fall-run population, required establishing survival rates within the Stanislaus and lower San Joaquin River that would support a population growth rate (or CRR) of 1.26; sustained CRR of 1.26 leads to population doubling in three generations. The SEP Group assumed no change in mean survival from Chipps Island to adult and from adult to spawner. Survival in the river (Eggs to Vernalis) and Delta (Vernalis to Chipps Island) were assumed to improve proportionate to current levels.

Survival necessary in the river (Eggs to Vernalis) and in the Delta (Vernalis to Chipps Island) to achieve a population growth rate of 1.26 (i.e., recruits per spawner required to double the population in three generations) were estimated (Table 2). To achieve a CRR of 1.26, it would require mean freshwater survival of juvenile Chinook salmon of 2.12%. To achieve freshwater survival of 2.12% overall, the following will need to be achieved within 10 years (Table 7):

- Median annual survival from Eggs to Vernalis of 7.55%; and
- Median annual survival from Vernalis to Chipps Island of 28.06%.

Variance around estimated survival rate targets, simulated using observed data and the logit function of R (100,000 simulations), indicated that 95% confidence intervals were constrained between 0 and 1 for survival from Eggs to Vernalis (95% confidence interval: 2.96% to 28.57%) and Vernalis to Chipps Island (7.95% to 71.81%).

Table 2

Survival Rates in Freshwater Environments Necessary to Support Watershed-specific Goal of Rebuilding the Stanislaus River Fall-run Chinook Salmon Population

Reach	Current	RM	Target Survival	Target Survival per RM
Eggs to Vernalis	1.01%	57.0	7.55%	95.57%
Vernalis to Chipps Island	3.75%	54.5	28.06%	97.69%
Chipps Island to Adult[1]	2.83%	-	2.83%[2]	-
Adult to Spawner[1]	60.24%	-	60.24%	-
Recruits per Spawner[3]			**1.26**	

Notes:
1 Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)
2 NMFS 2009b
3 Recruits per spawner is calculated as product of survival rates (e.g., Eggs to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
– Target survivals assume an equal increase over current survival in Delta and riverine habitats. See text for calculation of survival in different riverine stretches.

6.2.5.3.2 Resiliency: Recruits per Spawner Equal 2.5

The population growth rate associated with the rebuilding objective (CRR equals 1.26; Section 6.2.5.3.1) would lead to a situation where low production in any one year could severely constrain production in the subsequent generation (i.e., the population would not be resilient). A higher CRR is in keeping with Central Valley Goals and Central Valley Objectives for this population, as the Watershed-specific Goal and this Biological Objective are designed to ensure that survival rates in the river environment do not prevent attainment of AFRP production targets following years with low returns (e.g., as would be necessary to hit a 5-year running average). Again, there is no Biological Objective related to attainment of the AFRP or other abundance target; this productivity objective simply specifies survival rates that are consistent with attainment of goals and objectives for the Central Valley and Watershed-specific Goals.

The SEP Group's second phase of productivity improvement is intended to establish population resilience by achieving freshwater survival rates that support a population growth rate (or CRR) of 2.5. The increase in survival necessary in the river (Eggs to Vernalis) and in the Delta (Vernalis to Chipps Island) required to support population resilience—or a minimum of 2.5 recruits per spawner—were estimated assuming no change in mean survival from Chipps Island to adult or adult to spawner (Table 3). Under these assumptions, a CRR of 2.5 would require freshwater survival of 4.22%. Although freshwater survival of 4.22% is higher than current survival estimates, the SEP Group considered it to be reasonable and achievable after 15 years of restoration effort, especially because it is well below typical freshwater survival for Chinook salmon populations across their range.

To achieve freshwater survival of 4.22% overall, the following will need to be achieved in each reach within 15 years (Table 7), assuming proportionate improvement in survival in the riverine and Delta environments:

- Median annual survival from Eggs to Vernalis of 10.64%; and
- Median annual survival from Vernalis to Chipps Island of 39.52%.

Variance around estimated survival rate targets, simulated using observed data and the logit function of R (100,000 simulations), indicated that 95% confidence intervals were constrained between 0 and 1 for survival from Eggs to Vernalis (95% confidence interval: 5% to 37.51%) and Vernalis to Chipps Island (11.83% to 81.61%).

Table 3

Survival Rates in Freshwater Environments Necessary to Support Watershed-specific Goal of Resiliency for the Stanislaus River Fall-run Chinook Salmon Population

Reach	Current	RM	Target Survival	Target Survival per RM
Eggs to Vernalis	1.01%	57.0	10.64%	96.15%
Vernalis to Chipps Island	3.75%	54.5	39.52%	98.31%
Chipps Island to Adult[1]	2.83%	-	2.83%[2]	-
Adult to Spawner[1]	60.24%	-	60.24%	-
Recruits per Spawner[3]			**2.5**	

Notes:
1 Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)
2 NMFS 2009b
3 Recruits per spawner is calculated as product of survival rates (e.g., Eggs to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
– Target survivals assume an equal increase over current survival in Delta and riverine habitats. See text for calculation of survival in different riverine stretches.

6.2.5.3.3 Sustainability: Recruits per Spawner Equal 5.95

The SEP Group adopted the average survival rate reported by Quinn (2005)—10% egg to smolt survival—as typical of Chinook salmon populations. This value was selected because Quinn (2005) was the most recent study available on this topic and this value was approximately the mid-point of the values from the two other studies (Healy 1991; Bradford 1995). Assuming no change in survival rates between Chipps Island and adult or from adult to spawner, the SEP Group's third phase of productivity improvement, establishing population sustainability by achieving freshwater survival of 10%, would result in a population growth rate (or CRR) of 5.95.

Although a 10% freshwater survival rate is much higher than current survival rates in the reaches from the Stanislaus River through the Delta, the SEP Group considered this objective to be attainable and perhaps conservative, after 24 years of restoration effort. This reasoning is two-fold: 1) because the survival rate is typical of other Chinook salmon populations studied in human-managed systems from across the range of the species; and 2) the resulting CRR is less than that reported by Quinn (2005) for the Chinook salmon populations in that study.

The assumption that survival in the river (Eggs to Vernalis) and Delta (Vernalis to Chipps Island) improved proportionately produced an estimated target for Delta survival that was judged not achievable on a sustained basis (i.e., not S.M.A.R.T.; calculated target survival on Table 4). Thus, maximum median through-Delta survival was assumed to be approximately 50%. To achieve the target freshwater survival objective, through-Delta survival of 50% was assumed (adjusted target survival; Table 4). Thus, to achieve an overall freshwater survival of 10%, the following will need to be achieved in each reach within 24 years (Table 7):

- Median annual survival from Eggs to Vernalis of 20%; and
- Median annual survival from Vernalis to Chipps Island of 50%.

Variance around estimated survival rate targets, simulated using observed data and the logit function of R (100,000 simulations), indicated that 95% confidence intervals were constrained between 0 and 1 for survival from Eggs to Vernalis (95% confidence interval: 9.91% to 55.32%) and Vernalis to Chipps Island (19.27% to 91.55%).

Table 4

Calculated Survival Required to Achieve Population Sustainability (10% Freshwater Survival)

Reach	Current	RM	Calculated Target Survival	Adjusted Target Survival	Target Survival per RM
Eggs to Vernalis	1.01%	57.0	20.88%	20%	97.22%
Vernalis to Chipps Island	3.75%	54.5	52.24%	50%	98.74%
Chipps Island to Adult[1]	2.83%	-	-	2.83%[2]	-
Adult to Spawner[1]	60.24%	-	-	60.24%	-
Recruits per Spawner[3]				**5.95**	

Notes:
1 Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)
2 NMFS 2009b
3 Recruits per spawner is calculated as product of survival rates (e.g., Eggs to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
– Summarizes the proportional increase in survival need to achieve 10% freshwater survival based on published values (Healy 1991; Bradford 1995; Quinn 2005), or a minimum of 5.95 recruits per spawner. Proportionate increase of river and Delta survival rates (as described above) resulted in Delta survival rates that the SEP Group believed were unrealistically high. Therefore, the necessary increase in river (Eggs to Vernalis) survival rates was calculated based on a median Delta (Vernalis to Chipps Island) survival rate of 50%.

6.2.5.4 Results: Productivity Objectives

6.2.5.4.1 Reach-specific Juvenile Freshwater Survival Objectives

Tables 2, 3, and 4 present the CRRs, total freshwater survival rates, and riverine and Delta survival rates necessary to achieve the three Watershed-specific Goals of rebuilding, resilience, and sustainability. The Eggs to Vernalis survival targets form the basis of Biological Objectives that can be attained in the geographic scope of the SEP. The SEP Group estimated survival targets in each freshwater reach bounded by monitoring points (Oakdale, Caswell, Vernalis/Mossdale, and Chipps Island) that are needed in order to achieve the total freshwater survival rates consistent with each of the three productivity Goals (Table 5).

Table 5
Current Reach-specific Survival and Survival Objectives for Three Productivity Goals

Reach	Current	RM	Rebuilding	Resilience	Sustainability
Eggs to Vernalis	1.87%	46.5	10.8%	14.3%	24.80%
Caswell to Vernalis	54.09%	10.5	69.8%	74.4%	80.70%
Vernalis to Chipps Island	3.75%	54.5	28.1%	39.5%	50%
Freshwater Survival	**0.04%**		**2.12%**	**4.20%**	**10%**

Current survival from Caswell to Vernalis was estimated based on the average per-RM survival rates estimated for Eggs to Oakdale and Oakdale to Caswell (Table 1). This average per-RM survival rate was applied to the 10.5 miles of river between Caswell and Vernalis; thus, the increase in survival assigned from Caswell to Vernalis is calculated by averaging the target per RM survival of the Eggs to Vernalis reach and the Vernalis to Chipps Island reach. Survival in the Stanislaus River reaches above Caswell (Eggs to Caswell) are those that will achieve the necessary river survival rates when multiplied by the survival calculated from Caswell to Vernalis (the last part of the riverine migration). That survival rate was disaggregated into components expected upstream and downstream of the first RST, at Oakdale. Current survival rates from Eggs to Oakdale and Oakdale to Caswell were compared only in those years where Oakdale RST data were available. Survival upstream and downstream of Oakdale was calculated only for a subset of the time series used to calculate median Eggs to Caswell survival. As a result, the product of Eggs to Oakdale survival and Oakdale to Caswell survival does not equal the survival estimate for Eggs to

Caswell. However, it was assumed that the proportionate survival in these two reaches is well estimated by the years in which data were available.

Survival targets for Eggs to Caswell and Caswell to Vernalis were adopted as Biological Objectives for productivity to attain the Watershed-specific Goals for population rebuilding, resilience, and sustainability (Table 7).

6.2.5.4.2 Supplemental Guidance to Support Productivity Objectives in the Stanislaus River

The productivity objectives described above will require improved success across several life stages, including fecundity, egg viability, incubation success, and juvenile survival throughout the Stanislaus River and lower San Joaquin corridors. Although overarching juvenile productivity rates (measured as survival from Eggs to Caswell and survival from Caswell to Vernalis) are the central focus of efforts to restore population productivity on the Stanislaus River, the SEP Group also developed guidance for egg and early juvenile productivity. This guidance allows for identification, prioritization, monitoring, and adaptive management of stressors affecting life stage transitions between adults and early fry as compared to those stressors that affect later juvenile survival (e.g., downstream of Oakdale).

Egg Viability

Viability of Chinook salmon eggs incubated under hatchery conditions is well studied and generally extremely high (more than 90%; Tappel and Bjornn 1983). Egg viability may be compromised by deleterious conditions experienced by migrating adult Chinook salmon (McCullough et al. 2001; USEPA 2003). Such negative effects can be detected by measuring hatchability of eggs taken from females that have completed their migration through freshwater. Low hatching success of eggs incubated under standardized conditions would reveal whether adult migration conditions inhibit attainment of the overall productivity (juvenile outmigrants-per-adult) objective.

The SEP Group established guidance for mean egg viability in hatchery conditions of 95% for eggs taken from female Chinook salmon that complete migration. This sub-objective should be attained by year 9 (Table 7). A small sample from one study on the Stanislaus River indicated mean incubation success of 92.5% (AFRP 2008). Ideally, attainment of this sub-objective would involve eggs taken from females caught in the early part of the fall-run migration season, as this is when physical conditions are most stressful to migrating fall-run Chinook salmon females.

Incubation Condition

Egg incubation may be compromised in the field by conditions that are unsuitable physically or chemically (e.g., due to gravel size distribution, temperature, and fine sediment accumulations). The SEP Group identified optimal, sub-optimal, and detrimental levels of physio-chemical variables that are important to egg incubation success (see Section 7.2.4). The combined effect of various levels of these variables on incubation success can be predicted based on previous studies of hatching success where conditions where controlled and varied systematically (e.g., for gravel size-distribution; Tappel and Bjornn 1983).

The SEP Group determined that physical conditions in the river should be those that would support incubation success of 80%, 85%, and 90% for all redds deposited in a given year (as predicted by hatchability under conditions studied by Tappel and Bjornn (1983) and other studies (e.g., Mesick (2001) by years 9, 15, and 24, respectively; (Table 7). The SEP Group emphasizes that it is not anticipating actual egg hatchability of ≥80% in the field; rather the sub-objective provides guidance that physical and chemical conditions (e.g., gravel quality; water temperature; DO; contaminant levels) should be consistent with conditions needed to produce these levels of incubation success in a controlled environment.

Fry Productivity

Egg-outmigrant productivity may also be compromised by low survivorship in very early life history stages (larvae, early fry). Because it is extremely challenging to measure incubation success of naturally deposited eggs directly, the SEP Group established guidance to capture impacts to incubation success as well as mortality that occurs immediately after hatching. By estimating escapement and female fecundity, the potential number of eggs deposited during a spawning season can be estimated. By measuring fry production just downstream of the spawning reach (e.g., at the Oakdale RST), the productivity from the egg stage to the fry stage can be estimated. USFWS (2014) employs such a calculation to estimate winter-run Chinook salmon productivity rates on the Sacramento River. Egg-fry productivity rates have been studied in other Chinook salmon populations (e.g., Quinn 2005), and these estimates informed the sustainability objective for expected egg-fry productivity on the Stanislaus River.

The SEP Group established guidance for expected fry production at the Oakdale RST. The geometric mean of egg-fry survival rates at the Oakdale RST from 1995 to 2013 was approximately 14% (based on assumptions regarding spawner sex ratio and female fecundity detailed in Appendix A). Under the assumption that survival of Chinook salmon upstream and downstream of Oakdale improved proportionately, egg to fry survival at Oakdale would be 26.8% and 30.8% by years 9 and 15, respectively, in order to attain the overarching productivity objectives (Eggs to Caswell survival rates; Table 7). The SEP Group's guidance for minimum egg to fry survival to Oakdale RST was slightly lower than that derived mathematically because there was no intention for the guidance to become prescriptive or constrain allocation of restoration effort. Final guidance for egg to fry survival is described in Table 6. The final guidance target for egg to fry productivity (35% by year 24) matches what is typical of Chinook salmon egg to fry survival rates measured elsewhere (Healy 1991; Quinn 2005).

Table 6
Guidance Related to Egg Viability and Incubation Success for Chinook Salmon (Fall- and Spring-run) in the Stanislaus River

Sub-objective	Metric	To be Achieved by
Egg viability	In hatchery hatching success = 95% (lower 90% confidence interval ≥ 87%, n= 5 – 10 females)	Year 9
Incubation condition	Field environmental conditions consistent with > 80% hatchery incubation success	Year 9
	Field environmental conditions consistent with > 85% hatchery incubation success	Year 15
	Field environmental conditions consistent with > 90% hatchery incubation success	Year 24
Egg to fry productivity	Egg to fry (@ Oakdale RST) survival > 25%	Year 9
	Egg to fry (@ Oakdale RST) survival > 30%	Year 15
	Egg to fry (@ Oakdale RST) survival > 35%	Year 24

6.2.5.4.3 Adult Migration, Holding, and Redd Success Objectives

Adult migration, holding, and redd success objectives include the following:

- At least 90% of adult migrants that pass the weir through survive to spawning;
- Less than 10% of female carcasses retain 10% or more of eggs; and
- Chinook salmon redd viability rate of greater than 90% (as projected by monitoring of temperature, flow, and superimposition).

The rationale for and approach to objectives related to fall-run Chinook salmon adult migration, holding, and redd success are described in detail under spring-run Chinook salmon productivity objectives (Section 6.3.5.1).

Productivity-related objectives and guidance for fall-run Chinook salmon are summarized in Table 7.

Table 7

Chinook Salmon Productivity Objectives

Objective		Productivity[1]												
Life History Stage		**Juvenile "rebuilding"**			**Juvenile "resiliency"**			**Juvenile "sustainability"**			**Adult and Egg**			
Description	**Briefly**	Juvenile survival rate consistent with population growth rate of 2x over three generations (CRR=1.26)			Juvenile survival rate consistent with population resilience (CRR=2.5)			Juvenile survival rate in freshwater typical of Chinook salmon populations across the Pacific coast (10%)			Survival/reproductive success of adult migrants and indicators of egg incubation success			
	Achieved by When?	Year 10			Year 15			Year 24			Year 9	Year 9	Varies (Year 9, 15, 24; see below)	Varies (Year 9, 15, 24; see below)
	Measure What?	Survival from/to	Survival from/to	Survival total	Survival from/to	Survival from/to	Survival total	Survival from/to	Survival from/to	Survival total	Survival from/to	Egg viability/ deposition	Egg/redd viability	Egg-emergence survival of surrogates
	Measured Where?	Spawning to Caswell [2]	Caswell to Vernalis [2]	Freshwater [3]	Spawning to Caswell [2]	Caswell to Vernalis [2]	Freshwater [3]	Spawning to Caswell [2]	Caswell to Vernalis [2]	Freshwater [4]	Caswell to spawning grounds at onset of spawning [5]	Spawning grounds	Spawning grounds	Spawning grounds
Fall-run	**Wet**	15.0%			18.0%			35.0%			≥ 90%	a) In hatchery hatching success = 95%; b) < 10% of female carcasses retain ≥ 10% of eggs	a) Environmental conditions consistent with in-hatchery incubation success: ≥ 80% (year 9); ≥ 85% (year 15); ≥ 90% (year 24) b) ≥ 90% redds remain intact through incubation period	Egg to fry survival (at Oakdale RST): ≥ 25% (year 9); ≥ 30% (year 15); ≥ 35% (year 24)
	Median Year	10.8%	69.8%	2.12%	14.3%	74.4%	4.20%	24.8%	80.7%	10.0%				
	Dry	5.0%			9.0%			15.0%						
Spring-run	**Wet**	15.0%			18.0%			35.0%			Same as above	Same as above	Same as above	Same as above
	Median Year	10.8%	69.8%	2.12%	14.3%	74.4%	4.20%	24.8%	80.7%	10.0%				
	Dry	5.0%			9.0%			15.0%						

Notes:

1 Juvenile productivity and life history objectives refer only to those Chinook that migrate before temperatures in the mainstem San Joaquin reach 25 degrees Celsius (°C) (77 degrees Fahrenheit [°F]).

2 Survival objectives from Spawning to Caswell are premised on attainment of Caswell to Vernalis survival rate. If median Caswell to Vernalis survival rate is unattainable or exceeded, the Spawning to Caswell survival rate objective will be adjusted accordingly.

3 For reference purposes. Includes through-Delta survival. Conditions on the San Joaquin and its tributaries affect Delta survival; however, responsibility of San Joaquin tributaries for through-Delta survival outcomes is yet to be determined. Improvement in freshwater survival rates assume river survival rates and Delta survival rates will improve proportionately from current levels.

4 For reference purposes. Assumes through-Delta survival of 50%. In this case, the improvement in river and Delta environments is no longer proportionate, as adherence to the proportionate improvement standard would require median survival of >50% in the Delta. There was no consensus that survival rates of > 50% in the Delta could be achieved.

5 Currently, adult survival objectives are only developed for spring-run fish after they have migrated past Caswell. This reflects desired outcomes in the ability of spring-run to successfully "hold" in the river through the summer. Adult survival objectives may be developed (and potentially for fall-run and steelhead) in the mainstem San Joaquin; however, those objectives would be part of basin-wide planning and may require adult migration monitoring in the lower San Joaquin.

6.2.5.5 Rationale for Timing of Migration Life History Objective

Differences in juvenile Chinook salmon size at and timing of migration are believed to represent different life history strategies. As discussed in Section 3.2 this "portfolio effect" of spreading risk through life history diversity is thought to maximize survival across the subsequent environments salmon are exposed to (e.g., mainstem river, Delta, and ocean). The ideal timing of migration for any size-class is unknown and believed to be variable across years (i.e., depending on future conditions in subsequent environments). Migration of Chinook salmon of different sizes across a broad migration window will reveal that the river environment is supporting a wide range of life history types that are characteristic of healthy Chinook salmon populations. A migration timing window is necessary to ensure that river function is maintained throughout a normal migration period for fall-run Chinook salmon. The SEP Group recognized that it would not be desirable to retain fish in the Stanislaus River beyond the time each year where temperatures in the lower San Joaquin River are unsuitable; thus, migration timing windows may be truncated in any year when temperatures exceed a threshold temperature prior to the end of the time period specified.

6.2.5.6 Methods for Timing of Migration Life History Objective

The metric for this Biological Objective is the presence (absence) of fall-run Chinook salmon juveniles measured on a weekly basis. The timing windows reflected here are similar to those already detected by RSTs in the Stanislaus River. For example, in 2000 (a wet year), outmigrants were detected at Caswell from January 2 to June 25. In 2003 (a drier year), outmigrants were detected at Caswell from January 23 to May 8. A summary of outmigrant timing data collected at the Caswell RST from 1996 to 2014 is provided in Table 8.

Table 8
Start and End Dates of Migration through the Lower Stanislaus River for Three Migratory Phenotypes of Juvenile Chinook Salmon, as Detected at Caswell Rotary Screw Trap 1996 – 2014

Year	Fry (Smaller than 55 mm [2.2 in] FL)		Parr (Larger than 55 mm [2.2 in], smaller than 75 mm [3 in] FL)		Smolt (Larger than 75 mm [3 in] FL)	
	Start Date	End Date	Start Date	End Date	Start Date	End Date
1996	February 1	April 12[2]	February 16	May 26	February 4	June 27
1997[1]	–	–	–	–	–	–
1998	January 3	April 29	February 18	May 26	March 6	June 30
1999	January 13	June 4	February 14	June 13	March 6	June 30
2000	January 2	April 25	February 4	May 29	March 8	June 25
2001	January 1	May 13	March 7	June 10	January 17	June 17
2002	January 11	April 1	February 9	June 11	March 1	June 12
2003	January 23	April 12	February 5	June 2	February 24	June 10
2004	January 19	April 17	February 26	May 31	February 29	June 8
2005	January 1	April 12	February 14	June 11	January 9	June 21
2006[1]	–	–	–	–	–	–
2007	January 7	May 13	March 10	June 24	February 24	June 27
2008	January 20	March 31	February 29	May 2	March 18	June 16
2009	January 9	April 3	March 8	May 7	March 8	June 2
2010	January 11	May 12	March 3	May 12	February 9	June 1
2011	January 1	May 10	February 14	May 2	February 21	June 27
2012	January 12	May 11	March 12	June 11	March 3	June 29
2013	January 1	April 19	February 22	June 4	January 22	June 4
2014	January 4	May 11	January 21	June 2	February 17	June 8

Notes:
1 These years had trap issues, and the data could not be included.
2 The range shows the first and last detection.
Sources: Cramer Fish Sciences RST database in Zeug et al. 2014; Table from Sturrock et al. 2015.
– = no data

For this objective, parr and smolt migration windows were set 1 to 2 weeks earlier than is typically detected currently; this reflects the desire to produce faster growth rates in-river and thus, earlier appearance of larger size classes among outmigrants. The SEP Group considered these objectives to be easily attainable, as the minimum required to demonstrate the suitability of the river corridor (for this objective) is the detection of one juvenile fish in a given size category each week.

The SEP Group recognizes that distinguishing in the field between fall- and spring-run Chinook salmon juveniles is challenging at this time. Thus, the objective will be satisfied by detection of any Chinook salmon juveniles in the specified time window, without regard to parentage. If field techniques that allow distinction between juveniles of different runs become available, the SEP Group will consider how the objective should be implemented on a run-specific basis.

6.2.5.7 Results: Timing of Migration Life History Objective

By year 10, in every year, migration of fall-run Chinook salmon will be detected in every week between the dates shown in Table 9, until such time that the mean daily temperature at Mossdale is greater than or equal to 25 degrees Celsius (°C; 77 degrees Fahrenheit [°F]).

Table 9
Fall-run Chinook Salmon Timing of Migration Objectives

Size Class	Caswell RST		Mossdale[1] Trawl	
	Start Week	End Week	Start Week	End Week
Fry (smaller than 55 mm [2.2 in])	Last of January	Second of April	N/A[2]	N/A[2]
Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in])	First of February	Last of May	Second of February	First of June
Smolt (larger than 75 mm [3 in])	Third of February	First of June	February	June

Notes:
1 Tributary contribution can be assigned (e.g., by otolith analyses).
2 Mossdale Trawl does not reliably detect fish smaller than 55 mm (2.2 in).

6.2.5.8 Rationale for Size at Migration Life History Objective

Juvenile Chinook salmon size at migration classes were assumed a proxy for life history strategies. It is important to have a portfolio of such strategies to improve overall survival rates across years (Beechie et al. 2006; Miller et al. 2010; Satterthwaite et al. 2014).

Currently, in wet years, the Stanislaus River produces a very large proportion of fry-sized juvenile migrants. For example, in 2000, 85% of total outmigrants at Caswell were fry-sized, with a smaller proportion of smolt-sized juveniles (5%). These smaller-sized fish likely have lower outmigration survival rates (Sturrock et al. 2015). Conversely, in dry years such as 2003, a larger proportion of outmigrants are smolt-sized, with approximately 34% of total outmigrants at Caswell classified as smolt-sized (Table 10). The SEP Group is concerned that smolt-sized fish may not survive a late spring migration through the lower Stanislaus River and San Joaquin rivers due to prohibitively warm temperatures during dry years. In wet years, a high proportion of outmigrants leave as fry, likely due to flushing flows and lack of rearing habitat (Fuller 2013, pers. comm.). A more balanced proportional representation of outmigrant size classes across the full winter-spring migration season would allow for bet-hedging and likely result in increased survival across years.

Table 10

Abundance and Proportions of Fry, Parr, and Smolt Outmigrants Sampled by Rotary Screw Traps and Timing of Migration from Stanislaus River in 2000 and 2003

Outmigration Cohort	Migratory Phenotype	N (95% Confidence Interval)	Proportion of the Sample	Duration of Migratory Period (Range)	Duration of "Peak" Migratory Period (Interquartile Range)	Peak Migration Date (Median)
2000 (wetter)	Fry	1,837,656 (1,337,351 to 2,495,523)	0.85	115 days (January 2 to April 25)	4 days (February 14 to February 17)	February 16
	Parr	212,042 (141,238 to 310,174)	0.1	116 days (February 4 to May 29)	29 days (March 18 to April 15)	April 1
	Smolt	100,827 (68,732 to 142,920)	0.05	110 days (March 8 to June 25)	34 days (April 15 to May 18)	May 9
	Total	**2,150,524 (1,577,379 to 2,915,064)**				
2003 (drier)	Fry	79,862 (59,795 to 103,916)	0.5	80 days (January 23 to April 12)	4 days (January 27 to January 30)	January 29
	Parr	25,729 (17,889 to 36,282)	0.16	118 days (February 5 to June 2)	27 days (March 18 to April 13)	March 21
	Smolt	55,573 (38,362 to 77,486)	0.34	107 days (February 24 to June 10)	21 days (April 18 to May 8)	April 25

Source: Sturrock et al. 2015

6.2.5.9 Methods for Size at Migration Life History Objective

The SEP Group recognized that prescribing specific size-class distributions was not wise or possible because size-class distributions naturally fluctuate (stochastically and with respect to environmental conditions) from year to year, and the ideal size-class distribution for conditions in any given year are unknowable, in advance. On the other hand, the SEP Group believed that it was possible to identify minimum thresholds for the relative abundance of different size-classes because failure to produce these minimum distributions would indicate a failure of the river environment to support a portfolio of life history strategies. Objectives were not prescriptive; rather, the SEP Group asked the following question, "Below what proportion of a given size-class would we be concerned that the river was not providing adequate opportunities for the life history strategies associated with that size class?" The Biological Objectives described below anticipate the attainment of Environmental Objectives (i.e., chemical, physical, and biological conditions) that would allow for greater in-river rearing opportunities. The ranges represent the following:

- Fry: The target is a percentage of the range currently observed across year types, scaled to accommodate an increase in the percentage of parr and smolt size outmigrants while still resulting in a total of well below 100% across all size classes(Sturrock and Johnson 2016, pers. comm.).
- Parr: The target for wetter years is approximately double the proportion of parr that is currently observed in wetter years (Sturrock and Johnson 2016, pers. comm.). The target for drier years is approximately 1.5 times the proportion currently observed during drier years. The intent is to set a reasonable target for improved growth and rearing.
- Smolt: The target for wetter years is approximately double the proportion of smolt migrants currently observed in wetter years. The target for drier years is currently attained.

The SEP Group included a temperature off-ramp for measuring the proportional production of each of these size classes to account for the low likelihood of survival for fish entering the lower San Joaquin River when temperatures exceeded a critical threshold.

6.2.5.10 Results: Size at Migration Life History Objective

By year 12, annual emigrant size-class distribution as measured at Caswell RST (includes only juveniles that migrate before daily mean temperatures exceed 25°C (77°F) at Mossdale) are detailed in Table 11.

Table 11
Fall-run Chinook Salmon Size at Migratory Objectives

Size Class	Wetter Years	Drier Years
Fry (smaller than 55 mm [2.2 in])	20% minimum	20% minimum
Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in])	20% minimum	30% minimum
Smolt[1] (larger than 75 mm [3 in])	10% minimum	20% minimum

Notes:
1 Includes only juveniles that migrate before daily mean temperatures greater than 25°C (77°F) at Mossdale
– Initial estimates of size class distribution are based on Sturrock et al. (2015)

Size distribution of migrants will be measured on an annual basis, but can also serve to guide management within each year (e.g., approach of the 25°C [77°F] temperature threshold can be used as a trigger to stimulate migration earlier during dry years).

Table 12 summarizes life history diversity objectives for fall-run Chinook salmon.

Table 12

Chinook Salmon Biological Objectives – Life History Diversity Objectives

	Objective	Life History Diversity (Migration Timing) [1]				Life History Diversity (Age-class Distribution Minima) [1]	
Description	Briefly	Support range of juvenile migration dates to maintain life history diversity				Support range of sizes at juvenile migration dates to maintain life history diversity	
Description	Achieved by When?	Year 10	Year 10	Year 10	Year 10	Year 12	Year 12
Description	Measure What?	Detection every week no later than…	Detection every week through at least…	Detection every week no later than…	Detection every week through at least…	Minimum % juvenile migrants annually (wetter years)	Minimum % juvenile migrants annually (drier years)
Description	Measured Where?	Caswell RST	Caswell RST	Mossdale Trawl	Mossdale Trawl	Caswell RST	Caswell RST
Fall-run	Fry	Last week of January	2nd week of April	N/A	N/A	20%	20%
Fall-run	Parr	1st week of February	Last week of May	2nd week of February	1st week of June	20%	30%
Fall-run	Smolt	3rd week of February	1st week of June	Last week of February	2nd week of June	10%	20%
Spring-run	Fry	1st week of January	2nd week of April	TBD	TBD	20%	20%
Spring-run	Parr					20%	30%
Spring-run	Smolt					10%	20%
Spring-run	Yearling [2]	Detection in ≥ 50% weeks October to January	Detection in ≥ 50% weeks February to April	TBD	TBD	≥ 1.5 yearlings per 1,000 female spawners	

Notes:
1 Juvenile productivity and life history objectives refer only to those fish that migrate before temperatures in the mainstem San Joaquin reach 25°C (77°F).
2 The yearling life history strategy is associated with spring-running adults (fall-run adults may produce yearlings as well, but it is considered to be extremely rare). Production of some yearlings is expected whenever spring-run Chinook reproduce successfully; however, detection of yearlings is only required when sufficient numbers of spring-run salmon reproduce.

N/A = not applicable; TBD = to be determined

6.2.5.11 Rationale for Genetic Objective

The primary genetic concern for fall-run Chinook salmon in the Stanislaus River is the influence of hatchery-produced fish on the fitness of the local stock and introgression with spring-run Chinook salmon. Artificial propagation of salmon in hatcheries has long played a role in meeting harvest and conservation goals for salmon and steelhead in California. The life history diversity and productivity objectives described above will only be achieved if managers can ensure little or no deleterious consequences to natural populations from hatchery-origin fish. It is necessary to achieve a low level of extinction risk for fall-run Chinook salmon, and part of attaining that acceptable level of risk relates to implementing hatchery best management practices.

Current escapement to the Stanislaus River reflects a very high proportion of hatchery fish produced in other river systems. In 2007, CDFW began marking and tagging a constant fraction (25%) of hatchery production (Constant Fractional Marking Program). Escapement in years 2010 and 2011 were the first 2 years where juveniles from this marking effort returned as 2-, 3-, and 4-year-olds to spawn in freshwater habitats as adults. Approximately 50% and 83% of the adults that returned in 2010 and 2011, respectively, were strays from hatcheries and were not produced from parents who spawned successfully in the Stanislaus River (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013). The majority of the strays were fish that were trucked and released into net-pens in the Estuary (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013). Releases of juveniles in-river versus out-of-basin have been found to have a significant effect on the likelihood that adults will stray to non-natal rivers (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013).

The rationale for establishing a fall-run Chinook salmon Biological Objective related to minimizing introgression with spring-run Chinook salmon mirrors the approach described below in the spring-run Chinook salmon Biological Objectives section.

6.2.5.12 Methods for the Genetic Objective

6.2.5.12.1 Hatchery Influence

The science of hatcheries focuses on several key management concepts that, if implemented, would make a greater contribution to harvest than the existing natural habitat can sustain on its own (HSRG 2014). For integrated hatcheries, one key element is managing hatchery- and natural-origin fish as two components of a single gene pool that is locally adapted to the natural habitat. The SEP Group relied on existing literature and reports regarding targets for minimizing hatchery influence in the Central Valley in order to identify objectives for the maximum level of hatchery-influence on the Stanislaus River. The SEP Group acknowledged that hatchery impacts are a regional concern and must be managed throughout the San Joaquin River basin and beyond. Still, an important component of minimizing hatchery influence relates to conditions on the target stream and the health of its natural spawning populations.

6.2.5.12.2 Introgression

The approach for establishing a fall-run Chinook salmon Biological Objective related to minimizing introgression with spring-run Chinook salmon mirrors the approach described subsequently in the spring-run Chinook salmon Biological Objectives section.

6.2.5.13 Results: Genetic Objectives

Benchmark metrics have been established based on genetic models to reduce the pHOS to less than 20% of adult spawners. Therefore, the genetic objective for fall-run Chinook salmon is to achieve, by year 9 of plan implementation, a spawning population that consists of greater than 80% Stanislaus River produced fish. In addition, , at any time that spring-running Chinook salmon adults are in the river, conditions in the Stanislaus River will support fall-run Chinook salmon spawning success in a way that reinforces long-term genetic integrity as measured by greater than 98% of fall-run Chinook salmon spawning with other fall-run Chinook salmon.

Genetic objectives for fall-run Chinook salmon are summarized in Table 13.

Table 13
Genetic Objectives

Objective		Genetic	
Life History Stage		**Adult**	**Egg/Juvenile**
Description	**Briefly**	Maintain wild run genetic integrity	
	Achieved by When?	Year 9	Whenever spring-running fish are present
	Measure What?	Percentage hatchery origin spawners	Introgression
	Measured Where?	Spawning grounds	Spawning grounds
Fall-run	**Wet**	pHOS < 20% of spawners	< 2% hatchery influence
	Median Year		
	Dry		
Spring-run	**Wet**	N/A	< 2% inter-run mating
	Median Year		
	Dry		

6.3 Spring-run Chinook Salmon

6.3.1 What is the Problem?

Central Valley spring-run Chinook salmon populations are listed under state and federal ESAs for the following reasons:

- Natural production is well below acceptable levels;
- Survival rates are inadequate to achieve population growth and maintain population resilience;
- Spatial extent is extremely constrained relative to historic conditions;
- Populations express only a narrow range of the life history variants that are typical of this species; and
- Introgression with fall-run Chinook salmon populations threatens to homogenize this distinct gene pool as well as compounding the other problems.

Spring-run Chinook salmon populations throughout the Central Valley are extremely constrained with regard to all viability criteria (Yoshiyama et al. 2001; Lindley et al. 2007; NMFS 2014). These problems are most evident in the San Joaquin River basin, where spring-run Chinook salmon were extirpated following the construction of impassable dams in the mid 20th century. The spring-run was historically the most abundant run of Chinook salmon in the San Joaquin River basin and was among the largest runs along the Pacific Coast (Fry 1961; CDFG 1972, 1990; Yoshiyama et al. 2001). Prior to major dam construction in the mid 20th century, spring-run was the dominant Chinook salmon population in the Stanislaus River (CDFG 1972). Until recently, spring-run Chinook salmon were considered to be extirpated from all waterways in the San Joaquin River basin. There have been manual spring-run Chinook salmon reintroduction efforts on the San Joaquin mainstem below Friant Dam as part of the San Joaquin River Restoration Program. There is growing recognition that spring-running Chinook salmon adults have been observed in San Joaquin tributaries in recent years (Franks 2012); however, the origin of these fish is unknown.

Throughout the Central Valley, genetic threats to spring-run Chinook salmon include introgression with fall-run Chinook salmon (CDFG 1998; Banks et al. 2000), wherever these two populations are forced to spawn in the same habitat (because dams block passage into the higher elevation habitats historically utilized by spring-run). Genetic introgression with fall-run Chinook salmon is a threat to the unique morphological, behavioral, and life historical phenotypes and genotypic distributions that make spring-run distinctive (Smith et al. 1995; CDFG 1998; Banks et al. 2000). Thus, maintaining opportunities for temporal and spatial isolation of spawning between fall- and spring-run Chinook salmon is a challenge that efforts to restore spring-run Chinook salmon to the San Joaquin River basin need to address.

6.3.2 What Outcome(s) (Central Valley Goals) will Solve the Problem?

Abundance

Increasing abundance of Central Valley spring-run Chinook salmon is a goal documented in Hanson (2007, 2008), NMFS (2014), USFWS (2001), and Section 3406 of the CVPIA (Title 34 of Public Law 102-575). These plans stem from different laws (or legal settlements) and take different approaches to restoration; for example, they cover different geographies within the Central Valley and address conceptually different standards for population restoration. As a result, there are multiple restoration goals for abundance of spring-run Chinook salmon in the Central Valley and San Joaquin River basin. However, no single goal applies across the Central Valley, except for the narrative goal described in F&G Code § 5937, which states that dam operators must maintain fish populations "in good condition." This requirement has not been specifically defined for individual rivers. Thus, the SEP Group worked from the clear intent of existing policies to restore spring-run Chinook salmon in rivers throughout the Central Valley that they historically occupied, and identified goals and defined objectives that would satisfy that intent in the San Joaquin River basin from a biological perspective.

Productivity and Life History Diversity

Improvements in spring-run Chinook salmon productivity (measured as juvenile survival and adult migration and holding success in freshwater) and increased life history diversity (i.e., size at and timing of juvenile migration) are necessary to:

- Achieve abundance targets for spring-run Chinook salmon in the Central Valley (CVPIA/AFRP);
- Maintain fish "in good condition" (F&G Code § 5937);
- Attain acceptable levels of the criteria NMFS uses to evaluate salmonid population viability (NMFS 2014; McElhany et al. 2000); and
- Be consistent with other fisheries-related and water management-related policies.

No specific goal statements for these attributes have been defined, so the SEP Group worked to define Plan Goals for spring-run Chinook salmon that were appropriate to the geographic and policy scope of this effort.

Spatial Diversity

The NMFS (2014) Recovery Plan for Central Valley salmonids specifies that spring-run Chinook salmon populations will be restored to the southern Sierra diversity group (i.e., the San Joaquin River basin) such that "two populations [are] at low risk of extinction" and "multiple populations at [are maintained at no worse than] a moderate risk of extinction." Restoration of spring-run abundance, productivity, and life history diversity to the San Joaquin River tributaries and mainstem will serve to improve the spatial diversity of this distinct run throughout the Central Valley.

Genetic Diversity

Eliminating genetic introgression with fall-run Chinook salmon or reducing it to a very low level is a major goal for the maintenance and restoration of spring-run Chinook salmon in the Central Valley (Lindley et al. 2007; HSRG 2014). Thus, providing opportunities for spring-run reproductive isolation is particularly important for the maintenance of spring-run populations in rivers where high elevation habitat is blocked by dams.

6.3.3 What Does Solving the Problem Look Like (Central Valley Objectives)?

Abundance

An understanding of Central Valley Objectives for abundance of Stanislaus River spring-run Chinook salmon provides valuable context for determining what the Stanislaus River can contribute to restoring spring-run Chinook salmon in the Central Valley as a whole. Furthermore, Central Valley Objectives for spring-run are essential to determining Environmental Objectives (e.g., physical, chemical, and biological conditions necessary to support juvenile rearing) for the Stanislaus River that will support attainment of the Watershed-specific Goal (increasing abundance of spring-run Chinook salmon on the Stanislaus River) and goals and objectives in the larger context of the Central Valley.

The CVPIA (Section 3406 of the CVPIA, Title 34 of Public Law 102-575) calls for naturally spawning populations of anadromous fish that are double the 1967 to 1991 baseline within 10 years. The AFRP identifies Central Valley production targets for spring-run Chinook salmon, but it does not provide specific targets for spring-run production from San Joaquin River tributaries as it does for fall-run (USFWS 2001). This is likely because spring-run Chinook salmon were not detected in the San Joaquin River basin at the time when the CVPIA was passed in 1992 or when the AFRP was finalized in 2001. Still, spring-run Chinook salmon produced naturally on the Stanislaus River would contribute to the CVPIA/AFRP objectives for total natural production of spring-run Chinook salmon in the Central Valley.

The NMFS Recovery Plan (NMFS 2014) identifies the level of spring-run Chinook salmon abundance that is sufficient to achieve the narrow outcome of "recovery," which in the ESA context means delisting this population. The Central Valley Goal particular to the San Joaquin River basin states that there must be at least two populations at low risk of extinction in the southern Sierra diversity group. For a population to have a "low risk" of extinction, NMFS (2014) specifies, among other things, that it must achieve a census population size of at least 2,500 individuals. Spread over a 3-year generation length, this translates to a 3-year running average population of approximately 833 returning adults.

The SEP Group determined that delisting spring-run Chinook salmon, as per the NMFS (2014) Recovery Plan, would represent only a preliminary step to fully restoring spring-run Chinook salmon to the San Joaquin River basin and Stanislaus River. In other words, the SEP Group's view was that delisting was a preliminary desired outcome, but that would not satisfy other Central Valley-wide policies regarding spring-run Chinook salmon (e.g., CVPIA, F&G Code §5937). Historically, the Stanislaus River's spring-run Chinook salmon population was larger than its fall-run population (CDFG 1972; Yoshiyama et al. 2001), and the SEP Group found no biological reason to expect that the spring-run population would be only a small fraction of the fall-run Chinook salmon population in the future, following restoration of the river. A Stanislaus River population of 833 returning spring-run spawners per year would be less than 10% of the escapement of approximately 13,225 fish that is implied by the Central Valley Objective for Stanislaus River fall-run Chinook salmon (assuming current harvest rates; Table 1). In addition, the SEP Group found no reason why the Stanislaus River would not be capable of supporting as many spring-run or total Chinook salmon as the restored San Joaquin mainstem below Friant Dam. The San Joaquin River Restoration Program has a target of restoring 30,000 spring-run Chinook salmon and 10,000 fall-run Chinook salmon to the mainstem below Friant Dam (Hanson 2007, 2008). Finally, the SEP Group noted that observed annual escapement to Butte Creek (a tributary to the Sacramento River that is much smaller than the Stanislaus River) has exceeded 10,000 spring-run Chinook salmon in more than half the years since carcass surveys began in in 2001 (GrandTab 2014). As a result of these considerations, the SEP Group determined that the Central Valley Objective for the natural production of Stanislaus River spring-run Chinook salmon roughly equals the Central Valley Objective for natural production of Stanislaus River fall-run Chinook salmon, which is the natural production in the ocean of 22,000 2-year-old salmon per year on average. The SEP Group believed this Central Valley Objective for the Stanislaus River may actually be conservative.

Spatial Diversity

NMFS (2014) calls for multiple populations in the San Joaquin River basin to be established, at least two of which must be at "low risk" of extinction and others must be at no greater than "moderate risk" of extinction.

Productivity

The SEP Group determined that Central Valley Objectives for productivity of spring-run Chinook salmon (young-of-the-year [YOY] juveniles and adults) are identical to those for fall-run Chinook salmon. The AFRP (USFWS 2001) and CVPIA provide guidance regarding the desired rate of population growth for anadromous fish populations in the Central Valley as a whole; the CVPIA is clear that anadromous fish populations in the Central Valley were expected to double from a baseline within 10 years. Furthermore, the CVPIA and AFRP imply that populations should be resilient such that periodic years of low production (due to any cause) do not constrain a population's ability to reattain any abundance targets in the following generation. In addition, restoration of a spring-run Chinook salmon population to a state where it is "in good condition" (per F&G Code § 5937) was taken to mean that spring-run Chinook salmon below dams in the Central Valley should display survival rates that support population growth rates typical of this species throughout its range. The SEP Group also looked to other viable populations of Chinook salmon to gauge freshwater survival rates that would characterize a restored Chinook salmon population in the Stanislaus River.

Spring-run Chinook salmon are different from fall-run Chinook salmon in that they return to freshwater several months before they spawn. They wait in freshwater, without feeding, throughout the summer in a process known as "holding." This protracted period of freshwater residence exposes spring-run Chinook salmon adults to additional mortality in freshwater if environmental conditions are not adequate. Maintenance of the unique life history strategy of spring-run Chinook salmon requires protection of all phases of their life cycle, especially the holding period.

Life History Diversity

Spring-run Chinook salmon are noted for producing a yearling life history variant. Yearling juveniles spend up to a full year in rivers before migrating to the ocean (Moyle 2002; Williams 2006). No policies speak directly to Central Valley-wide Objectives for necessary improvements in the life history diversity of spring-run Chinook salmon. However, there is increasing evidence that life history strategies of spring-run Chinook salmon are constrained in the Stanislaus River, and improvements will be necessary to attain Central Valley Goals for this population. There is evidence of yearling juvenile salmon that are likely not sub-yearling progeny of fall-run Chinook salmon and may represent the yearling life history strategy (Figure 6). From 1996 to 2013, 49 yearlings (visually defined) were detected prior to May 1 at the Caswell RST (Zeug et al. 2014; Cramer Fish Sciences, unpublished data).

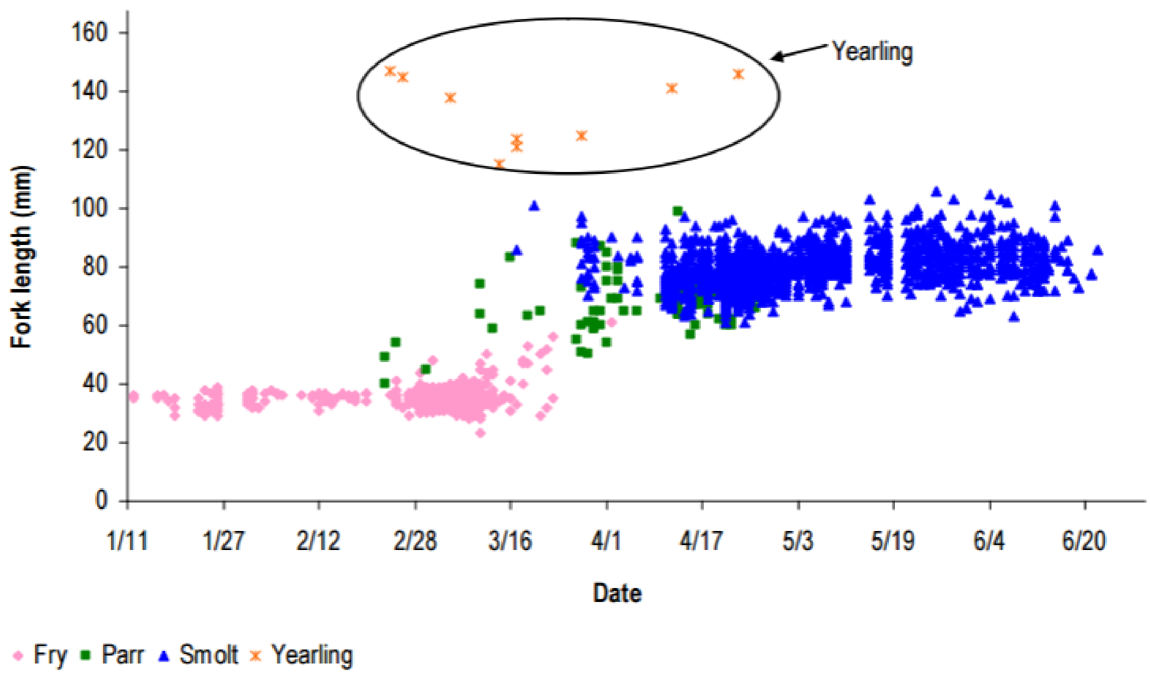

Figure 6

Estimates of Natural- and Hatchery-produced Fish Contributions to Stanislaus River Spawning Population

Source: Watry et al. 2007.

Genetic Diversity

Specific gene-flow criteria (less than 2% introgression) between ESUs have been proposed to achieve long-term genetic integrity and maintain a low extinction risk for natural populations in the Central Valley (Lindley et al. 2007; HSRG 2014).

6.3.4 How Will this Effort Contribute to Attainment of these Central Valley Objectives (Watershed-specific Goals)?

As described, the scope of the SEP Group's current effort is the Stanislaus River through the lower San Joaquin River to the Delta. Specific goals and objectives for the Stanislaus and lower San Joaquin rivers were developed to support the system-wide goals identified.

Abundance

Establishing a self-sustaining population of spring-run Chinook salmon on the Stanislaus River is a Watershed-specific Goal that will advance Central Valley Goals and Objectives, including delisting this species and achieving CVPIA production targets. No specific abundance target for spring-run Chinook salmon on the Stanislaus River accompanies this goal. Attainment of a Central Valley abundance objective for any particular river requires adequate conditions throughout the fish's life cycle. Abiotic and biotic conditions in the Stanislaus River and lower San Joaquin River must support, but may not be sufficient to result in, attainment of this objective, depending on conditions in the Delta and ocean. Thus, increased abundance is a Watershed-specific Goal, but no specific abundance target was established as a Biological Objective for spring-run in the Stanislaus River.

As with other anadromous populations in the SEP's scope, the SEP Group used Central Valley Objectives for abundance as context for defining Watershed-specific Goals and Environmental Objectives for the Stanislaus River. Specifically, to appropriately scale Environmental Objectives for the river, it was assumed that natural production of spring-run Chinook salmon from the Stanislaus River would be roughly equivalent to the Central Valley Objective for fall-run Chinook salmon (or 22,000 fish per year on average). The adult returns (escapement) that would result from this level of ocean production of spring-run depends on assumptions regarding ocean and in-river harvest targets; such targets are zero currently because the spring-run Chinook salmon is threatened. However, commercial and recreational fisheries may be restored as spring-run populations are restored across the Central Valley.

Spatial Diversity

The Stanislaus River watershed is believed to be amongst the most likely candidates in the southern Sierra diversity group to support a population of spring-run Chinook salmon at low risk of extinction, given the current habitat available below dams. As a result of the geographic limits set by this scope, Watershed-specific Goals and Biological Objectives were not required for the spatial diversity of spring-run Chinook salmon—the SEP Group's focus on restoring spring-run abundance, life history diversity, productivity, and genetic integrity to the Stanislaus River satisfies, in part, the spatial diversity objectives in the Central Valley.

Productivity

Central Valley Goals and Objectives were used to guide development of Plan Goals for productivity (freshwater survival rates). The goals for spring-run Chinook salmon productivity track those for fall-run Chinook salmon. The goals are to be implemented in phases and become progressively more protective over time, to achieve freshwater survival rates sufficient to generate the following results:

- Rebuilding: achieve a population growth rate that supports increasing populations in a relatively short time (i.e., doubling the population in three generations);
- Resilience: achieve a population growth rate that allows the population to rebound after years with poor returns (i.e., increasing the population up to 2.5-fold in one generation); and
- Sustainability: achieve freshwater survival rates that are characteristic of salmon in human-modified rivers on the West Coast of North America (i.e., outmigrating smolt represent at least 10% survival from eggs to smolt).

The SEP Group acknowledges that it would be extremely difficult or impossible to achieve freshwater survival targets without improvement in the river and Delta environments; thus necessary improvements in overall freshwater survival were distributed across riverine and estuarine habitats.

Life History Diversity

Life history diversity must be maintained to allow for Chinook salmon populations to respond to varying climatic, hydrologic, and ocean conditions over time (Beechie et al. 2006; Miller et al. 2010; Spence and Hall 2010; Satterthwaite et al. 2014). The Watershed-specific Goal for spring-run Chinook salmon life history diversity was to:

> **Support the fullest expression of spring-run Chinook salmon life history diversity (as seen in other Central Valley populations and in other rivers that support this phenotype). In particular, a goal for spring-run population restoration in the Stanislaus River is to achieve measureable production of yearling juveniles, a life history type that is the hallmark of stream-type Chinook salmon such as the spring-run. Attaining the fullest expression will result in increased population stability, resilience, and productivity**

Genetic Diversity

The SEP Group's intent is to create conditions that support restoration of a self-sustaining spring-run phenotype that contributes to the overall diversity, productivity, abundance, and resilience of Chinook salmon populations in the San Joaquin River basin and the Central Valley as a whole. The SEP Group adopted a Watershed-specific Goal for genetic diversity to mirror the Central Valley Goal:

> **Maintain genetic integrity of wild spring-run Chinook salmon by minimizing genetic introgression with fall-run Chinook salmon.**

Establishing and maintaining such a distinct population requires that gene flow between distinct life history types be limited. It also requires that Environmental Objectives support the spring-running phenotype at all life history stages.

6.3.5 What Suite of Species-specific Outcomes (Biological Objectives) Characterize Success?

In many cases, Biological Objectives for spring-run Chinook salmon in the Stanislaus River are identical to those the SEP Group adopted for fall-run Chinook salmon on the Stanislaus River. For large portions of their life cycle, spring-run and fall-run Chinook salmon from the same river are exposed to similar or identical conditions. Therefore, juvenile survival and somatic growth rates, YOY size distribution, and timing of juvenile migration for spring-run and fall-run Chinook salmon are expected to overlap largely (Yoshiyama et al. 1998; Moyle 2002; Williams 2006). Furthermore, it is not currently possible to distinguish definitively between juvenile fall-run and spring-run Chinook salmon in the field; monitoring for differences between these populations' vital rates would be impractical if not impossible.

Substantial and important differences between spring-run and fall-run Chinook salmon are apparent in their upstream migration timing (hence their different names), the protracted delay between migration and spawning ("holding") that spring-run display, and the production of a small but measurable fraction of yearling migrants by spring-run Chinook adults (Figure 7). These differences in behavior and life history lead to important differences in the environmental conditions that are needed to support spring-run and fall-run Chinook salmon.

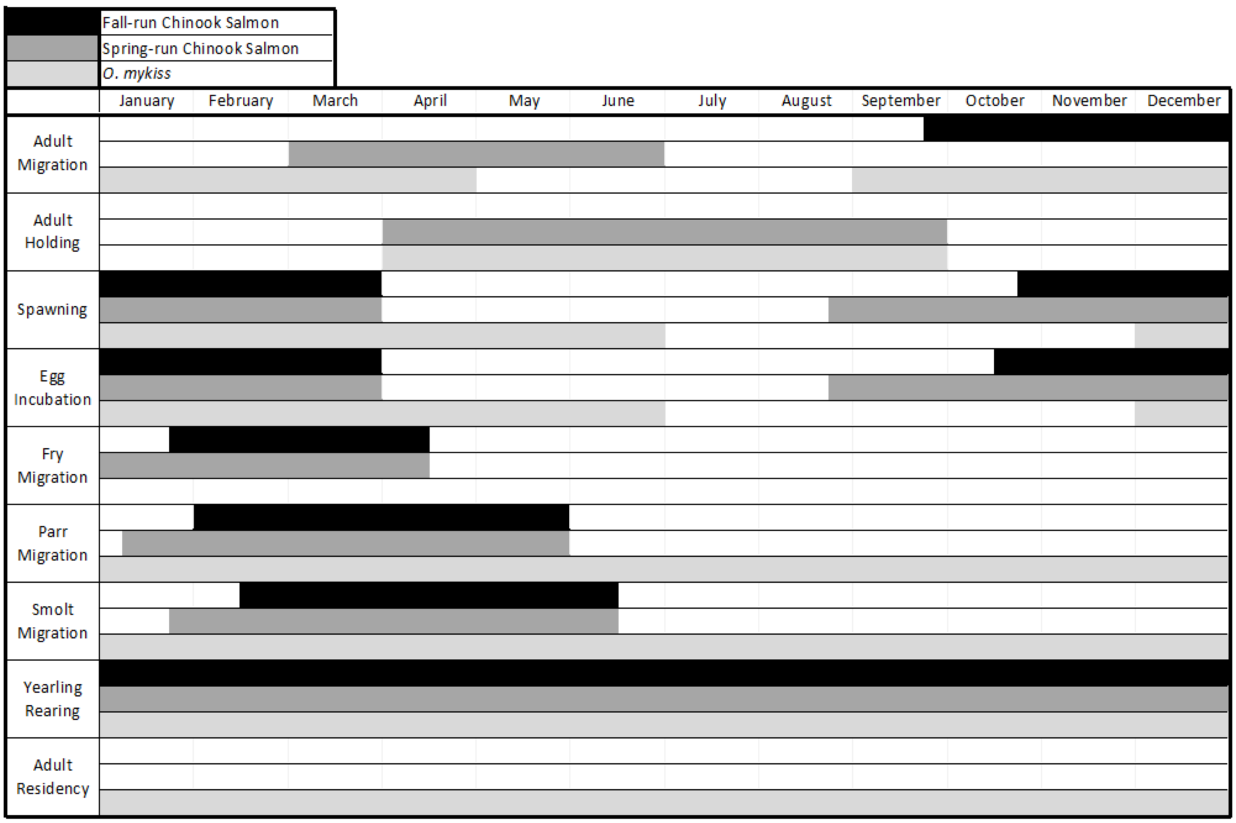

Figure 7

Timeline for Chinook Salmon and *O. mykiss* Migration and Rearing Periods in the San Joaquin River Basin

6.3.5.1 Rationale for Productivity Objectives

The Watershed-specific Goals for productivity (survival) of juvenile spring-run Chinook salmon are the same as those set for fall-run Chinook salmon. Although it is possible to distinguish spring-run Chinook salmon from fall-run Chinook salmon (using genetic and/or otolith markers), the SEP Group considered it impractical to measure differences in the survival rate of spring-run and fall-run Chinook salmon juveniles. The SEP Group found no reason to expect different juvenile survival rates among YOY spring-run Chinook salmon juveniles than those identified for fall-run Chinook salmon in the Stanislaus River. Because juvenile per spawner productivity objectives are the same for fall-run and spring-run, total juvenile production expected at Caswell in any year should reflect the total number of Chinook salmon adults returning in the prior year. The proportional mix between spring-run and fall-run spawners will not affect the juvenile production objective. Similar to fall-run, should productivity objectives not be met, monitoring for the attainment of egg productivity targets and adult productivity objectives will facilitate identification of the phase(s) of the life cycle in which problems occur (e.g., pre-spawning mortality or egg viability impacts vs. egg incubation impacts).

Spring-run Chinook salmon juvenile productivity might differ from fall-run Chinook salmon productivity if the production of the yearling life history phenotype far exceeds the objectives for this life history type, making it a larger proportion of outmigrants than observed in other rivers. This outcome is explicitly addressed within the objectives for yearling production, as the objective for yearling production includes a specific conversion between yearlings and YOY migrants such that overall egg to outmigrant survival can be evaluated fairly.

The same freshwater survival rates for spring-run Chinook salmon and fall-run Chinook salmon will generate different population growth rates if ocean mortality for spring-run is different than that assumed (based on recent data) for fall-run Chinook salmon from the Stanislaus River. The assumption that spring-run ocean mortality will ultimately be similar to current fall-run ocean mortality cannot be addressed at this stage because it is not known how fishing regulations will change to reflect restoration of spring-run Chinook salmon, and there is some amount of spring-run Chinook salmon bycatch in the current fishery. If ocean mortality rates for spring-run Chinook salmon remain different from those for fall-run Chinook salmon, productivity objectives for year 10 (rebuilding) and year 15 (resilience) may be modified accordingly.[4]

The SEP Group designed targets for adult holding success and redd persistence that apply to fall-run and spring-run Chinook salmon. These objectives are described in the context of spring-run Chinook salmon because, unlike fall-run Chinook salmon, spring-run Chinook

[4] The third productivity objective (sustainability) is not influenced by ocean survival rates.

salmon experience a prolonged period of holding between their arrival in the river and the onset of spawning. It is during this period that spring-run Chinook salmon complete gametogenesis. The amount of time spent holding by fall-run Chinook salmon is generally much less than for spring-run. Yet, there is frequently a holding period between the end of migration and onset of spawning, and the objectives described in this report provide necessary context for evaluating and improving conditions during fall-run adult migration (the life history stage in which this run completes gametogenesis). Survival and success rates of Chinook salmon during holding periods can strongly influence overall population productivity—having survived through so many other phases of the life cycle, holding fish are extremely valuable from a population dynamics point of view. Holding and redd persistence objectives support the goals of restoring the unique behavioral phenotype of spring-run Chinook salmon and improving productivity for fall-run and spring-run Chinook salmon.

6.3.5.2 Methods for Productivity Objectives

6.3.5.2.1 Juvenile Productivity

Specific calculations and assumptions regarding the Biological Objectives for juvenile survival of spring-run Chinook salmon and for guidance regarding egg productivity targets are described in Section 6.2.5.2 for fall-run Chinook salmon productivity objectives. Because the survival objectives for spring-run and fall-run juvenile Chinook salmon are the same, the total number of Chinook salmon spawners (fall + spring) in a given year results in a minimum number of juvenile Chinook salmon outmigrants (fall + spring) at Caswell and Mossdale in the following year. This total will not vary based on the ratio of spring-run to fall-run Chinook salmon spawners.

In addition to the YOY size classes identified for fall-run Chinook salmon, the SEP Group expects that the existence of spring-run Chinook salmon spawning adults will correspond to production and detection of yearling outmigrants (Moyle 2002; Williams 2006). If yearling production rates or the ratio of spring-run to fall-run Chinook salmon adults is low, the total number of juveniles produced by the Chinook salmon spawning class should not be affected by this investment in the yearling life history strategy because yearlings will be a very small fraction of the total outmigrants resulting from any year-class of eggs. However, investment in yearlings may affect the total number of juveniles expected under the following conditions:

- Yearling production is much higher than the minimum specified in the life history size-class distribution objective, suggesting a substantial fraction of spring-run egg production is directed toward a yearling strategy and not a YOY strategy; and
- Spring-run populations are a substantial fraction (greater than 33%) of the total spawning population such that spring-run Chinook salmon investment in a yearling life history strategy affects overall productivity estimates.

Under these conditions, the productivity objectives would credit the previous year's production of YOY juveniles as though three smolts had been produced in year "y" for each yearling-sized fish produced in year "y+1." This is based on expectations that the ratio of survival of smolt-sized spring-run Chinook salmon to yearling-sized fish would be approximately 33% (i.e., one yearling survives for every three smolt-sized fish that attempt a yearling strategy). The basis for this conversion is that a 50% overwintering mortality is commonly assumed for fall-run Chinook salmon fingerlings (Mullan 1990). Because spring-run Chinook salmon YOY juveniles would need to survive through summer months before emigrating as the following year's yearlings, the SEP Group assumed that additional mortality would occur; therefore, they increased the expected mortality of spring-run Chinook salmon YOY to the yearling life stage to 66%.

6.3.5.2.2 Adult Productivity

In order to support the life history strategy of the spring-run phenotype and the productivity of this run, the vast majority of adult spring-run Chinook salmon that migrate into the Stanislaus River must survive until spawning commences. Generally speaking, there is no reason to expect much mortality of either spring-run or fall-run adult migrants of in the river if there is suitable habitat (i.e., cover, temperature, DO) in which they can hold. Furthermore, holding spring-run (and migrating fall-run adult) females should experience conditions that facilitate spawning success; post-spawning egg retention should be low. Finally, the SEP Group expects that a very high proportion of redds constructed by fish that over-summer in the river (spring-run) and by adult fall-run migrants will experience good conditions throughout the incubation period. Redd persistence will be indicated when redds are not superimposed on other redds, dewatered, scoured, or otherwise heavily disturbed, and when redds experience water quality conditions that are generally conducive to egg development and fry emergence. Attaining these objective will require, among other things, sufficient summer holding habitat for returning spring-run adults as well as adequate spawning habitat for spring-run that can be isolated (temporally, physically, or by temperature or flow conditions) from spawning fall-run Chinook salmon.

6.3.5.3 Results: Productivity Objectives

6.3.5.3.1 Juvenile Productivity Objectives

Juvenile productivity objectives include the following:

- Rebuilding Objective : Eggs to Caswell survival greater than 10.8%;
- Resilience Objective: Median Eggs to Caswell survival greater than 14.3%; and
- Sustainability Objective: Median Eggs to Caswell survival equal to 24.8%.

See fall-run Chinook salmon productivity objectives (Section 6.2.5.3) for further description of juvenile productivity objectives and supplemental guidance to support egg incubation success in the Stanislaus River.

6.3.5.3.2 Adult Holding and Redd Success Objectives

Adult holding and redd success objectives include the following for spring-run Chinook salmon:

- At least 90% of adult migrants that pass the weir through survive to spawning;
- Less than 10% of female carcasses retain 10% or more of eggs; and
- Chinook salmon redd viability rate of greater than 90% (as projected by monitoring of temperature, flow, and superimposition).

All spring-run Chinook salmon productivity Biological Objectives are summarized in Table 7.

6.3.5.4 Rationale for Timing of Migration Life History Objective

The Watershed-specific Goal is to support the fullest expression of spring-run Chinook salmon life history diversity in order to increase population stability, resilience, and productivity.

Size at date of migration was used as a proxy for life history strategy. An objective that specifies a window for juvenile migration is necessary to ensure that river function is maintained during a normal migration period. Allowing for spring-run Chinook salmon migration throughout a broad migration window is intended to expose some spring-run Chinook salmon juveniles to "optimal" migration conditions (throughout their life cycle) whenever those optimal conditions occur (a timing that is expected to vary unpredictably with the timing of hydrological, estuarine, and marine conditions, across years).

6.3.5.5 Methods for Timing of Migration Life History Objective

In other Central Valley watersheds where they co-occur, spring-run Chinook salmon spawning begins approximately 1 month (or more) earlier than fall-run Chinook salmon (Yoshiyama et al. 1998; Moyle 2002). Thus, the expectation that detection of migrating fry-sized spring-run Chinook salmon juveniles would begin at least 3 weeks earlier than fall-run fry ought to be easily attained in a healthy river.

The migration timeframe for yearling-sized fish was based on yearling emigration data from Mill, Deer, and Butte creeks (Figure 25 of Lindley et al. 2004). The SEP Group investigated migration timing patterns in Sacramento River tributaries and determined that among watersheds and across years, yearling emigration primarily occurred throughout the migration period that was weeks or months long, and less so in single, short-duration pulses, which were more common for fry (Ward et al. 2004; Lindley et al. 2004; McReynolds et al. 2006, 2007; Garmin and McReynolds 2008, 2009). Collectively, these studies suggest that yearlings emigrate over a broader timeframe than fry.

The SEP Group recognizes that distinguishing between fall- and spring-run Chinook salmon juveniles in the field is challenging at this time. Thus, these life history objectives will be satisfied by detection of appropriately sized Chinook salmon juveniles, without regard to parentage, in the specified time window. If field techniques that allow distinction between juveniles of different runs become available, the SEP Group will consider how the objective should be implemented on a run-specific basis.

6.3.5.6 Results: Timing of Migration Life History Objective

By year 15 of plan implementation, Chinook salmon monitoring will detect, in every year, migration of spring-run Chinook salmon juveniles as shown in Table 14.

Table 14

Spring-run Chinook Salmon Timing of Migration Objectives at Caswell Rotary Screw Trap

Size/Life History Type	Frequency	Start	Fall-run Start	End (Both Runs)
Yearling (to be measured two calendar years following parent cohort return [escapement])	a) Detection in at least 50% of weeks between the second week of October to January, and b) 50% of weeks February to April (The division between time periods is intentional and meant to ensure that some yearlings migrate in each of the time periods)	October	No Applicable Objective	April
YOY (Fry, Parr, and Smolt)[1]	Every week	First week of January	Last week of January	First week of June

Note:
1 See Table 9 for definitions of fry, parr, and smolt size classes.

This yearling migration timing objective will be in place any time spring-run Chinook salmon are spawning in the Stanislaus River. Because overall yearling abundance may be low, the SEP Group's expectation is only that yearling-sized Chinook salmon will be detected, at least once, in 50% of weeks between the second week of October and January and in 50% of weeks between February and April. However, it may only be a measureable objective when spring-run escapement and spawning are sufficient to produce a number of yearlings that can satisfy the objective. There are 30 weeks in the entire period, so at least 15 yearlings would need to be detected to meet the objective of at least one yearling detection in 50% of weeks in the two time periods.

The minimum number of yearlings needed to meet the objective implies that a total escapement of at least 16,700 spring-run Chinook salmon is needed. This is based on the following assumptions:

- At least 1.5 yearlings are produced per 1,000 returning adult females (i.e., 1.5 yearlings per 1,000 female spawners; see size at migration life history objective below);
- 60% of the escaped fish are females (as per current estimate for fall-run Chinook salmon; Appendix A); and
- A sampling efficiency for yearlings similar to that of Butte Creek, the system from which the minimum yearling/spawner expectation is derived.

If the assumptions above are met and escapement is lower than this target, the yearling production objective can be revised to an expectation that roughly equal numbers of yearling are detected in each of the two time periods (October to January and February to April).

As described below, the SEP Group believes it is likely that yearling production will be substantially greater than the 1.5 per 1,000 spawner rate identified in the size at migration life history objective. Additionally, the SEP Group believes that choosing the lowest documented yearling-to-spawner ratio known in the Central Valley (Butte Creek) is highly conservative, and this objective should be easily exceeded in a healthy river.

6.3.5.7 Rationale for Size at Migration Life History Objective

Size at date of migration was used as a proxy for life history strategy. The timing of migration objective (Section 6.3.5.6) establishes targets for the duration of the migration timing window, whereas this objective identifies a minimal distribution of size at migration among juvenile spring-run Chinook salmon. Production of a broad portfolio of spring-run Chinook salmon sizes during migration is intended to generate at least some spring-run Chinook salmon that are of "optimal" size to capitalize on conditions (throughout their freshwater migration) that exist in a given year. The SEP Group recognizes that the size class that will perform best under a given year's set of environmental conditions is not knowable in advance and varies from year to year. Production of a wide portfolio of size at migration is needed so that some proportion of the population is appropriately sized to take advantage of conditions in each year (Satterthwaite et al. 2014).

6.3.5.8 Methods for Size at Migration Life History Objective

For YOY migrants, the SEP Group found no reason to expect a different annual size class distribution for spring-run than was expected for fall-run. Run-specific size class distributions may differ at any given time because the two populations spawn at different times; however, over the course of a migration season (the time step at which this objective is implemented), the overall distribution of size classes should be similar across runs. These minima seem reasonably attainable, based on the size-class distributions currently observed in the river (Figure 6; Table 8), and should capture intended benefits of anticipated habitat restoration activities. Furthermore, it would not be practical to attempt to measure differences in the annual size distribution at migration of spring-run Chinook salmon juveniles versus fall-run Chinook salmon juveniles. If field techniques that allow distinction between juveniles of different runs become available, the SEP Group will consider how this objective should be implemented on a run-specific basis.

The yearling production objective was calculated based on the expectation that at least 1.5 yearlings can be produced per 1,000 returning adult females, which is the minimum ratio detected for Butte Creek in the years 2001 to 2007 (Ward et al. 2004; McReynolds et al. 2006, 2007; Garman and McReynolds 2008, 2009). The rate of yearling production for spring-run detected in Butte Creek is the lowest rate among the populations that have been studied on Sacramento River tributaries (Ward et al. 2004; Lindley et al. 2004; McReynolds et al. 2006, 2007; Johnson and Merrick 2012). For example, the percentage of yearlings among juvenile spring-run Chinook salmon on Butte Creek ranged from 0.01% to 0.05% during 2001 through 2006 (Ward et al. 2004; McReynolds et al. 2006, 2007). This compares to approximately 5% of all juveniles being yearlings on Deer and Mill creeks from 1994 to 2010 (Johnson and Merrick 2012). These numbers are believed to underestimate the true proportion of spring-run yearlings present. This is due to the following: 1) capture efficiency for yearling salmon is less than for YOY; and 2) the sampling location was downstream of redds built by fall-run Chinook salmon, which are generally expected to produce a much lower proportion of yearling migrants than spring-run Chinook salmon.

The SEP Group expects the yearling productivity objectives to be easily attainable in a restored Stanislaus River. Given the lack of information on yearling production rates for the Stanislaus River (spring-run escapement has only been sporadically monitored or documented; Franks 2012), there was no evidence to justify a higher yearling production rate. Failure to attain the objective will strongly suggest some impediment to yearling production in the Stanislaus River that should be investigated and addressed. If, over several years, the yearling to spawner ratio is higher than the very low level targeted here, it is recommended to increase the objective to account for the higher capacity to produce the yearling life history type.

This yearling production objective will be in place any time spring-run Chinook salmon are spawning in the Stanislaus River. However, it may only be a measureable objective when spring-run Chinook salmon escapement and spawning are sufficient to produce a number of yearlings that can be reliably detected. It is estimated that total escapement of approximately 5,600 spring-run Chinook will be necessary to detect whether this objective is being met assuming the following:

- Yearling production of at least 1.5 per 1,000 returning adult females and 60% of escapement are females (as per the current estimate for fall-run Chinook salmon; Appendix A
- A sampling efficiency for yearlings similar to that for Butte Creek (the system from which the minimum yearling/spawner expectation is derived)

When escapement is lower than this target, the objective should be revised such that at least one yearling is detected any time that spring-run escapement is greater than 1,100 fish. Yearling-sized fish are currently detected in the RSTs of the Stanislaus River (Watry et al. 2007), despite the fact that since the installation of the VAKI RiverWatcher weir run by FISHBIO, the cumulative number of spring-run Chinook salmon escapement (2007 to 2012) has not exceeded 70 individuals (Franks 2012).

6.3.5.9 Results: Size at Migration Life History Objective

By year 15, generate a broad size-class distribution of emigrating juveniles such that the annual emigrant size-class distribution as measured at Caswell RST is as follows:

- For YOY migrants, same size distribution minima as for fall-run objective; and
- For yearling migrants, minimum of 1.5 yearlings per 1,000 female spawners.

Biological Objectives for spring-run Chinook salmon life history diversity are summarized in Table 12.

6.3.5.10 Rationale for Genetic Objective

Central Valley spring-run Chinook salmon have a unique life history and physiology, which facilitate their abilities to ascend to higher elevation habitat than fall-run and delay spawning for several months (Healey 1991; Yoshiyama et al. 2001). However, much of this high-elevation spawning habitat is no longer accessible to salmon due to the presence of dams, thus limiting the opportunity for differences in spawning locations between spring- and fall-run Chinook salmon (Figure 4; Lindley et al. 2006; Moyle et al. 2008). In rivers with dams blocking access to historic spawning habitat, such as the Sacramento and Feather rivers, hybridization between spring- and fall-run Chinook salmon has occurred (Banks et al. 2000; CDFG 1998). For creeks where access to historic spawning habitat is not blocked by dams (e.g., Mill and Deer creeks), genetic differences between spring- and fall-run Chinook salmon have been maintained and documented (Banks et al. 2000). Due to the genetic, life history, morphological, ecological, and behavioral differences between spring- and fall-run Chinook salmon, the two runs are designated as different ESUs and are managed based on these designations (Waples 1991; Smith et al. 1995; NMFS 2004).

One primary way to maintain distinct and heritable life history characteristics among ESUs is to limit gene flow among ESUs and allow for co-evolved gene complexes to be established and maintained through processes of local adaptation. Providing opportunities for spring-run Chinook salmon reproductive isolation is particularly important for the maintenance of spring-run Chinook salmon populations in rivers where high elevation habitat is blocked by dams.

The objective and rationale are not intended to prescribe or preclude the introduction of individuals with a spring-run Chinook salmon genetic lineage (e.g., from current spring-run ESU populations). Rather, it is possible that spring-run Chinook salmon that are genetically distinct from fall-run Chinook salmon are recolonizing San Joaquin River tributaries on their own or were never entirely extirpated. Spring-run Chinook salmon are also part of a large reintroduction effort on the mainstem San Joaquin River downstream of Friant Dam that may result in additional colonization of the San Joaquin tributaries in the future. The intent of this objective is to promote the recolonization of the San Joaquin River and its tributaries as well as the long-term success of individuals that exhibit spring-run life history characteristics independent of their near-term genetic origin.

6.3.5.11 Methods for the Genetic Objective

Gene-flow criteria (less than 2% introgression) between ESUs have been proposed to achieve long-term genetic integrity and maintain a low extinction risk for natural populations (Lindley et al. 2007; HSRG 2014). Initial hybridization and introgression between runs should be avoided because, once gene flow between runs has occurred, it will be more difficult to establish and maintain genetic isolation between runs in the future. The SEP Group assumed that the general guidance for introgression between ESUs should apply to introgression between spring-run and fall-run in the Stanislaus River.

6.3.5.12 Results: Genetic Objective

Immediately following plan implementation, conditions on the Stanislaus River will be established that support spring-run Chinook salmon spawning success and reinforcement of long-term genetic integrity as measured by greater than 98% of spring-running Chinook salmon spawn with other spring-running salmon.

Genetic objectives for spring-run Chinook salmon are summarized in Table 13.

6.4 Central Valley Steelhead

6.4.1 What is the Problem?

Central Valley steelhead are listed as a threatened species under the federal ESA. Natural production is well below desired levels, survival rates are inadequate to achieve population growth and maintain population resilience, the populations express only a narrow range of the life history variants that are typical of this species, and hatchery influence on wild stocks compounds all of these problems.

Counts of steelhead in the San Joaquin River basin's three major tributaries—the Stanislaus, Tuolumne, and Merced rivers—are at very low levels (McEwan 2001). Unlike Chinook salmon, there is no dedicated escapement survey for steelhead. However, counts at weirs on these rivers all show only a few adult steelhead returning in any given year, and no fish returning in some years. The species exists in larger numbers as the resident rainbow life history form in the tailwaters below the major rim dams, but the anadromous, ESA-listed form of *O. mykiss* is extremely rare.

6.4.2 What Outcome(s) (Central Valley Goals) Will Solve the Problem?

Abundance

Increasing abundance of Central Valley steelhead is a goal of several policies governing Central Valley salmonids. The CVPIA (Section 3406 of the CVPIA, Title 34 of Public Law 102-575) calls for naturally spawning populations of anadromous fish that are double the 1967 to 1991 baseline within 10 years. State law (F&G Code § 6902(a)) and water quality regulations (SWRCB 2006) express the same target. In addition, increased abundance of this life history type will be required in order to recover the population (i.e., delist the population from the federal ESA). Furthermore, increased abundance of resident *O. mykiss* is believed to be necessary in order to support the following:

- Increased frequency of the anadromous phenotype;
- Resilience of *O. mykiss* populations to prolonged natural occurrence of conditions that render anadromy a poor strategy; and
- Local recreational fisheries.

Productivity and Life History Diversity

Improvements in Central Valley productivity (measured as parr survival and smolt production) and increased life history diversity (i.e., more anadromous adults) are necessary for the following reasons:

- To achieve abundance targets for steelhead in the Central Valley;
- To maintain fish "in good condition" (F&G Code § 5937);
- To achieve acceptable levels of the criteria NMFS uses to evaluate salmonid population viability (McElhany et al. 2000); and
- To be consistent with other fisheries-related and water management-related policies.

Genetic Diversity

For steelhead, as for salmon, concerns about genetic diversity and what is needed to sustain healthy and viable populations revolve around the influence of hatchery production and management (Williams 2006). In the Sacramento River basin, steelhead populations are dominated by hatchery fish, as there are hatcheries on Battle Creek, the Feather River, and the American River. However, as none of the three major San Joaquin River tributaries has a steelhead hatchery, straying of stocked steelhead is not currently a major concern in these rivers. The closest steelhead hatchery to the San Joaquin tributaries is on the Mokelumne River, an eastside tributary.

6.4.3 What Does Solving the Problem Look Like (Central Valley Objectives)?

Abundance

Central Valley Objectives for resident *O. mykiss* abundance have not been determined. The AFRP set an abundance objective of 13,000 naturally produced steelhead, but this only applied to the Sacramento River above the RBDD. This estimate was based on Mills and Fisher (1994), which calculated returns from a combination of RBDD ladder counts, hatchery returns, and estimates based on harvest rates. The NMFS Recovery Plan (NMFS 2014) has targets for the minimum number of viable steelhead populations needed for recovery by watershed and sub-region; a viable population at low risk of extinction is defined as having a minimum adult escapement of 2,500 individuals over 3 years, with a minimum effective population size of 500 fish in freshwater. This implies an average minimum escapement of 850 steelhead each year.

Productivity

The CVPIA and AFRP inform Central Valley Objectives for population growth rates as these policies call for doubling of anadromous fish populations in 10 years. Current productivity is not sufficient to produce the Central Valley Objective (AFRP target) of 13,000 naturally produced steelhead in the upper Sacramento River or 850 adults (ESA recovery target) in most rivers in the Central Valley. Survival and population growth rates need to improve greatly to meet these system-wide objectives.

Life History Diversity

Existing policies inform Central Valley Objectives for life history diversity among *O. mykiss,* emphasizing the need to support the anadromous life history type (steelhead). The extensive loss of historic spawning and rearing habitat in the Central Valley has led to a near loss of steelhead in many watersheds. Currently, many rivers in the Central Valley are dominated by the freshwater fluvial, or resident, form of *O. mykiss*, also known as rainbow trout. Reversing this loss of life history diversity will require extensive habitat improvements in the rivers and Delta, which will allow for higher production of parr with faster growth rates, greater smolt survival, and higher adult survival. These changes should lead to increases in the proportion of *O. mykiss* population represented by the anadromous form.

Genetic Diversity

The Central Valley steelhead population is currently dominated by hatchery fish, all of which are released as age-1 smolts. Hatchery fish tend to increasingly mature after only one year in the ocean, and to have low numbers of repeat spawners (Hankin et al. 2009). This has led to few age-classes of fish present in populations and an overall loss of diversity within the Central Valley population. Natural production of steelhead in Central Valley rivers and hatchery reforms are needed to reverse the genetic influence of hatchery-origin steelhead populations.

6.4.4 How will this Effort Contribute to Attainment of Central Valley Objectives (Watershed-specific Goals)?

As described, the scope of the SEP Group's current effort is the Stanislaus River through the lower San Joaquin River to the Delta. Specific goals and objectives for the Stanislaus and lower San Joaquin rivers were developed to support the system-wide goals identified.

Abundance

The Watershed-specific Goal for steelhead abundance in the Stanislaus River is to increase steelhead escapement to permit, delist, and eventually permit a limited, regulated catch and release steelhead fishery.

Productivity

The SEP's goals for *O. mykiss* include producing riverine growth, density, and survival levels for *O. mykiss* that encourage production of sufficient numbers of anadromous smolt to support a viable steelhead population.

Life History Diversity

The Watershed-specific Goal for life history diversity is to support the fullest expression of *O. mykiss* life history diversity in order to increase population stability, resiliency, and productivity.

Currently, the San Joaquin River basin's tributaries are dominated by the resident form of *O. mykiss*. Increasing expression of the anadromous phenotype is necessary to meet NMFS recovery goals and the SEP's Watershed-specific Goals for steelhead.

Genetic Diversity

The genetic Watershed-specific goal for *O. mykiss* on the Stanislaus River is to maintain an independent population that is largely free from the influence of steelhead hatchery strays.

6.4.5 What Suite of Species-specific Outcomes (Biological Objectives) Characterize Success?

The SEP Group has set Biological Objectives for *O. mykiss* that differ in many respects from those for Chinook salmon. This is partially due to *O. mykiss* displaying very different, complex life history strategies that are more diverse (within and across populations) and more plastic (within individuals) than those displayed by Chinook salmon. For example, *O. mykiss* populations display resident forms and anadromous forms, both of which must be protected in order to maintain population productivity and stability. In addition, the timing of the various migration and rearing periods for various *O. mykiss* life stages and age-classes is highly variable even within the same population (Figure 7).

Few data exist regarding steelhead demographics on the Stanislaus River, and no data exist on their age structure, growth rates, or survival rates. Nonetheless, the anadromous form of *O. mykiss* is underrepresented in the Stanislaus River, and it will require large improvements in river and Delta habitats to reach suitable levels of abundance, productivity, and diversity.

6.4.5.1 Rationale for O. mykiss Abundance Objectives

Total adult *O. mykiss* abundance is affected by conditions that are controllable solely on the Stanislaus River. As such, there is a Biological Objective for *O. mykiss* abundance, which is a significant difference from Chinook salmon Biological Objectives. Additionally, productivity and the balance between the anadromous and resident life history strategies are strongly influenced by resident *O. mykiss* density. Because abundance (density) is a specific, measureable desired outcome (Biological Objective) and driver of other Biological Objectives, the SEP Group's Biological Objectives for *O. mykiss* abundance are described in sections describing resident parr density (Section 6.4.5.4.1) and a range of life history objectives for the Stanislaus population (Section 6.4.5.8).

As with Chinook salmon, no specific Biological Objective is set for the number of steelhead that must return to the Stanislaus River. However, the inclusion of the Biological Objective for abundance for resident *O. mykiss* in the Stanislaus River will ultimately contribute in the attainment of the Central Valley Objectives for steelhead. Furthermore, combined with the Biological Objective for resident *O. mykiss* abundance, Central Valley Objectives for steelhead are essential to determining Environmental Objectives (e.g., physical, chemical, and biological conditions necessary to support juvenile rearing; see below) for the Stanislaus River that will support attainment of larger goals and objectives.

In order to qualify as one of the two independent, viable populations of steelhead in the San Joaquin River basin called for in the NMFS Recovery Plan (NMFS 2014), the steelhead population must be a naturally produced population at low risk of extinction. The NMFS Recovery Plan (NMFS 2014) states that a viable population at low risk of extinction should have a minimum adult escapement of 2,500 individuals over 3 years, with a minimum effective population size of 500 fish in freshwater (the census size of standing stock; for every one fish returning two fish remain in ocean; 850 escapement in 1 year). The abundance objective would be measured as a minimum 3-year running average of 850 adult steelhead (not counting sexually immature fish, such as "half-pounders"), with a minimum effective population size of 500 in any given year.

Given the popularity of this species as a sportfish, it may be desirable in the future to allow a sport fishery on the recovered steelhead population of the Stanislaus River. Adult escapement beyond the recovery threshold would allow for a catch and release steelhead sport fishery in the Stanislaus River, assuming a low level of mortality from hooking and handling. If hooking mortality rates, defined as total catch and release fishing-related mortality up to outmigration as kelts, were an average of 15% (Ashbrook et al. 2010), then an escapement of 1,000 wild adult steelhead would allow for 850 fish to survive to the kelt stage. These figures imply that the final restoration target for steelhead in the Stanislaus River should be 1,000.

These levels of abundance are lower than the abundance levels anticipated for fall-run and spring-run Chinook populations (in Central Valley Objectives). Even in relatively healthy watersheds, steelhead are not typically as abundant as salmon populations. While salmon spawning runs often number in the hundreds of thousands to low millions, healthy wild steelhead runs typically reach hundreds in smaller coastal streams, thousands in larger rivers, and up to tens of thousands of fish in major river systems of the Northwest and northern California (Busby et al. 1996).

6.4.5.2 Rationale for Productivity Objectives

Increasing smolt production levels while maintaining a strong resident rainbow trout population will require production of a larger number of age-0 *O. mykiss* and an increase in the somatic growth rate of *O. mykiss* on the Stanislaus River. Abundance (density) and growth rate affect the relative rate of anadromy in *O. mykiss* populations (McMillan et al. 2012; Kendall et al. 2014). Even at good smolt-to-adult return rates, a minimum number of smolts are needed to support Central Valley Goals and Objectives for steelhead abundance. High smolt production may also help swamp predators in the lower river and Delta and result in increased survival. Faster growing *O. mykiss* juveniles typically smolt at younger ages, as long as they reach approximately 140 mm FL by the spring (Seelbach 1993). Large smolts have been shown to have higher survival to the adult stage (Ward et al. 1989).

The growth rates of juvenile *O. mykiss*, as well as the timing of growth, can vary greatly among watersheds in California. Sogard et al. (2012), using passive integrated transponder (PIT)-tag mark recapture methods, found that juveniles in two central coastal streams, Scott Creek and Soquel Creek, grew very slowly during the dry summer and fall months (0.11 mm/day [0.004 in/day] and 0.14 mm/day [0.006 in/day], respectively). These streams had faster growth rates for fish during the winter-spring months (0.24 mm/day [0.009 in/day] and 0.21 mm/day [0.008 in/day]) when flows were relatively high, even though water temperatures were colder. Lower American River juveniles grew 1.12 mm/day (0.044 in/day) in the summer-fall months, likely due to the warm water temperatures and high food production in that system, and those juveniles grew at 0.61 mm/day (0.024 in/day) in the winter-spring months (Sogard et al. 2012). Hence, stream flows, water temperatures, and food production can clearly interact to produce wide-ranging growth rates in the same life stage of this species in different seasons of the year.

6.4.5.3 Methods for Productivity Objectives

In the near future, an *O. mykiss* population model for the Stanislaus River may be available, which would allow for the setting of age- and stage-specific survival rates for in-river and through-Delta reaches. A similar survival methodology for steelhead escapement could be used, as was developed for fall-run Chinook salmon escapement described in Section 6.2.5.2. However, current data limitations present challenges for establishing Biological Objectives for *O. mykiss* productivity. For example, through-Delta survival rates of steelhead are not well known, and have often been assumed to be low (e.g., 10% in NMFS 2012a). Recent acoustic tagging studies suggest that survival may be much higher, as results from a recent 6-year study have estimated through-Delta survival rates at 54% in 2011 (Buchanan 2013) and 32% in 2012 (Buchanan 2015).[5] In addition, steelhead smolts are more likely the Chinook salmon juveniles to avoid capture in RSTs because they are often larger and stronger swimmers than Chinook juveniles (Volkhardt et al. 2007).

To overcome data limitations, alternative methods of measuring *O. mykiss* productivity are proposed, including measures of parr density and growth rates, smolt size, and smolt production. Smolt production is a direct measurement of anadromy in the *O. mykiss* population, whereas higher growth and survival of *O. mykiss* parr (i.e., among the "resident" population) are believed to be correlated with higher frequency of anadromy. Snorkel

[5] The Buchanan (2015) study used large hatchery steelhead, which might account for these relatively high rates, but they are much higher than survival rates from studies on Chinook salmon, which also used large hatchery smolts.

surveys on the Stanislaus River (Kennedy 2008) have shown very low densities (0 to 0.15 per square meter [m^2]) of age-0 *O. mykiss* in most locations, with a location near Goodwin showing higher densities (0.30 per m^2). Bergman (2014) estimated 0.63 to 2.13 fish per linear meter (3.28 feet [ft]) in the Stanislaus River in a reach just below Goodwin Dam. By comparison, Kozlowski (2004) electrofished 19 sites on the lower Yuba River and estimated that there was an average of approximately 0.40 age-0 *O. mykiss* per m^2. Even this density is very low compared to populations in coastal California streams, where average densities of over two fish per m^2 are common in electrofishing surveys (Sogard et al. 2012).

6.4.5.4 Results: Resident O. mykiss Productivity Objectives

6.4.5.4.1 Parr Density

The density of juvenile *O. mykiss* shall increase over time to one age-0 individual per m^2 or 20,000 per river km (0.62 RM),[6] on average, in specified reaches, by year 15. This could be measured though snorkel surveys, electrofishing, or other appropriate sampling techniques.

6.4.5.4.2 Parr Growth Rates

The growth rates of individual age-0 and age-1 *O. mykiss* shall increase over time to 0.60 mm/day (0.024 in/day) by year 15. An exception to this requirement shall be at age-0 densities over 2 per m^2 on average, or 2,000 per river km, on average, at which growth rates could be as low as 0.40 mm/day (0.016 in/day), to allow for lower growth rates at high juvenile densities. Growth rates could either be measured by capturing, PIT tagging, and recapturing juvenile *O. mykiss* in the river or estimated by back calculating lengths at age from scales.

This rate is intermediate between the lower Mokelumne River, which has colder water temperatures and smaller invertebrates than the lower American River, which has extremely fast growth due to warm water temperatures and good invertebrate production.

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[6] One age-0 *O. mykiss* per m^2 translates to roughly 20,000 per river km (0.62 mile), assuming a river averaging 20 m (65.6 ft) wide.

Productivity Biological Objectives for *O. mykiss* are summarized in Table 15.

Table 15
Resident *O. mykiss* Productivity Objectives

Objective		Productivity	
Life History Stage		**Juvenile Density**	**Juvenile Growth Rate**
Description	**Briefly**	Densities of *O. mykiss* that support desired frequency of anadromy in the population	Average individual growth rates that support desired frequency of anadromy in the population
	Achieved by When?	Year 15	Year 15
	Measure What?	Population density (parr/river km^2)	Average growth rate (mm/day)
	Measured Where?	Upstream of Oakdale, in reaches identified as having high quality *O. mykiss* holding habitat	Upstream of Oakdale, in reaches identified as having high quality *O. mykiss* holding habitat
Resident *O. mykiss*		The minimum density of age-0 *O. mykiss* during the summer equals $1/m^2$ on average	Minimum average growth of both age-0 and age-1 *O. mykiss*, averaged over an entire season, equals 0.60 mm/day

Note:
km^2 = square kilometer

6.4.5.5 Results: Anadromous O. mykiss (Steelhead) Productivity Objectives

6.4.5.5.1 Smolt Size

By year 15, at least 90% of the smolts (Stage 5 in Table 16) observed in the lower Stanislaus River should be 150 mm (5.9 in) FL or greater in length.

Table 16
Life Stage Numbering and Nomenclature for *O. mykiss*, with Special Reference to Steelhead Life History

Stage No.	Stage Name	Stage Description
1	Egg-sac fry	Newly emerged, still has egg yolk visible
2	Fry	Small parr, only a few weeks old
3	Parr	Distinct parr marks, scales not silvery
4	Silvery parr	Scales slightly silvery
5	Smolt	Bright silvery scales, dark edges on caudal fin
6	Adult	Sexually mature fish

Current technology for measuring steelhead smolt production in large rivers is limited, especially in rivers with high and turbid spring flows. Steelhead smolts are believed to be strong enough swimmers that they can avoid capture in RSTs. The most successful methods for counting smolts have been inclined-screen traps and video cameras, which require some type of structure, such as a weir or low-head dam, to concentrate fish and allow individuals to be captured or filmed. Potential future technologies include next-generation Didson imaging sonar system cameras and mark-resight estimates based on PIT tagging of age-0 or age-1 fish prior to smolt emigration combined with mobile PIT-tag antennae.

6.4.5.5.2 Parr and Smolt Production

The number of naturally produced smolts (Stages 4 and 5 in Table 16) greater than 150 mm (5.9 in) FL per adult female steelhead shall be at least 165 by year 15 of the implementation of habitat restoration. This could be measured at either Caswell or another suitable location further downstream, but prior to the confluence with the mainstem San Joaquin River. The methodology would be the same as for smolt size; but it would not necessarily require that smolts be captured, rather only be observed well enough to be identified and counted.

6.4.5.5.3 Parr and Smolt Survival

By year 15, 90% of all the silvery parr and smolts (Stages 4 and 5 in Table 16) counted at the lower end of the gravel bedded reach must be detected at the lower river/beginning of Delta.

6.4.5.5.4 Adult Spawning

By year 15, when adult steelhead are present and spawning, their eggs will have a minimum egg to emergence survival rate of 35% in the wild. See Section 6.2.5.4.2 (Supplemental Guidance to Support Productivity Objectives in the Stanislaus River) for further details regarding the identification, prioritization, monitoring, and adaptive management of this objective.

Biological Objectives for productivity of the steelhead life history type are summarized in Table 17.

Table 17
Steelhead Productivity Objectives

<table>
<tr><th colspan="2">Objective</th><th colspan="8">Productivity</th></tr>
<tr><th colspan="2">Life History Stage</th><th colspan="2">Juvenile Smolt Size</th><th colspan="2">Juvenile Smolt Production</th><th colspan="3">Juvenile Smolt Survival</th><th>Adult</th></tr>
<tr><td rowspan="4">Description</td><td>Briefly</td><td colspan="2">Proportion of smolts (Stages 4 and 5 in Table 16) observed should be of a size able to survive the ocean phase and return as anadromous adult</td><td colspan="2">Naturally produced smolts (Stages 4 and 5 in Table 16) per female spawner increase to levels consistent with other healthy steelhead populations…</td><td colspan="3">Smolt survival – smolt (Stages 4 and 5 in Table 16) survival rate consistent with population resilience</td><td>Egg survival consistent with…</td></tr>
<tr><td>Achieved by When?</td><td colspan="2">Year 15</td><td colspan="2">Year 15</td><td colspan="3">Year 15</td><td>Year 15</td></tr>
<tr><td>Measure What?</td><td colspan="2">FL</td><td colspan="2">Number of smolts per female spawner</td><td colspan="3">Survival through lower Stanislaus River</td><td>Egg survival</td></tr>
<tr><td>Measured Where?</td><td colspan="2">To be determined (Caswell area)</td><td colspan="2">Caswell (or other location prior to confluence with mainstem)</td><td>Lower end of gravel bedded reach</td><td></td><td>Delta entry</td><td></td></tr>
<tr><td colspan="2" rowspan="4">Steelhead</td><td colspan="2">At least 90% of the smolts (Stages 4 and 5) observed should be 150 mm (5.9 in) FL or greater in length</td><td colspan="2">Naturally produced smolts (Stages 4 and 5) emigrating from the river each year shall increase to at least 165 per female spawner</td><td colspan="3">> 90%</td><td rowspan="4">> 35%</td></tr>
<tr><td>FL</td><td>150 mm (5.9 in)</td><td rowspan="2">3-year running average</td><td rowspan="2"></td><td colspan="3" rowspan="3"></td></tr>
<tr><td>Percentage</td><td>90%</td></tr>
<tr><td>Year type</td><td>All years</td><td>Minimum</td><td>165</td></tr>
</table>

6.4.5.6 Rationale for Life History Objectives

The proportion of anadromous adults in the Stanislaus River appears to be very low. Several factors are likely contributing to this low production of anadromous individuals. The river habitat may not be producing many age-0 *O. mykiss.* Those that are produced may be growing slowly or have poor survival. Delta habitat conditions may result in low survival of smolt. In rivers with healthy wild steelhead, the majority of juveniles tend to be produced by anadromous mothers, even if there are female resident rainbow present (Donohoe et al. 2008). The sex ratio of adult resident *O. mykiss* tends to be heavily biased toward males (Rundio et al. 2012). Genetic parentage analysis has shown that resident males contribute more to the next generation of steelhead than resident females (Christie et al. 2011). This is consistent with species that exhibit partial anadromy, where resident males are predicted to be more abundant (Jonsson and Jonsson 1993).

Age-0 *O. mykiss* have not yet selected an anadromous or resident life history pathway (Thorpe et al. 1998; Beakes et al. 2010). Tracking the proportion of those that eventually smolt is a measure of the life history diversity of the *O. mykiss* population. In a population dominated by the resident form, nearly all will choose to mature in the stream as residents due to the following (Satterthwaite et al. 2009):

- Generations of selective pressure against anadromy, likely from some combination of low smolt survival;
- Large asymptotic size; and/or
- High survival rates of adult residents.

In keeping with the Watershed-specific goal for life history (i.e., to support the fullest expression of *O. mykiss* life history diversity in order to increase population stability, resiliency, and productivity), Biological Objectives were established to provide for a balance between anadromous and resident *O. mykiss* life history types. These objectives also support the Watershed-specific goal for abundance, as they will maintain a minimum number of adult residents to allow the continuation of the popular sport fishery in the lower Stanislaus River. Finally, the life history Biological Objectives support population resilience by creating a “refuge population” of *O. mykiss* in the Stanislaus River that can potentially give rise to anadromous progeny.

6.4.5.7 Methods for Life History Objectives

These Biological Objectives for steelhead use different metrics to measure, sometimes directly, sometimes indirectly, the proportion of the *O. mykiss* population that is anadromous versus resident. The SEP Group acknowledges that there is no method available to determine the future migratory life history of individual *O. mykiss* parr in the Stanislaus River. Therefore, the general approach adopted was to increase overall productivity of juveniles, individual growth rates, and survival rates in the Stanislaus River. In concert with increased smolt to adult survival rates in the lower San Joaquin River and the Delta, these parameters should lead to higher numbers of juveniles following the anadromous life history strategy (Satterthwaite et al. 2010).

6.4.5.8 Results: Life History Objectives

6.4.5.8.1 Anadromy – Juvenile Stage

By year 15, a minimum of 150 steelhead smolts shall be produced per female spawner in the poorest water years up to a minimum of 300 per female spawner in good water years. This will be tracked on a broodyear basis, as smolt years in steelhead do not necessarily match broodyears. Measurement of how well this objective has been achieved will require accurate estimates of adult escapement and smolt production each year for several years, plus ages of smolts in order to assign broodyears.

6.4.5.8.2 Anadromy – Adult Stage

By year 15, the proportion (as a 5-year running average) of all counted adult *O. mykiss* over a full season shall be a minimum of 25% resident (less than 460 mm [18.1 in] FL), counted during the summer or fall) and 20% anadromous (greater than 460 mm [18.1 in] FL) individuals (counted during the spawning migration). Stream resident adults could be counted by snorkel surveys or estimated by mark and recapture through hook and line sampling. Anadromous adults could be estimated at a weir, snorkel surveys, or redd surveys.

6.4.5.8.3 Anadromy – Maternal Origin

The proportion of age-0 *O. mykiss* that are the progeny of anadromous mothers shall increase to a minimum of 45% by year 15. This percentage could be met with approximately ten times more resident adults (approximately age 3 and older) than adult steelhead.

This objective is measureable and should be monitored using otolith microchemistry studies. Several published papers have used otolith microchemistry to determine the maternal origin of individual *O. mykiss* (Donohoe et al. 2008; Zimmerman et al. 2008). For this type of study, it is best to take otoliths from age-0 fish to avoid biases from sampling older fish that have decided to become resident, as it is known that anadromy in *O. mykiss* has some genetic heritability.

6.4.5.8.4 Anadromy – Balance

The objective for anadromy—balance is by year 15, attain and maintain a minimum abundance of resident adults (as defined by a combination of year-round presence, size at age, and scale analysis) that at least meets the lower end of the abundance range (i.e., a superpopulation of 1,492 to 7,873 age 1+ [or 3 to 9 age 1+ per 100 m^2 (1,076 ft^2)]) specified by Bergman et al. (2014). Resident adult numbers can be estimated by mark recapture studies, snorkel surveys, or electrofishing.

6.4.5.8.5 Anadromy – Smolt Emigration

In most *O. mykiss* populations that produce steelhead, the largest, oldest smolts (often age 3) emigrate first, followed by the smaller, younger smolts (age 2 and age 1) as the emigration progresses. In order to maintain this age-class diversity among smolts, environmental conditions should be suitable for smolt emigration for several months of the year. Steelhead smolts have been detected emigrating from the Stanislaus River anywhere from December through June, based on data from the Caswell and Oakdale RSTs, though the abundance of smolts is usually greatest from January through April. Thus, by year 15, the Stanislaus River RSTs should detect emigrating steelhead smolts (Stages 4 [silvery parr] and 5 [smolt] of at least 150 mm [5.9 in] FL in a minimum of 4 months of each emigration season [October through September]).

Biological Objectives for life history diversity for *O. mykiss* on the Stanislaus River are summarized in Table 18.

Table 18

***O. mykiss* Life History Diversity Objectives**

Objective		Life History Diversity (Anadromy)				
Life History Stage		**Juvenile**			**Adult**	
Description	**Briefly**	Smolts produced per female spawner indicative of healthy spawner	Supports anadromy via a sufficient proportion of juveniles with anadromous *O. mykiss* mothers	Supports a range of outmigration dates for life history diversity	Support viable levels of both life history types	Support viable levels of both life history types
	Achieved by When?	Year 15	Year 15	Year 15	Year 15	Year 15
	Measure What?	Smolts/ female spawner	Proportion of age-0 juveniles with anadromous maternal origin in otolith	Smolt (Stages 4 and 5; at least 150 mm [5.9 in] FL) Detection	Proportion of adult *O. mykiss*	Resident adult abundance
	Measured Where?	Spawning reach	Age-0 *O. mykiss* collected in rearing areas	Caswell RST		Reach just downstream of Goodwin Dam
O. mykiss		This shall be tracked on a brood year basis				Age 1+ fish superpopulation > 1,492 to 7,873
		Annual hydrology > 50% exceedance: > 300	> 45%	Minimum of 4 months of the year	> 25% resident – Summer	3 to 9 age 1+ fish per 100 m^2 (1,076 ft^2)
		Annual hydrology ≤ 50% exceedance: > 150			> 20% anadromous – immigrating adults	

7 ENVIRONMENTAL OBJECTIVES

The Environmental Objectives developed by the SEP Group are intended to represent physical and chemical conditions needed to support the Biological Objectives for Chinook salmon populations and the *O. mykiss* population (including resident and anadromous life history types) within the Stanislaus River. They define the physical and chemical conditions needed to attain the Biological Objectives. They also provide life stage-specific guidance that should be used in the development, prioritization, and adaptive management of Conservation Actions.

Attainment of Watershed-specific Goals and Biological Objectives is unlikely until Environmental Objectives are met; thus, the speed with which Environmental Objectives are met is important. In addition, producing these necessary environmental conditions is not a substitute for attaining the Biological Objectives. In other words, attainment of the Biological Objectives is the intent; attainment of Environmental Objectives should result in achievement of Biological Objectives, but adjustment of the Environmental Objectives may be necessary to ensure full attainment of the desired biological outcomes. Environmental Objectives are considered hypotheses of the conditions necessary to support the Biological Objectives; thus, they should be implemented within an adaptive management framework that allows for modification if necessary to achieve desired biological outcomes.

Environmental objectives have been developed to support the following life stages:

- Adult upstream migration;
- Adult holding;
- Spawning;
- Egg incubation; and
- Juvenile rearing and migration.

The specific criteria for each Environmental Objective and category are detailed in this section and summarized in Appendix B. Temperature, DO, and contaminants are critical to all life stages; these parameters are discussed by life stage in this section. A more integrated discussion of temperature, DO, and contaminants is provided in Appendix C. A general approach for and the intended application of the Environmental Objectives as well as descriptions of key variables are also presented below.

7.1 General Approach for, and Intended Application of, Environmental Objectives

Environmental Objectives are intended to quantify the desired habitat and ecosystem conditions in the planning area (e.g., Stanislaus River) necessary to achieve and sustain the Biological Objectives. Environmental Objectives are defined in terms of a range of specific measurable parameters that together make up suitable environmental conditions for the species in question. Because habitat and ecosystem condition needs vary across species as well as among different life history stages within a single species, Environmental Objectives are defined separately for each species and life history stage combination.

In general, and specifically in the application of Environmental Objectives to the identification and prioritization of Stressors and the subsequent development of Conservation Actions, it is important to note that Watershed-specific Goals and Biological Objectives can only be attained if all of the target species' life history stages are successful. As a result, though Environmental Objectives are specified by distinct life history stages, attaining the Biological Objectives related to each life history stage will require that Environmental Objectives for all life history stages for the species be achieved.

Environmental Objectives for each species and life history stage have been assigned the following:

- A timing window indicating the months of the calendar year during which the conditions described by the objectives should be maintained, and
- A geographic range (defined by reach) where the objectives are applicable.

It is important to note that Environmental Objectives do not necessarily need to be met across the specified geographic range in order to achieve Biological Objectives. Rather, the geographic range merely indicates those reaches where sufficient spatial habitat extent (quantified as a component of Environmental Objectives where applicable) can be achieved, given inherent characteristics of the system (e.g., geologic, topographic, and geomorphic).

Geographic ranges have been defined as broadly as possible to allow for maximum flexibility in the attainment of Environmental Objectives, given the inherent constraints of the system.

In some cases, for some portion of the applicable timing window or during some years, only a subset of the optimal conditions for a given species or life history stage may be attainable. However, this does not necessarily indicate that an individual or cohort experiencing those sub-optimal conditions will not contribute to population success or the attainment of Biological Objectives. For this reason, Environmental Objectives have been defined in three categories of conditions for all applicable parameters:

- Optimal conditions
  - Contribute to the health and growth of individuals and the population without harmful effects
  - Support the attainment of the Biological Objectives
- Sub-optimal conditions
  - Associated with some degree of impact at the individual or population level (e.g., observable or measurable stress, increased vulnerability to disease, reduced growth, reduced survival)
  - May or may not support attainment of the Biological Objectives
    - Where likelihood of detriment increases with lower suitability (relative to optimal range), or decreased occurrence (frequency or duration) of suitable conditions
- Detrimental conditions
  - Associated with a significant level of harm at the individual or population level
  - Do not support and are a detriment to the attainment of one or multiple Biological Objectives

Optimal conditions are supportive of individual and population health as well as fitness. Sub-optimal conditions, by contrast, if maintained for an extended period or experienced across multiple parameters, should be considered harmful and will inhibit the potential for the species/life history stage experiencing them to contribute to the attainment of the Biological Objectives for that year-class.

When looked at in their totality, the complete set of Environmental Objectives provides a spatial and temporal depiction of the system that will support the attainment and maintenance of the Biological Objectives. Therefore, Environmental Objectives are intended to serve as the basis for the development and evaluation of Conservation Actions designed to create the habitat and ecosystem conditions necessary to support Biological Objectives. Achieving the Biological Objectives will therefore require a suite of Conservation Actions that together address Environmental Objectives. In cases where it has been provided, the required spatial extent of the habitat conditions specified in the Environmental Objectives is a function of population size and fish density relative to habitat area relationships and has been calculated based on the target population size.

Additionally, prior to achieving desired Environmental Conditions, habitat conditions may be less optimal for certain species and life history stages than for others. Resolving the conditions for one life history stage may therefore have a disproportionately large effect on the ability to advance Biological Objectives for other or all of that species' life history stages. To inform prioritization of Conservation Actions, the SEP Group identified, described, and prioritized stressors to provide guidance on the relative impact of existing stressors on life history stages (Section 8).

Given the dynamics and needs necessary to achieve Biological Objectives, the SEP Group anticipates the need for a conservation plan that encompasses the following:

- A suite of Conservation Actions designed to achieve all Environmental Objectives;
- A phased implementation approach for those objectives through time; and
- Prioritized sequences for implementation based, in part, on the relative needs of different life history stages and the evolving habitat extent of the growing population.

7.2 Environmental Objectives and Supporting Rationale for each Life Stage

7.2.1 Adult Upstream Migration

Chinook salmon and steelhead return from the ocean to freshwater to spawn in the rivers of the Central Valley. Fall-run Chinook salmon return to San Joaquin River tributaries, including the Stanislaus River, between late September and December (Figure 7). Spring-running Chinook salmon have been observed in San Joaquin Tributaries in recent years and are being restored to the mainstem San Joaquin under the San Joaquin River Restoration Program. These fish are expected to migrate to their spawning grounds between March and June (Figure 7; SJRRP 2010). Central Valley steelhead migrate upstream from September through April (Figure 7).

After spawning, Chinook salmon adults die, whereas steelhead may attempt to return to the Estuary and Pacific Ocean for possible repeat spawning in subsequent years. Both Chinook salmon and steelhead cease to eat during their spawning migrations; somatic energy reserves and nutrients are used to complete the upstream journey, the processes of attaining and defending nest sites and mates, and spawning. Nutrients and energy are also allocated to production of gametes. Adult migration and gametogenesis are energy-intensive and time-sensitive activities; thus, delays caused by barriers or disorientation can result in death, lost opportunities to spawn, or other forms of reduced reproductive success.

Chinook salmon and steelhead typically return to their natal streams to reproduce, a process called homing, and its opposite (i.e., returning to a non-natal stream to spawn) is called straying. Several modes of orientation play a role in successful homing. However, once adult fish enter freshwater, olfactory identification of water emanating from the natal stream is the dominant cue driving salmonid orientation (Healy 1991; Quinn 2005). In highly managed watersheds like those of the Central Valley where large fractions of a river's flow may be diverted at one or more locations along the migration path, homing success can be influenced by the amount of flow from a particular spawning stream that reaches migrating adult salmon and the ratio of flow from various source streams in a watershed (Marsten et al. 2012). The magnitude of pulse flows or attraction flows to facilitate adult migrations, and the ratio of flows from various San Joaquin River tributaries that must reach any point along the migratory corridor, are not addressed as Environmental Objectives because establishing such San Joaquin River basin-wide objectives will require completion of Environmental and Biological Objectives for all the major San Joaquin River tributaries and the mainstem. Likewise, base flow conditions in the Stanislaus River as well as the mainstem San Joaquin below its confluence with the Stanislaus River are not identified here.

Environmental Objectives that are required for successful completion of adult migrations (from freshwater entry to arrival at holding sites for spring-run Chinook salmon) or to spawning grounds (for fall-run Chinook salmon and steelhead) include those for temperature, DO, minimum channel depth at critical riffles, and contaminants (metals and pesticides). Contaminants can interfere with migration success and subsequent reproductive success; therefore, maximum tolerable levels of these compounds are also included. Although adult Chinook salmon and steelhead may have different environmental requirements for optimal performance, such differences were not apparent in the literature. Thus, all Environmental Objectives for adult migration apply to runs of Chinook salmon and steelhead.

Poor environmental conditions may result in the delay of spawning migrations rather than outright mortality. Delayed migrations are expected to negatively affect reproductive success. Consistent with this expectation are the observations that adult (sockeye) salmon migrate at speeds much faster than those that would be energetically optimal (Brett 1983) and that fat reserves are largely depleted by the time fish spawn and die (as reviewed in Quinn 2005). This report assumes that "optimal" conditions for adult migration are those that result in no delay (i.e., 0-hours delay) in the migration process, and "sub-optimal conditions" will result in delays that are less than 24 hours. Environmental conditions that result in migration delays greater than 24 hours are considered "detrimental." Delays of greater than 24 hours may result in reduced ability to acquire and defend spawning territory, mates, or completed redds. In addition, environmental conditions that result in extended delay of migration are likely to be associated with stresses that affect fecundity (e.g., egg or sperm viability).

A summary of the Environmental Objectives detailed below for the adult upstream migration life stage is provided in Table B-1 (Appendix B).

7.2.1.1 Temperature

7.2.1.1.1 Temperature Objective Rationale (Adult Upstream Migration)

Water temperature affects all aspects of salmonid metabolism and physiology. Low water temperatures are not likely to be a problem for migrating Central Valley salmonids. High water temperatures approaching physiological limits occur with some frequency in most of the larger Central Valley rivers (Williams 2006). These temperatures result in high metabolic rates and increased susceptibility to disease (USEPA 1999, 2003; NRC 2004). In addition, increases in temperature reduce the ability of water to hold DO, which may stress migrating salmonids. Finally, development and maintenance of gametes appear to be negatively affected by prolonged exposure to elevated temperatures (Berman and Quinn 1990 as cited by USEPA 1999).

7.2.1.1.2 Temperature Approach (Adult Upstream Migration)

Several literature reviews provide insight into temperature levels that are optimal, sub-optimal, or detrimental to the success of migrating adult Chinook salmon and steelhead. The SEP Group relied primarily on USEPA (1999, 2003) guidance for temperature effects on Pacific salmon and supplemented that information when newer information and studies specific to Central Valley salmon were available.

Wherever possible, temperature thresholds are reported as both a daily average (corresponding roughly to the temperature thresholds reported from studies using constant temperature conditions) and 7-day average of daily maximum temperatures (7DADM), as per the practice of the USEPA (2003). The 7DADM that corresponds to a daily threshold was calculated by adding half of the difference between daily average and daily maximum temperatures (USEPA 2003) to the daily threshold reported in the literature. For the Stanislaus River, the average difference during the summer and fall months between daily average and daily maximum temperatures was approximately 3°C (5.4 °F) at the Orange Blossom Bridge gage. So, a conversion factor of 1.5°C (2.7°F) was added to daily recommended temperature thresholds to estimate the "midpoint" temperature for the corresponding 7DADM. For some temperature-related effects, other temperature metrics are reported when the effect occurs on a shorter or longer timeframe.

7.2.1.1.3 Temperature Objectives (Adult Upstream Migration)

Raleigh et al. (1986) identified weekly average optimal temperatures of 8°C to 12°C (46.4°F to 53.6°F) for Chinook salmon; however, USEPA (1999, 2003) identified no sub-optimal impacts at constant temperatures lower than 14°C (57.2°F). Optimal temperatures range from 9.5°C to 15.5°C (49.1°F to 59.9°F) as a 7DADM (accounting for the typical difference between daily average and daily maximum temperatures in the Stanislaus River).

Sub-optimal temperatures (those associated with negative sub-lethal effects) ranged from constant laboratory temperatures of 14°C to 19°C (57.2°F to 66.2°F) or 15.5°C to 20.5°C (59.9°F to 68.9°F) as a 7DADM. Exposure to high water temperatures facilitates infection among migrating adult salmonids (Noga 1996). USEPA (2001) identified an elevated risk of disease spread at weekly average temperatures between 14°C to 17°C (57.2°F to 62.6°F) and a high risk of infection at prolonged exposure to temperatures greater than 18°C (64.4°F; USEPA 2003). USEPA (2003) reported reduction in migration fitness due to cumulative stresses associated with prolonged exposure to temperatures 17°C to 18°C (62.6°F to 64.4°F). Swimming performance is reduced at temperatures greater than 20°C (68°F; USEPA 2003); however, Williams (2006) and Richter and Kolmes (2005) indicate that migration may be impeded when temperatures are as low as 19°C (66.2°F). Many sources recommend maintaining temperatures less than 20°C to 21°C (68°F to 69.8°F) to prevent direct impairment of Chinook salmon migrations (USEPA 1999, 2003; Richter and Kolmes 2005). Furthermore, although the impact of water temperatures on developing embryos is not well understood, there is evidence that developing reproductive tissues exposed to high temperature may be less viable than those that are formed under cooler temperatures. USEPA (2003) indicates that eggs in holding females exposed to constant temperatures greater than 13°C (55.4°F) suffer reduced viability. Berman (cited by USEPA 1999) found that offspring of adult Chinook salmon that had been held for 2 weeks at temperatures between 17.5°C to 19°C (63.5°F to 66.2°F) had higher pre-hatch mortality as well as developmental abnormality rates and lower weight than a control group. The SEP Group's 7DADM of 15.5°C to 20.5°C (59.9°F to 68.9°F) reflects the thresholds for sub-optimal effects, including delays in adult migration that would exceed 24 hours.

Detrimental temperatures are those that will tend to prohibit attainment of Biological Objectives for the Stanislaus River. The Incipient Upper Lethal Temperature (IULT) for Chinook salmon may be as low as 21°C to 22°C (69.8°F to 71.6°F) for adult Chinook salmon and steelhead during migration (Richter and Kolmes 2005; USEPA 1999, 2003). Williams (2006) reported that salmon returning to the Stanislaus River in 2003 endured water temperatures greater than 21°C (69.8°F) on their migration; however, there is no information regarding the fate of adults that experienced these temperatures or their offspring.

Given the range of detrimental effects to migrating adult salmon and steelhead and their future offspring, and the different exposure timesteps in which these negative effects would be expected to occur, the SEP Group provides several thresholds for detrimental temperature effects. Weekly mean temperatures greater than 18°C (64.4°F) expose migrating salmonids to a high risk of disease, which could lead to catastrophic failure of a year-class (e.g., NRC 2004). On a 7DADM basis, temperatures greater than 20.5°C (68.9°F) must be avoided in the migration corridor. Instantaneous temperatures (e.g., daily maxima) must be below 22°C (71.6°F) to avoid detrimental effects to migrating adult salmon.

Table 19 summarizes the temperature objectives for adult upstream migration for Chinook salmon and steelhead.

Table 19
Temperature Objectives for Chinook Salmon and Steelhead Adult Upstream Migration

Habitat Type	Temporal Extent	Condition	Range (Metric)
Delta to Holding/ Spawning Grounds	Fall-run: Late September to December Spring-run: March to June Steelhead: September to April	Optimal	8°C to 14°C (46.4°F to 57.2°F) (Daily Average)
			9.5°C to 15.5°C (49.1°F to 59.9°F) (7DADM)
		Sub-optimal	14°C to 19°C (57.2°F to 66.2°F) (Daily Average)
			15.5°C to 20.5°C (59.9°F to 68.9°F) (7DADM)
		Detrimental	> 18°C (64.4°F) (Weekly Average)
			> 19°C (66.2°F) (Daily Average)
			> 20.5°C (68.9°F) (7DADM)
			> 22°C (71.6°F) (Instantaneous)

7.2.1.2 Dissolved Oxygen

7.2.1.2.1 Dissolved Oxygen Rationale (Adult Upstream Migration)

The DO is critical to producing the energy adult salmonids need to complete their upstream migrations. Oxygen consumption increases exponentially with increased swimming velocity (Brett 1964), and adult salmon tend to migrate at speeds approaching their physiological maxima. The capacity of water to hold DO varies inversely with temperature and the concentration of other substances dissolved in the water. In addition, increasing abundance of organic material in the water column can generate increasing demand for DO (e.g., biochemical oxygen demand [BOD]; Tetra Tech 2006; USEPA 2006). High temperatures, high concentrations of dissolved substances, and high BOD contribute to periodically low levels of DO in the San Joaquin mainstem.[7] As a result, areas of the lower San Joaquin River and Delta are listed as being impaired on the USEPA Clean Water Act Section 303(d) list for not meeting water quality standards due to low DO (USEPA 2011). These low levels of DO have been observed to delay or block adult salmon migrations into the San Joaquin River basin during some years.[7]

7.2.1.2.2 Dissolved Oxygen Approach (Adult Upstream Migration)

The SEP Group relied on DO criteria established by the USEPA (1986), the Central Valley Regional Water Quality Control Board (CVRWQCB; 2015a), and other technical literature to identify DO objectives that are optimal (no negative effects), sub-optimal (observably negative, sub-lethal effects), and detrimental (preventing attainment of Biological Objectives) ranges for migrating adult salmonids. The Washington State Department of Ecology (WDOE; 2002) reported that DO concentrations above 8 to 9 milligrams per liter (mg/L) are needed for maximum swimming performance in salmon. Several researchers report decreased swimming efficiency at DO less than 7 mg/L (Dahlberg et al. 1968; WDOE 2002). The DO levels below 5 to 6 mg/L elicited avoidance (WDOE 2002). Davis (1975) reported a "distress" response when adult salmon were exposed to DO less than 6 mg/L.

Hallock et al. (1970) found that adult Chinook salmon migrating up the San Joaquin River avoided DO concentrations below 5 mg/L. However, their observation that these fish began to migrate when DO increased above 5 mg/L is not conclusive evidence that DO levels between 5 to 6 mg/L are acceptable. First, these fish had already suffered an extended delay while avoiding DO levels below 5 mg/L, so this is not an indication that the fish Hallock et al. (1970) observed would not have been delayed had they initially encountered DO levels between 5 to 6 mg/L. Second, the final fates and reproductive successes of the fish Hallock et al. (1970) observed were not recorded. Therefore, it is not known if the eventual migration through waters with low DO had negative fitness consequences.

[7] See http://www.sjrdotmdl.org/concept_model/about.htm and sources cited there.

The regulatory limit for DO in the Stockton Deep Water Ship Channel (DWSC) is 6 mg/L during months when fall-run Chinook salmon migrate; however, that standard applies only to the DWSC, not other waters that San Joaquin River basin fall-run Chinook salmon might migrate through. The standard in other stretches of the fall-run migratory pathway is 5 mg/L. Similarly, the standard is only 5 mg/L during the spring (CVRWQCB 2015a). Spring-run Chinook salmon adults (which were not known to be present in the San Joaquin River basin when the regulatory standard was implemented) require the same levels of DO as do fall-run Chinook salmon and steelhead are believed to require similar DO levels to complete migration; therefore, the 6 mg/L boundary between sub-optimal and detrimental conditions must apply during the spring migration season as well. DO concentrations above 8 mg/L were assumed to represent optimal conditions, and concentrations below 6 mg/L were detrimental. Between 6 and 8 mg/L was identified as sub-optimal for migrating and holding adults.

7.2.1.2.3 Dissolved Oxygen Objectives (Adult Upstream Migration)

Table 20 provides a summary of DO objectives for adult upstream migration for Chinook salmon and steelhead.

Table 20
Dissolved Oxygen Objectives for Chinook Salmon and Steelhead Adult Upstream Migration

Habitat Type	Temporal Extent	Condition	Range (Metric)
Delta to Holding/ Spawning Grounds (Main Channel)	Fall-run: Late September to December Spring-run: March to June Steelhead: September to April	Optimal	> 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	< 6 mg/L (Daily Minimum)

7.2.1.3 Channel Depth

7.2.1.3.1 Channel Depth Rationale (Adult Upstream Migration)

Migrating adult salmonids require water of sufficient depth to facilitate upstream passage. Although migrating salmonids can transit areas with water that is less than their body depth, such conditions are not desirable as they cause stresses associated with the following:

- Increased drag and reduced swimming efficiency,
- Low oxygen availability (if gills are exposed),
- Exposure to predators and poachers,
- Abrasion on the riverbed,
- Crowding, and the
- Cumulative effect of these negative conditions.

7.2.1.3.2 Channel Depth Approach (Adult Upstream Migration)

Riffles that do not provide depths greater than the body depth of an adult salmon between adjacent pools impede salmon migration. For many decades, the CDFW (2013) has used a protocol for determining minimum depth of the critical (most shallow) riffle, which is applied in higher-elevation waterways to determine necessary instream flows (depth increases with increased flow). The methodology for calculating necessary flows from estimates of critical riffle depth may not be applicable to low gradient, mainstem rivers. However, the criteria for estimating minimum depths and minimum extent of those depths in the shallowest riffle are relevant and likely conservative estimates for mainstem rivers. Indeed, to account for the long distances that migrating salmon must travel in mainstem rivers, the SEP Group has modified the CDFW criteria to include a longitudinal minimum depth (i.e., addressing depths in riffles up and downstream of the critical [shallowest] riffle).

The critical riffle methodology (as modified by the SEP Group) describes the boundary between sub-optimal and detrimental conditions. In other words, this Environmental Objective describes the minimum allowable depth of the Stanislaus and lower San Joaquin rivers. An optimal depth distribution (in cross-section and longitudinally) has yet to be determined and would likely depend on factors such as water temperature, clarity, DO, and velocity as well as the density of salmon migrating during any particular period.

7.2.1.3.3 Channel Depth Objectives (Adult Upstream Migration)

The SEP Group developed the following depth objectives for adult upstream migration:

- Shallowest riffle (critical riffle):
  - At least 25% of the entire transect (perpendicular to flow) of the shallowest riffle in the migratory corridor will be deeper than or equal to 0.3 m (1 ft), and
  - At least 10% of the entire transect will be contiguously greater than or equal to 0.3 m (1 ft; CDFW 2013).
- Frequency of shallow riffles:
  - 90% of the riffles in the migratory corridor must satisfy the requirements of the critical riffle for depths greater than or equal to 0.46 m (1.5 ft) instead of greater than or equal to 0.3 m (1.0 ft).

7.2.1.4 Contaminants

7.2.1.4.1 Contaminants Rationale (Adult Upstream Migration)

The Stanislaus River, San Joaquin River, Delta, and San Francisco Bay have been identified as impaired for pesticides on the USEPA Clean Water Act Section 303(d) list (SWRCB 2010; USEPA 2011). In addition, mercury, selenium, and nutrients have been identified as impairing beneficial uses in the Stanislaus River, San Joaquin River, Delta, and San Francisco Bay (SWRCB 2010; USEPA 2011). Contaminants have the high potential to adversely impact the successful completion of adult migration throughout the migratory corridor. However, mercury and selenium bioaccumulation in the ocean is likely low, and returning adults cease to eat during their migration, so there are low risks to adult salmonid migration from mercury and selenium (though exposure earlier in the life cycle may impair adult performance; CEDEN 2014c). There is some evidence that other contaminants (e.g., hydrocarbons and metals) from urban runoff have caused pre-spawn mortality in salmonids in the Pacific Northwest (Scholz et al. 2011); however, there are no data that suggest that these contaminants are at the levels that would impact upmigrating salmonids to the Stanislaus River. Therefore, pesticides and nutrients are the only contaminants that were analyzed by the SEP Group for direct impacts on adult salmon migration to and in the Stanislaus River.

Adult fish are typically less sensitive to pollutants than juveniles; however, pre-spawn adult salmonids are likely less tolerant of chemical stressors because they have used most of their accumulated fat stores for gamete production (NMFS 2008, 2010, 2013b). It is probable that some pre-spawn migrating adults will die because of short-term exposures to pesticides or nutrients (i.e., ammonia, nitrate, or nitrite), especially when subjected to additional stressors such as elevated temperatures. Pre-spawn mortality is a particularly important factor in the recovery of salmonid populations with low abundance because every adult is crucial to the population's reproductive potential and viability (NMFS 2013b).

Successful migration of adult fish may also be impeded by exposures to sub-lethal concentrations of pesticides and nutrients or indirect ecological impairments caused by excessive nutrients. For example, most pesticides, in addition to other chemical contaminants like metals, have been found to disrupt fish olfaction (Hansen et al. 1999; Scholz et al. 2000; Moore and Waring 2001). This disruption of the olfactory sense can eliminate the detection of natal waters or disrupt orientation in adult migrants, which can increase straying (Potter and Dare 2003; Scott and Sloman 2004). Pollutants have also been found to alter migration patterns and delay timing in adult migrating Atlantic salmon in the Maramichi River, Canada (Elson et al. 1972). Furthermore, contaminant exposures have been found to result in metabolic costs in fish that may decrease salmonids' ability to complete subsequent life stages (Beyers et al. 1999; Coghlan and Ringler 2005).

Nutrients occur naturally; however, anthropogenic activities may elevate levels of certain nutrients or change the ratios among different nutrients, which can result in impairments to aquatic life. For example, ammonia, nitrite, and nitrate (to a lesser extent) have been found to be toxic to fish via disruption of oxygen transport by the blood (Russo et al. 1974; Camargo et al. 2005; USEPA 2013). Anthropogenic sources of nutrients (e.g., nitrogen and phosphorus) from activities like agriculture, urbanization, sewage treatment, and livestock operation have been shown to cause eutrophication in Central Valley rivers (CVRWQCB 2013a; Gowdy and Grober 2005; Schlegel and Domagalski 2015). Detrimental impacts from eutrophication include increased temperatures, hypoxia, disrupted migratory corridors, and reduced habitat associated with macrophytes or the release of biotoxins by cyanobacteria or other phytoplankton (Berg and Sutula 2015; Boyer and Sutula 2015; Gowdy and Grober 2005; Schlegel and Domagalski 2015).

For more information on the rational, approach, or objectives for contaminants, see Appendix C, Section 1.3.

7.2.1.4.2 Contaminants Approach (Adult Upstream Migration)

The SEP Group relied on adopted numeric water quality objectives for pesticides from the Sacramento and San Joaquin River Water Quality Control Plan and proposed pesticide water quality objectives from developing pesticide control programs (CVRWQCB 2011, 2014, 2015a,b) to determine pesticide levels that would not cause adverse impacts to adult migration. In addition, for pesticides that do not have state or federally promulgated objectives or criteria, the SEP Group used the USEPA Office of Pesticide Programs (OPP) aquatic-life benchmarks with a level of concern for impacts to endangered and threatened species as the safe level for pesticides.

Unfortunately, no pesticide monitoring program exists throughout the migratory corridor for Stanislaus River salmonids, nor is there likely a program that will exist in the future that will be able to monitor all possible pesticides that may adversely impact adult salmonids during their migration to the Stanislaus River spawning area. Furthermore, the multitude of possible pesticide combinations, differing biochemical interactions of pesticides, and variations of direct and indirect effects preclude the possibility of quantifying the true impact of pesticides on salmonids in the Central Valley (e.g., EC25 of a surface water sample that included direct and indirect impacts of all contaminants).

The SEP Group has relied on a pesticide prediction model (Hoogeweg et al. 2011) to estimate the current frequency of pesticide water quality objective or benchmark exceedances to categorize optimal, sub-optimal, and detrimental conditions for adult migration pesticide Environmental Objectives. That is, the categories are an evaluation of the risks that a species is exposed to pesticide concentrations that could cause harm in a river reach; pesticide conditions were estimated and categorized for each month of the year. The categories assume that, while zero occurrences of pesticides are preferred, such low levels of exposure may not be achievable considering the amount of urban and agricultural development in the Central Valley. Models, monitoring, toxicity bioassays, and other information will need to be updated, developed, conducted, and further gathered in the future to determine if pesticide concentrations are adversely impacting salmonid migration to the Stanislaus River. The SEP Group used this approach (i.e., frequency of water quality criteria or benchmark exceedances) for all Chinook and steelhead life stages. For more information or rationale for this approach, see Appendix C, Section 1.3.

Nutrient imbalances can impair salmonid adult migration through direct toxicity and ecological use impairments, so the SEP Group used two approaches to develop nutrient Environmental Objectives. To evaluate the possible direct toxicity of ammonia, nitrite, and nitrate to salmonids in the Stanislaus River, the SEP Group relied on promulgated USEPA (2013) aquatic-life criteria for toxicological effects from ammonia and literature benchmarks for protective concentrations for nitrate and nitrite exposures. Phosphate does not appear to have direct toxicological impacts to fish or daphnids at ecologically relevant concentrations (Kim et al. 2013), so it is not considered further for this evaluation.

The second category of nutrient Environmental Objectives is ecological use impairments (e.g., migratory corridors), which would include nutrient imbalances that result in a reduction of beneficial habitat for salmonids. Recent efforts for evaluating environmental impacts from nutrients have moved away from the strict application of a single nutrient concentration criterion across broad landscapes or watersheds (Tetra Tech 2006; USEPA 2000). These efforts were developed, in part, because predefined nutrient limits could result in eutrophication in all waterbodies. The evaluation of appropriate nutrient levels requires the evaluation of aquatic beneficial uses needing protection, and classification of waterbodies by type and trophic status as well as consideration of other external environmental factors (Tetra Tech 2006; USEPA 2000). For example, an indirect way to evaluate possible nutrient impairments is to examine some of the detrimental outcomes of nutrient impairments (e.g., depressed DO, excessive macrophytes, or chlorophyll-a concentrations).

7.2.1.4.3 Contaminants Objectives (Adult Upstream Migration)

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and steelhead migration are expected to be similar. The optimal condition for pesticide occurrence is less than 1% chance of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month (Bin 1, Table 23). This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 Code of Federal Regulations [CFR] Part 131; CVRWQCB 2014).

Table 21

Central Valley Regional Water Quality Control Board Adopted and Proposed Water Quality Objectives for Current Use Pesticides

Pesticide	Acute (µg/L)	Chronic (µg/L)
Adopted Water Quality Objectives[1]		
Diazinon	0.16	0.1
Chlorpyrifos	0.025	0.015
Carbofuran	40	40
Simazine	4	4
Thiobencarb	1	1
Pentachlorophenol	5.3	4
Copper	5.7	4.1
Proposed Water Quality Objectives[2]		
Bifenthrin	0.00006	0.00001
Cyfluthrin	0.0002	0.00004
Lambda cyhalothrin	0.00003	0.00001
Cypermethrin	0.00004	0.00001
Esfenvalerate	0.0002	0.00003
Permethrin	0.006	0.001

Notes:
1 CVRWQCB 2015a
2 Proposed water quality objectives for the Central Valley Pyrethroid Pesticides TMDL and Basin Plan Amendment (CVRWQCB 2015b)

Table 22

U.S. Environmental Protection Agency Office of Pesticide Programs' Aquatic-life Benchmarks for the 40 Pesticides that Pose the Greatest Risk in the Central Valley Region

Pesticide	Pesticide Type	Acute Benchmark (µg/L)	Endangered and Threatened Acute Benchmark (µg/L)	Chronic Benchmark (µg/L)	Source of Acute/ Chronic Value[1]
Abamectin	Insecticide	0.17	0.017	0.006	IA/IC
Bifenthrin	Insecticide	0.075	0.0075	0.0013	FA/IC
Bromacil	Herbicide	6.8	0.68	3000	AA/FC
Captan	Fungicide	13.1	1.31	16.5	FA/FC
Carbaryl	Insecticide	0.85	0.085	0.5	IA/IC
Chlorothalonil	Fungicide	1.8	0.18	0.6	IA/IC
Chlorpyrifos	Insecticide	0.05	0.005	0.04	IA/IC
Clomazone	Herbicide	167	16.7	350	AA/FC
Copper hydroxide	Fungicide	5.9	0.59	4.3	IA/IC
Copper sulphide	Insecticide/Algaecide	5.9	0.59	4.3	IA/IC
Cyfluthrin	Insecticide	0.0125	0.00125	0.007	IA/IC
Cyhalofop butyl	Herbicide	245	24.5	134	FA/FC
Cypermethrin	Insecticide	0.195	0.0195	0.069	FA/IC
Deltamethrin	Insecticide	0.055	0.0055	0.0041	IA/IC
Diazinon	Insecticide	0.11	0.011	0.17	IA/IC
Dimethoate	Insecticide	21.5	2.15	0.5	IA/IC
Diuron	Herbicide	2.4	0.24	26	AA/FC
Esfenvalerate	Insecticide	0.025	0.0025	0.017	IA/IC
Hexazinone	Herbicide	7	0.7	17000	AA/FC
Imidacloprid	Insecticide	35	3.5	1.05	IA/IC
Indoxacarb	Insecticide	12	1.2	3.6	FA/IC
Lambda cyhalothrin	Insecticide	0.0035	0.00035	0.002	IA/IC
Malathion	Insecticide	0.3	0.03	0.035	IA/IC
Mancozeb	Fungicide	47	4.7	N/A	AA/na
Maneb	Fungicide	13.4	1.34	N/A	AA/na
Methomyl	Insecticide	2.5	0.25	0.7	IA/IC
(s)-Metolachlor	Herbicide	8	0.8	30	AA/FC
Naled	Insecticide	25	2.5	0.045	AA/IC
Oxyfluorfen	Herbicide	0.29	0.029	1.3	AA/FC
Paraquat	Herbicide	0.396	0.0396	N/A	AA/na

Pesticide	Pesticide Type	Acute Benchmark (µg/L)	Endangered and Threatened Acute Benchmark (µg/L)	Chronic Benchmark (µg/L)	Source of Acute/ Chronic Value[1]
Pendimethalin	Herbicide	5.2	0.52	6.3	AA/FC
Permethrin	Insecticide	0.01	0.001	0.0014	IA/IC
Propanil	Herbicide	16	1.6	9.1	AA/FC
Propargite	Insecticide	37	3.7	9	IA/IC
Pyraclostrobin	Fungicide	0.0015	0.00015	0.002	FA/FC
Simazine	Herbicide	36	3.6	960	AA/FC
Thiobencarb	Herbicide	17	1.7	1	AA/IC
Tralomethrin	Insecticide	0.055	0.0055	0.0041	IA/IC
Trifluralin	Herbicide	7.52	0.752	1.14	AA/FC
Ziram	Fungicide	9.7	0.97	39	FA/IC

Notes:
1 Identifies which taxa was the most sensitive to the pesticide from available toxicity evaluations defined as FA = fish acute; IA = invertebrate acute; AA = Algae Acute; FC = fish chronic; IC = invertebrate chronic; na = not available.
Sources: USEPA OPP. Table modified from Hoogeweg et al. (2011).
– Aquatic-life benchmarks are used by the USEPA OPP for risk assessments in the registration of pesticides. To assess a pesticide not listed, the entire list of nearly 500 pesticide benchmarks can be acquired at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-pesticide-registration

Table 23

Categories of Predicted Pesticide Aquatic-life Benchmark Exceedances

Bin Category	Condition	Range of the Frequency of Benchmark Exceedances		
1	Optimal	0	–	0.017
2	Sub-optimal	0.018	–	0.055
3		0.056	–	0.1
4		0.101	–	0.153
5		0.154	–	0.206
6		0.207	–	0.303
7	Detrimental	0.304	–	0.447
8		0.448	–	0.5
9		0.501	–	0.589
10		0.59	–	0.994

Note:

Frequencies were calculated from the total number of predicted exceedance days for each month from 2000 to 2009. Any day that had at least one pesticide that exceeded benchmarks was counted as an exceedance day. – Source: Adapted from Hoogeweg et al. 2011

It is estimated that exposure of salmon to pesticides 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has a similar impact on salmonid physiology and responses across all life stages, exposures of pesticides greater than 30% (Bins 7 – 10, Table 23) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2 – 6, Table 23. See Appendix C, Section 1.3.3.1 for more information.

Environmental Objectives for ammonia, nitrate, and nitrite toxicity (nutrient toxicity) are provided in Table 24. The USEPA (2013) has promulgated aquatic-life ambient water quality criteria for ammonia for the protection of sensitive species, including salmonids. The USEPA has not developed water quality criteria for protection from direct toxicity to fish or other aquatic life for nitrate or nitrite, so the SEP relied on literature benchmarks for these constituents. The toxicity of ammonia, nitrate, and nitrite are highly dependent on other environmental factors (e.g., pH, temperature, and DO); therefore, an evaluation of the environmental conditions will require a consideration of these other factors.

Table 24

Nutrient Toxicity Objectives for All Life Stages of Chinook Salmon and Steelhead

Nitrogen Species	Maximum Average Continuous Concentration
Ammonia[1]	1.9 mg total NH_3-N/L @ pH 7.0 and 20°C (68°F)
Nitrate[2]	2 mg NO_3-N/L
Nitrite[3]	0.06 mg NO_2-N/L

Notes:
1 USEPA (2013) *Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater 2013*. Ammonia toxicity is temperature- and pH-dependent. Actual ammonia limits can be calculated using the following equation:

$$CCC = 0.8876 \times \left(\frac{0.0278}{1 + 10^{7.688-pH}} + \frac{1.1994}{1 + 10^{pH-7.688}}\right) \times \left(2.126 \times 10^{0.028 \times (20-MAX(T,7))}\right)$$

2 Camargo et al. (2005)
3 Russo et al. (1974)
– (Ammonia) NH_3 -N/L = milligrams of ammonium as nitrogen per liter
– (Nitrite) NO_2-N/L = milligrams of nitrite as nitrogen per liter

– (Nitrate) NO_3 – N/L = milligrams of nitrate as nitrogen per liter

The USEPA (2000) has provided guidance for developing nutrient criteria for rivers and streams. The generalized environmental conditions that define oligotrophic, mesotrophic, and eutrophic lotic systems are displayed in Table 25. The San Diego Regional Water Quality Control Board adopted water quality objectives for nitrate (10 mg/L), total nitrogen (1.0 mg/L), and total phosphorus (0.1 mg/L)—not to be exceeded 10% of the time—as part of a Rainbow Creek nutrient total maximum daily load (SDRWQCB 2006). These objectives are waterbody-specific, but they can be used as a general level of nutrients that may cause impairments to aquatic life beneficial uses. Nutrient concentrations and other environmental conditions (e.g., DO and primary productivity metrics) should be assessed in combination to determine ecological support for adult upstream migration.

Table 25
Suggested Boundaries for Trophic Classifications of Lotic Systems from USEPA (2000)

Variable (Units)	Oligotrophic to Mesotrophic Boundary	Mesotrophic to Eutrophic Boundary
Mean benthic chlorophyll (mg/m^2)	20	70
Maximum benthic chlorophyll (mg/m^2)	60	200
Sestonic chlorophyll (µg/L)	10	30
Total nitrogen (µg/L)	700	1500
Total phosphorus (µg/L)	25	75

Note:
mg/m^2 = milligrams per square meter

7.2.2 Adult Holding

Spring-run Chinook salmon migrate upstream in the spring and require deep, cool, well-oxygenated water during the summer months while they rest and wait to spawn in the early fall. Adult *O. mykiss* also require cool, well-oxygenated water in which to hold as they await the spawning period during the summer months. The holding behavior among fall-run Chinook salmon is abbreviated, relative to the length of the holding period for spring-run and *O. mykiss*; however, fall-run may spawn days to weeks after arriving on the spawning grounds, so they too require adequate holding conditions. During these resting periods, salmonids seek to minimize energy expenditures by avoiding high temperatures, high velocities, low oxygen, and disturbances from predators or people.

Environmental objectives for the adult holding life stage were established for temperature, DO, water depth and velocity, and contaminants. No objectives were developed for potential disturbance (people and predators) or distribution of holding habitat as these parameters seem unlikely to adversely impact oversummering adult salmonids in the current and future states of the Stanislaus River. The objectives and supporting rationale for each of these parameters is discussed below. A summary of Environmental Objectives is provided in Table B-2 of Appendix B.

7.2.2.1 Temperature (Adult Holding)

7.2.2.1.1 Temperature Rationale (Adult Holding)

Optimal water temperatures during the holding stage will allow adult salmon to maintain a low metabolic rate. High temperatures during holding can increase their metabolic rate to a point where sufficient energy reserves will not be available for the rigors of digging redds, spawning, and nest guarding. Elevated pre-spawn mortality can occur if water temperatures are too high during the holding period (McCullogh 1999).

7.2.2.1.2 Temperature Approach (Adult Holding)

As described in detail in Appendix C (Section 1.1.2), the SEP Group relied primarily on USEPA (2003) guidance for temperature effects on Pacific salmon.

7.2.2.1.3 Temperature Objectives (Adult Holding)

The USEPA (2003) reports reduced viability of gametes in holding adult salmonids at constant temperatures in excess of 13°C (55.4°F). While lethal temperatures (1 week constant exposure) range from 23°C to 26°C (73.4°F to 78.8°F), disease risk is high at 18°C to 20°C (64.4°F to 68°F). Sustained water temperatures above 27°C (80.6°F) are lethal to adult spring-run Chinook salmon (Moyle et al. 1995). Temperature objectives are provided in Table 26.

Table 26
Temperature Objectives for Chinook Salmon and *O. mykiss* Adult Holding

Habitat Type	Temporal Extent	Condition	Range (Metric)
Main Channel	April through September	Optimal	< 13°C (55.4°F) (Daily Average)
			< 14.5°C (58.1°F) (7DADM)
		Sub-optimal	13°C to 17°C (55.4°F to 62.6°F) (Daily Average)
			14.5°C to 18.5°C (58.1°F to 65.3°F) (7DADM)
		Detrimental	> 18°C (64.4°F) (Weekly Average)
			> 19°C (66.2°F) (Daily Average)
			20.5°C (68.9°F) (7DADM)
			> 22°C (71.6°F) (Instantaneous)

7.2.2.2 Dissolved Oxygen (Adult Holding)

7.2.2.2.1 Dissolved Oxygen Rationale (Adult Holding)

Low levels of DO can result in adverse physiological effects on salmonids, up to and including death. Low DO levels can be associated with high nutrient inputs; contaminated runoff from urban, industrial, or agricultural lands; or mass die-offs of algal species.

7.2.2.2.2 Dissolved Oxygen Approach (Adult Holding)

The SEP Group used the same approach for holding habitat as was used for upstream migration (Section 7.2.1.2.2).

7.2.2.2.3 Dissolved Oxygen Objectives (Adult Holding)

The SEP Group used the same objectives for holding habitat as was used for upstream migration (Section 7.2.1.2.3); however, these objectives are applied only to habitats upstream of Oakdale (Table 27).

Table 27
Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Adult Holding

Habitat Type	Temporal Extent	Condition	Range (Metric)
Main Channel	April through September	Optimal	> 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	< 6 mg/L (Daily Minimum)

7.2.2.3 Water Depth and Velocity (Adult Holding)

Water velocity experienced by adults during holding should be low enough so that little energy is expended. Spring-run Chinook salmon may hold for several months in a stream prior to spawning, so it is essential that they limit how much energy they use during this period. Water depth should be sufficient to provide cover and refuge from predators and human disturbance.

7.2.2.3.1 Water Depth and Velocity Rationale (Adult Holding)

Holding adult salmon seek to maximize energy reserves through occupying habitats with minimal nonzero velocities. Energy expended to hold position is energy not available for redd construction, spawning, and redd defense. Disturbance by predators or humans result in flight response of fish seeking to escape, using additional energy beyond that necessary to hold position.

7.2.2.3.2 Water Depth and Velocity Approach (Adult Holding)

The depth of the river should provide sufficient cover to hide from predators. Spring-run Chinook salmon hold in pools that are at least 1 m to 3 m (3.3 ft to 9.8 ft) deep (Moyle et al. 1995), and usually greater than 2 m (6.6 ft) deep (Moyle 2002).

Holding pools for adult spring-run Chinook salmon have been characterized as having moderate water velocities ranging from 0.15 meter per second (m/s) to 0.4 m/s (0.5 feet per second [ft/s] to 1.3 ft/s; DWR et al. 2000). According to Moyle (2002), the adults prefer mean water column velocities of 0.15 m/s to 0.8 m/s (0.49 ft/s to 2.6 ft/s).

Holding pools usually have a large bubble curtain at the head, underwater rocky ledges, and shade cover throughout the day. Adult spring-run Chinook salmon also seek cover in smaller "pocket" water behind large rocks in fast water (Moyle et al. 1995).

7.2.2.3.3 Water Depth and Velocity Objectives (Adult Holding)

Targets for depth and velocity are presented in Table 28.

Table 28
Depth and Velocity Objectives for Chinook Salmon Adult Holding

Habitat Type	Temporal Extent	Variable	Optimal Condition
Main Channel	April through September	Depth	≥ 1.5 m (4.9 ft)
		Velocity	< 0.37 m/s (1.2 ft/s)

7.2.2.4 Contaminants (Adult Holding)

7.2.2.4.1 Contaminants Rationale (Adult Holding)

Water quality conditions can impact survival during the salmonid holding period. Studies in the Pacific Northwest have shown high pre-spawn mortality in Coho salmon due to urban contaminants such as in stormwater runoff (Feist et al. 2011; Scholz et al. 2011). In addition to pesticides, urban runoff contaminants often include metals, petroleum, and other compounds. However, unlike pesticides, there is no evidence that these other types of contaminants are currently causing an adverse impact in the holding reaches in the Stanislaus River. Consequently, no Environmental Objectives for these other contaminants are addressed in this report. However, contaminant exposures have been found to result in metabolic costs in fish that may decrease the ability of salmonids to complete subsequent life stages (Beyers et al. 1999; Coghlan and Ringler 2005), so urban runoff and other non-point discharges should occasionally be assessed in the future to confirm that there are no adverse impacts to salmonids.

Nutrient constituents (i.e., ammonia, nitrate, and nitrite) can cause direct toxicity to holding salmonids. Similar to adult migration, excessive nutrients can result in adverse environmental conditions that reduce the fitness and survival of holding adults (e.g., low DO or elevated temperatures).

7.2.2.4.2 Contaminants Approach (Adult Holding)

For discussion of the SEP Group's approach to setting pesticide objectives and objectives for concentrations of nitrogen-based nutrients, see Section 7.2.1.4.2.

7.2.2.4.3 Contaminants Objectives (Adult Holding)

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and *O. mykiss* holding are expected to be similar. Based on the described approach of pesticide Environmental Objectives, the optimal condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 23) of a pesticide exposure, or exposure to a combination of pesticides that exceed water quality objectives, or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2014).

It is estimated that salmon exposed to pesticides at a frequency 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has similar impact on salmonid physiology and responses across all life stages, exposures of pesticides greater than 30% (Bin 7 – 10, Table 23) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2 – 6, Table 23. See Appendix C, Section 1.3.3.1 for more information.

Ammonia, nitrate, and nitrite concentrations necessary to protect holding adult salmonids are provided in Table 24.

7.2.3 Spawning

Salmonids in the Pacific portion of North America have evolved a life history that requires rivers and streams with relatively high gradients for reproduction and rearing. These waterways are cold, low in trace elements, low in nutrients, and high in DO. Movement within the sediment is adequate to disperse fine materials to lower elevations and larger pools more quickly than the larger sediments, resulting in sorting of sediment differentially in low and high velocity waters. Factors such as high water temperatures, high spawner densities, and presence of pathogens can contribute to prespawn mortality or high rates of egg retention in females (Quinn et al. 2007).

The extensive building of large dams resulted in alteration of spawning habitats (Lignon et al. 1995). The dams impede migration of adult salmonids to high elevation spawning areas. At the same time, dams alter a river's hydrograph and sediment supply, reducing movement and availability of large sediment downstream of the dam and allowing fine sediment to settle into interstitial spaces among gravel and cobble. This altered geomorphology reduces suitability of any remaining spawning habitat downstream of a dam. Studies often focus on changes in the purely structural aspects of spawning habitat downstream of dams (i.e., habitat quantity). For example, Hanrahan et al. (2004) evaluated spawning habitat in a large drainage area in the Columbia River system. The spawning habitat parameters Hanrahan et al. (2004) considered were a typical set of depth, velocity, substrate, and channel-bed slope.

Dams also alter water quality aspects of salmon spawning habitat. Water retained behind the dam for extended periods can have high levels of nutrients and trace elements that are toxic to various salmonid life stages. Water stored behind a dam also absorbs heat, causing temperatures to rise and DO levels to drop when it is released downstream. These changes in water quality caused by dams often create physiological stress on the salmonids using the river below the dam.

The structure of redds requires specific characteristics for sediment, water quality, and placement of the redd within the river's geomorphology (Tonina and Buffington 2009). Free flowing rivers develop an alternating pool/riffle sequence structure that gives a non-uniform distribution of sediment within the river. The faster moving riffles have coarser sediment than the slower flowing pool areas. Redds are generally built in the faster moving water that occurs in the coarse sediment areas, at the top and bottom of the riffles. The distribution of sediment sizes, along with water velocity and depth, is an essential component of spawning habitat. Redd distribution in a river is patchy, reflecting the non-uniform distribution of sediment. Availability of coarse substrate (up to 10% of body length), swift water flow, and the structure of a redd are important to maintaining water quality in the nest for egg incubation (Tonina and Buffington 2009; Merz et al. 2013). In addition, redd placement at the top or bottom of the riffles increases the permeation of water through the redd, thus improving water quality and increasing survival of eggs over the 1.5 to 3 months of incubation. Stressful conditions can negatively affect spawning success.

There is evidence that salmon production in the Stanislaus River is limited by carrying capacity constraints, particularly in dry years (Figure 3). The apparent limit on juvenile production in dry years suggests that limited available habitat constrains success in spawning and egg incubation, or juvenile rearing, or both.

Parameters considered important in this review of spawning habitat are quantity and quality of available habitat, as defined by temperature, DO, water flow (depth and velocity), availability of coarse sediment (sediment size distribution), habitat quantity and distribution, and contaminants (pesticides and trace elements). Optimal levels of some of these parameters vary between species (gravel particle size distribution, depth, velocity, and temperature), while the criteria for DO, pesticides, and trace element contaminants are the same for both species. Most of the variation between species is a result of differences in body size, which has often been identified as the primary factor affecting variance in salmonid spawning habitat (Kondolf 2000; Zeug et al. 2013). Body size determines the preferred particle size distribution that makes up quality spawning habitat.

7.2.3.1 Temperature (Spawning)

7.2.3.1.1 Temperature Rationale (Spawning)

The background and development of these temperature objectives are discussed in Appendix B, Section 1.1. Adult spawning Chinook salmon and *O. mykiss* temperature needs are generally similar to their eggs. Considerations specific to spawning habitat include temperature triggers for spawning and potential thermal stress that could lead to high rates of prespawn mortality and egg retention. In general, the temperature criteria for eggs are protective of spawning and the subsequent egg incubation phase.

7.2.3.1.2 Temperature Approach (Spawning)

Salmonid eggs and larvae require cold water to successfully complete spawning and incubation. With the construction of impassable dams, Chinook salmon spawning in the San Joaquin Valley became dependent on cold-water storage in reservoirs to provide sufficient cold-water storage to protect their incubating eggs. The accessible supply of cold-water storage limits successful spawning habitat for Chinook salmon populations in the Central Valley in general, and the San Joaquin River basin in particular.

USEPA (2003) found that constant temperatures between 4°C to 12°C (39.2°F to 53.6°F) result in good egg survival and that a narrower range (6°C to 10°C [42.8°F to 50°F]) is optimal; a 7DADM of less than 13°C (55.4°F) is recommended (Table 29 in Section 7.2.3.1.3). In a review, the USFWS (1999 cited by Myrick and Cech 2004) concluded that temperature-related egg mortality in Chinook salmon increased at temperatures above 13.3°C (55.9°F) and this is the limit applied in most regulatory arenas (e.g., NMFS 2009b; SWRCB Order 90-05). A review of research on different populations of Chinook salmon from within and outside of the Central Valley indicated that temperatures between 6°C and 12°C (42.8°F to 53.6°F) were optimal for Central Valley Chinook salmon (Myrick and Cech 2004).

As with Chinook salmon, *O. mykiss* eggs and larvae require cold water to successfully complete incubation. With the construction of impassable dams, *O. mykiss* eggs incubating in the San Joaquin Valley became dependent on cold-water storage in reservoirs. The accessible supply of cold-water storage limits successful spawning habitat for *O. mykiss* populations in the southern Central Valley. Additional study of temperature impacts on *O. mykiss* eggs is needed (Myrick and Cech 2004). Optimal incubation temperatures for *O. mykiss* occur in a narrower range than those for Chinook salmon. Indeed, Myrick and Cech (2004) warned against managing water temperatures for the upper end of the Chinook salmon thermal tolerance range in waterways and during periods when steelhead are also incubating because incubating steelhead cannot tolerate such high temperatures. Richter and Kolmes (2005) concluded that egg mortality increased as incubation temperatures exceeded 10°C (50°F), and substantial mortality may occur when temperatures exceed 13.5°C to 14.5°C (56.3°F to 58.1°F). Based on experience at hatcheries in the Central Valley, optimal incubation temperatures appear to be in the 7°C to 10°C (44.6°F to 50°F) range (Myrick and

Cech 2004). California's steelhead management plan (McEwan and Jackson 1996) suggests a slightly higher temperature range (from 9°C to 11°C [48.2°F to 51.8°F]).

7.2.3.1.3 Temperature Objectives (Spawning)

Temperature objectives for Chinook salmon and *O. mykiss* spawning are provided in Tables 29 and 30.

Table 29
Temperature Objectives for Chinook Salmon Spawning

Habitat Type	Temporal Extent	Condition	Range (Metric)
Spawning Gravel	Fall-run: Late October to March Spring-run: Late August to March	Optimal	6°C to 12°C (42.8°F to 53.6°F) (Daily Average)
			< 12.5°C (< 54.5°F) (7DADM)
		Sub-optimal	4°C to 6˚C (39.2°F to 42.8°F) (Daily Average))
			12°C to 13.3°C (53.6°F to 55.9°F) (Daily Average)
			12.5°C to 13.8°C (54.5°F to 56.8°F) (7DADM)
		Detrimental	> 13.3°C (55.9°F) (Daily Average)
			> 13.8°C (56.8°F) (7DADM)

Table 30
Temperature Objectives for *O. mykiss* Spawning

Habitat Type	Temporal Extent	Condition	Range (Metric)
Spawning Gravel	December to June	Optimal	7°C to 10°C (44.6°F to 50°F) (Daily Average)
			10.5°C (50.9°F) (7DADM)
		Sub-optimal	4°C to 7°C (39.2°F to 44.6°F) (Daily Average)
			10°C to 13.5°C (50°F to 56.3°F) (Daily Average)
			10.5°C to 14.0°C (50.9°F to 57.2°F) (7DADM)
		Detrimental	> 13.5°C (56.3°F) (Daily Average)
			> 14.0°C (57.2°F) (7DADM)

7.2.3.2 Dissolved Oxygen (Spawning)

7.2.3.2.1 Dissolved Oxygen Rationale (Spawning)

The background and development of these DO objectives are discussed in Appendix B, Section 1.2. Adult spawning Chinook salmon and *O. mykiss* DO needs are generally similar to their eggs. However, the eggs are more sensitive to oxygen minima. Since the result of spawning is the production of eggs, the dissolved criteria for eggs becomes the limiting factor for spawning. Therefore, the spawning DO objective in Section 7.2.3.2.3 is the same as the DO objective identified for egg incubation.

7.2.3.2.2 Dissolved Oxygen Approach (Spawning)

The summaries of egg incubation mortality through hatching and incubation growth rates (Section 7.2.4.1.2) provide rationale for the DO objectives identified in Section 7.2.3.2.3.

7.2.3.2.3 Dissolved Oxygen Objectives (Spawning)

The DO objectives for Chinook salmon and *O. mykiss* spawning are provided in Table 31.

Table 31
Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Spawning

Habitat Type	Temporal Extent	Condition	Range (Metric)
Gravel (measurement must occur in gravel, not water column)	Fall-run: Late October to March Spring-run: Late August to March *O. mykiss*: December to June	Optimal	> 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	< 6 mg/L (Daily Minimum)

7.2.3.3 Depth and Velocity (Spawning)

7.2.3.3.1 Depth and Velocity Rationale (Spawning)

Depth and velocity of water are two components of salmonid spawning habitat that salmonids can detect. As such, these parameters are considered core components of spawning habitat for salmon and *O. mykiss* (Hanrahan et al. 2004). These two habitat features have been part of the definition of salmonid spawning habitat for more than 50 years (Wickett 1958; Thompson 1972; Bovee 1978). As a result, these habitat features have become important to a form of river habitat evaluation called IFIM/PHABSIM (for early work on Stanislaus River, see Aceituno 1993). Recent work has been performed on the Stanislaus River modeling discharge-habitat relationships for rearing salmonids (Bowen et al. 2012).

7.2.3.3.2 Depth and Velocity Approach (Spawning)

The tool used to describe depth and velocity is referred to as the habitat suitability index (HSI) or habitat suitability criteria. Both refer to a curve that represents the relative usefulness of particular depth (y-axis) or velocity (x-axis) for spawning by ascribing an index value of 0 to 1 (0 = useless, 1 = most preferred). These HSI charts are developed from measurements of actual redd locations (e.g., Gard 2006), which are then used to produce a probability curve with the x-axis representing the increments of the measured component that were used (such as depth) and the y-axis showing the percent of redds that fell in that increment. If a large sample of redd measurements is made, the probability curves for the depths and velocities can become the HSI by making the highest probability equal to 1 and adjusting all other values equally (essentially divide by maximum probability). The depth and velocity spawning criteria are based on the assumptions that HSI greater than 0.6 is optimal, all other values of habitat used are suboptimal ($0< HSI \leq 0.6$), and all values outside of the range used by salmonids are considered detrimental (which is essentially habitat that cannot be used for spawning). In this context, "non-habitat" is a better term than "detrimental."

Chinook salmon have been observed spawning in a broad range of water depths (0.15 m to 4.6 m [0.5 ft to 15 ft]), although the preferred range is approximately 0.61 m (2 ft) deep for fall-run (Gard 2006). Using these data, optimal habitat is 0.3 m to 0.76 m (1 ft to 2.5 ft) in depth, with sub-optimal ranging from 0.15 m to 0.3 m (0.5 ft to 1 ft) on the shallow end and 0.76 m to 3.05 m (10 ft) in deeper water. Although spawning has been observed to depths of nearly 4.6 m (15 ft), very few observations of spawning have been made in water greater than 3.05 m (10 ft) deep.

Gard (2006) found that optimal water velocity ranged from 0.3 m/s to 1.2 m/s (1 ft/s to 4 ft/s). Outside of that range, velocities down to 0.12 m/s (0.4 ft/s) and up to 1.5 m/s (5 ft/s) could support some spawning, but should be considered sub-optimal. Gard (2006) had few observations of spawning at velocities greater than 1.2 m/s (4 ft/s); thus, 1.2 m/s (4 ft/s) should be considered the upper limit of spawning.

For *O. mykiss*, depth and velocity requirements are slightly lower than for Chinook salmon due to the smaller average size of adult *O. mykiss*. Bovee (1978) indicated depths of 0.36 m (1.17 ft) on average (range of 0.15 m to 0.61 m [0.5 ft to 2 ft]) were satisfactory, and these results are supported by more recent literature (Hannon 2015, pers. comm.). As with Chinook, *O. mykiss* are more sensitive to water velocity than depth when selecting redd locations.

Velocities during spawning of 0.3 m/s to 1.1 m/s (1 ft/s to 3.6 ft/s) are recommended for the Central Valley (Hannon 2015, pers. comm.). Bovee (1978 as cited by McEwan and Jackson 1996 and USFWS 1995) found 0.61 m/s (2.0 ft/s) was the preferred velocity, and Reynolds et al. (1993) found 0.46 m/s (1.5 ft/s) was preferred. Sub-optimal velocities are identified as a very small range at the lower end of the velocities; flows outside that overall range are considered to be detrimental or “non-habitat.”

7.2.3.3.3 Depth and Velocity Objectives (Spawning)

Depth and velocity objectives for Chinook salmon and *O. mykiss* spawning (eggs and larvae) are provided in Tables 32 and 33.

Table 32
Depth and Velocity Objectives for Chinook Salmon Spawning

Habitat Type	Temporal Extent	Condition	Range (metric)
Spawning Gravel	Fall-run: Late October to December Spring-run: Late August to October	Optimal	Depth: 0.3 m to 0.76 m (1 ft to 2.5 ft)
			Velocity: 0.3 m/s to 1.2 m/s (1 ft/s to 4 ft/s)
		Sub-optimal	Depth: 0.15 m to 0.3 m (0.5 ft to 1 ft) and 0.76 m to 3.05 m (2.5 ft to 10 ft)
			Velocity: 0.12 m/s to 0.3 m/s (0.4 ft/s to 1 ft/s)
		Detrimental	Depth: < 0.15 m (< 0.5 ft) or > 3.05 m (> 10 ft)
			Velocity: < 0.12 m/s (< 0.4 ft/s) or > 1.5 m/s (> 5 ft/s)

Table 33
Depth and Velocity Objectives for *O. mykiss* Spawning

Habitat Type	Temporal Extent	Condition	Range (metric)
Spawning Gravel	December to April	Optimal	Depth: 0.15 m to 0.61 m (0.5 ft to 2 ft)
			Velocity: 0.5 m/s to 1.1 m/s (1.6 ft/s to 3.6 ft/s)
		Sub-optimal	Depth: 0.08 m to 0.15 m (0.26 ft to 0.5 ft) and 0.61 m to 1 m (2 ft to 3.3 ft)
			Velocity: 0.32 m/s to 0.4 m/s (1.1 ft/s to 1.3 ft/s)
		Detrimental	Depth: < 0.08 m (0.26 ft) or > 1 m (> 3.3 ft)
			Velocity: < 0.3 m/s (< 0.98 ft/s) or > 1.2 m/s (> 4 ft/s)

7.2.3.4 Sediment Size Distribution

7.2.3.4.1 Sediment Size Distribution Rationale Sediment Size Distribution

Sediment size is an important consideration in the construction of redds. The female fish must be able to move most of the coarse sediments at the chosen site with a fanning of her tail. There is a long history and a large number of evaluations of coarse sediment available for review (Reiser and Bjornn 1979; Barnhart and Parsons 1986; Healey 1991; Williams 2006). These evaluations indicate a large variation in the extent sizes of gravel considered appropriate by salmon for spawning. Much of this variation is a result of varying size of the females.

7.2.3.4.2 Sediment Size Distribution Approach (Spawning)

Coarse gravel is essential for holding salmonid eggs in the redd without blocking the water flow necessary to provide oxygen to incubating eggs. Kondolf and Wolman (1993) give an extensive review of studies to identify characteristics of gravel that are chosen by salmonids (also see Kondolf 2000; Riebe et al. 2014). Kondolf and Wolman (1993) looked at a variety of gravel size metrics and species. The two species will be differentiated based on size. Optimal grain size for a salmon redd varies with the size of the female. The largest size of a female for *O. mykiss* was assumed to be 600 mm (23.6 in). The largest assumed size for Chinook was assumed to be 1,000 mm (39.4 in). For the purposes of this report, the D_{50} metric (median grain diameter) was used to determine appropriate grain sizes as reported in Kondolf and Wolman (1993) and Kondolf (2000).

Based on Kondolf and Wolman (1993) and Kondolf (2000), average values for D_{50} were abstracted in two ways. Kondolf and Wolman (1993) presented box-and-whisker plots that summarized the distribution of gravel sizes used for spawning by salmonids from a large number of studies for each species. Using these plots, the optimal level for each species was defined as the interquartile range, or that from the lower 25% (D_{25}) to the upper 75% (D_{75}) of the distribution of gravel sizes. For Chinook, this gives a range from 48 mm to 22 mm (1.89 in to 0.87 in). For *O. mykiss*, the range is from 25 mm to 15 mm (0.98 in to 0.59 in). The full range of the distribution of gravel sizes used for spawning by salmonids was then used to define the sub-optimal ranges—Chinook run from 80 mm to 10 mm (3.15 in to 0.39 in) and *O. mykiss* from 48 mm to 10 mm (1.89 in to 0.39 in).

The second method for determining the optimum and suboptimum values was derived from the relationship between female size and D_{50} of sediment as presented in Figure 4 of Kondolf (2000). The optimum range was defined as the values between the best fit line (average for all values) and half the distance between the best fit line and upper envelope curve limit line. The full range is from the lowest value recorded for females of a given size to the upper envelope curve limit line. Sub-optimal values are all the values in the full range that are outside the optimum range. Using this method, the *O. mykiss* optimum range was 35 mm to 20 mm (1.38 in to 0.79 in; full range was 55 mm to 5 mm [2.2 in to 0.2 in]), and the Chinook optimum range was 60 mm to 30 mm (2.36 in to 1.18 in; full range was 85 mm to 25 mm [3.35 in to 0.98 in]). Riebe et al. (2014) suggest a broader range of grain sizes may define the optimum range, depending on fish size distribution for a watershed.

Averaging these two assessments (using data from many studies) gives a *O. mykiss* optimum range of 30 mm to 15 mm (1.18 in to 0.59 in) and a full useable range of 50 mm to 10 mm (1.97 in to 0.39 in). The Chinook optimum with this same averaging technique results in an optimum range from 55 mm to 25 mm (2.2 in to 0.98 in) and a full useable range of 80 mm to 10 mm (3.15 in to 0.39 in). Detrimental values are anything outside the full range of observed spawning (it is detrimental in the sense that it is, by definition, not spawning habitat). The detrimental range includes coarse sediment that is too large for a female to move and too large of a proportion of fine sediment relative to larger gravel (greater than 10 mm), which may plug interstitial spaces between gravel and small cobble, thus reducing water flow.

7.2.3.4.3 Sediment Size Distribution Objectives (Spawning)

Coarse sediment objectives for Chinook salmon and *O. mykiss* spawning are provided in Tables 34, 35, and 36.

Table 34

Sediment Size Distribution Objectives for Chinook Salmon Spawning

Habitat Type	Temporal Extent	Condition	Range (Metric)
Spawning Gravel	Fall-run: Late October to December Spring-run: Late August to October	Optimal	D_{50} 55 mm to 25 mm (2.2 in to 0.98 in)
		Sub-optimal	D_{50} 80 mm to 56 mm (3.15 in to 2.2 in) and 24 mm to 10 mm (0. 94 in to 0.39 in)
		Detrimental	Not spawning habitat D_{50} < 9 mm (0.35 in) or > 81 mm (3.19 in)

Table 35

AFRP Recommendations for Sediment Particle Size Distribution for Spawning Habitat

Particle Size (in)	Percent passing	Percent retained
4 or 5	95% to 100%	0% to 5%
2	75% to 85%	15% to 30%
1	40% to 50%	50% to 60%
¾	25% to 35%	60% to 75%
½	10% to 20%	85% to 90%
¼	0% to 5%	95% to 100%

Table 36
Sediment Size Distribution Objectives for *O. mykiss* Spawning

Habitat Type	Temporal Extent	Condition	Range (Metric)
Spawning Gravel	December to April	Optimal	D_{50} 30 mm to 15 mm (1.18 in to 0.59 in)
		Sub-optimal	D_{50} 50 mm to 30 mm (1.97 in to 1.18 in) and D_{50} 15 mm to 10 mm (0.59 in to 0.39 in)
		Detrimental	Not spawning habitat D_{50} < 9 mm (< 0.35 in) or D_{50} > 51 mm (> 2 in)

7.2.3.5 Habitat Quantity and Distribution Objectives (Spawning)

A number of objectives associated with spawning habitat do not fit into an optimal and sub-optimal framework. They will be dealt with in this subsection as a group and will not have a table of values. The first of these objectives addresses the question of how much habitat Chinook and *O. mykiss* need for spawning. Other subsections described the quality of the habitat needed but do not address the quantity of that habitat. A spreadsheet model was developed and used to estimate the number of female Chinook that would be needed to reach the population goal that has been identified for the Stanislaus River (Appendix A).

The fall-run Chinook salmon minimum suitable spawning habitat area target was identified as 14.7 acres, assuming attainment of the AFRP production target (i.e., 22,000 natural production in the ocean) for the Stanislaus River. This habitat would be located particularly at the tail of holding pools. The calculations used to set the suitable spawning habitat area target are based on an average redd size for Chinook salmon of 10 m^2 (107.6 ft^2; Hannon 2015, pers. comm.) and the fact that an escapement of 9,942 salmon (for a total of 5,965 female spawners) would be necessary to achieve the AFRP target for a natural production of fall-run Chinook salmon from the Stanislaus River, with the following assumptions:

1. The population is 60% female;
2. Average fecundity is 5,813 eggs;
3. Egg-Age 2 survival rates are those identified in the rebuilding objective (Items 1 through 3 on this list are SEP population model assumptions; see Appendix A);
4. Mean redd size for fall-run and spring-run Chinook salmon on the Stanislaus is 10 m^2; and

5. Minimum spawning habitat would be the space needed to support one redd for each spawning female, with no overlap among redds or open space (i.e., territory buffer) between redds.

The spawning habitat needed for 5,965 female spawners equals a minimum of 14.7 acres as demonstrated in the following equation:

$$10\ m^2\ [107.6\ ft^2]/female\ \times 5{,}965\ females = 59{,}650\ m^2\ [641{,}855\ ft^2] = 14.7\ acres$$

There is no evidence that spring-run would have different redd sizes than fall-run in the Stanislaus River. The spring-run production target, survival rates from egg to age 2, fecundity, and the ratio of males to females were assumed to be the same as those for fall-run. Therefore, the amount of spawning habitat needed for spring-run would be the same as fall-run at 14.7 acres.

The *O. mykiss* target was identified as 2.7 acres. The *O. mykiss* redd size used to arrive at this value is 5.43 m^2 (58.4 ft^2; Orcutt et al. 1968) and a territory buffer of 50% (just over 2.5 m^2 [26.9 ft^2]), resulting in a value of 8 m^2 (86.1 ft^2) per female. The population size would be an average of 600 female spawners. The calculation for *O. mykiss* spawning habitat is demonstrated in the following equation:

$$600\ females\ \times 8\ m^2\ [86.1\ ft^2]\ per\ female = 4{,}800\ m^2\ = 1.19\ acres$$

In addition, spawning habitat is needed for resident rainbow trout to meet the *O. mykiss* objective. For resident *O. mykiss*, 1.35 m^2 (14.5 ft^2) per redd was used, plus a territory buffer of 50%, for a total of approximately 2 m^2 (21.5 ft^2) per redd (Hannon 2015, pers. comm.). The target population size for resident rainbows is 3,000 adult females. The calculation is demonstrated in the following equation:

$$3{,}000\ females\ \times 2\ m^2\ [21.5\ ft^2]\ per\ female = 6{,}000\ m^2\ = 1.48\ acres$$

Thus, the total amount of spawning habitat needed for *O. mykiss* is 1.2 acres for *O. mykiss* plus 1.5 acres for resident rainbow trout, for a total of 2.7 acres.

Additional considerations for spawning habitat for Chinook and *O. mykiss* include the need for cover and feeding areas adjacent to spawning areas such as holding pools, undercut banks, overhanging vegetation, large wood, and boulders. Spawning habitat should be increased in locations in the river that address the specific needs of spring-run and *O. mykiss*, in addition to fall-run. A possible action would be to provide additional spawning habitat in the canyon downstream of Goodwin Dam where temperatures are generally low and fall-run are less likely to spawn.

7.2.3.6 Contaminants (Spawning)

7.2.3.6.1 Contaminants Rationale (Spawning)

The background and development of these contaminant objectives are discussed in Appendix C, Section 1.3. Adult spawning Chinook salmon and *O. mykiss* likely have some differences in sensitivities to the various contaminants; however, the SEP Group found no studies that supported separate Environmental Objectives for contaminants. Therefore, the contaminant objectives will be applicable to all species during their period of spawning.

Mercury and selenium toxicity were not considered in setting objectives for spawning salmonids. Mercury and selenium bioaccumulation in the ocean are likely low, and returning adults cease to eat during their spawning period, so there are low risks to adult salmonid spawning from mercury and selenium. Therefore, pesticides and nutrients are the only contaminants that have perceived direct impacts on adult spawning in the Stanislaus River.

Pesticides can have lethal and sub-lethal impacts to salmonid spawners. Pre-spawn mortality of adult salmonids from pesticide exposures is discussed in Section 7.2.1.4.1; there is some evidence that salmonids will die from exposure prior to spawning. However, the studies of the causes of prespawn mortality did not specify whether mortality occurred during the acts of migration, holding, or spawning (Scholz et al. 2011).

Sub-lethal impacts of pesticides are more likely than direct mortality of spawners. Most pesticides, in addition to other chemical contaminants such as metals, have been found to disrupt fish olfaction (Hansen et al. 1999; Scholz et al. 2000; Moore and Waring 2001).

Disruption in olfaction has been linked to the elimination of fish behaviors important for reproduction (Potter and Dare 2003; Scott and Sloman 2004). For example, the pyrethroid insecticide cypermethrin inhibited male Atlantic salmon from detecting and responding to the reproduction priming pheromone prostaglandin, which is released by ovulating females (Moore and Waring 2001). The males exposed to cypermethrin did not respond to prostaglandin with the expected increased levels of plasma sex steroids and expressible milt. The disruption of spawning synchronization would likely result in an increase in the number of unfertilized eggs in the river (NMFS 2009c).

Pesticide exposures have been found to decrease the number of viable fertilized eggs. For example, Moore and Waring (2001) found that salmon egg and milt exposed to cypermethrin resulted in a greater proportion of unfertilized eggs. Adult zebrafish exposed to low doses of deltamethrin for 3 months showed reduced fecundity in females, and the number of unhatched fertilized eggs increased when compared to the control (Sharma and Ansari 2010). Furthermore, even short adult exposures to pesticides have been shown to impair fish reproduction. For instance, Brander et al. (2016) observed that 21-day exposures to bifenthrin caused significant differential expression of genes related to reproduction and immune function at sub-lethal concentrations to *Menidia beryllina* (inland silversides). Additionally, Brander et al. (2016) reported a statistically significant 30% reduction in fertilized eggs from the adult *M. beryllina*, and their population dynamic modeling predicted that these reductions in reproductive success would cause a significant decline in fish population over time.

Nutrient constituents (i.e., ammonia, nitrate, and nitrite) can also cause direct toxicity to spawning adults. Similar to the previous life stages, excessive nutrients can result in adverse environmental conditions that reduce the fitness and survival of spawning adults (e.g., low DO or elevated temperatures).

7.2.3.6.2 Contaminants Approach (Spawning)

For discussion of the SEP Group's approach to setting pesticide objectives and objectives for concentrations of nitrogen-based nutrients, see Section 7.2.1.4.2.

7.2.3.6.3 Contaminants Objectives (Spawning)

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and *O. mykiss* spawning are expected to be similar. Based on the described approach of pesticide Environmental Objectives, the optimal condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 23) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2014).

It is estimated that salmon exposed to pesticides at a frequency 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has similar impact on salmonid physiology and responses across all life stages, then exposures of pesticides greater than 30% (Bin 7 – 10, Table 23) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2 – 6, Table 23. See Appendix C, Section 1.3.3.1 for more information.

Ammonia, nitrate, and nitrite concentrations necessary to protect spawning adult salmonids are provided in Table 24.

7.2.4 Egg Incubation

The egg incubation life stage takes place in the gravel, beginning when the female salmon or *O. mykiss* deposits her eggs in a redd and ending when fry swim up out of the river bottom. The time period from egg deposition to fry emergence from the redd for a particular egg lasts roughly 3 to 5 months, depending on egg and alevins developmental rates, which are determined by water temperature. Egg incubation in the Stanislaus River generally occurs from late October through March for fall-run Chinook salmon and from December through June for *O. mykiss*. For spring-run Chinook salmon in the Sacramento River basin, egg incubation generally occurs from September through March; it is assumed that that timeframe would apply for spring-run Chinook salmon in the Stanislaus River should a population become reestablished there.

Salmon and *O. mykiss* eggs incubating in the gravel are vulnerable to low DO, warm water temperatures, poor water quality, physical disturbance (e.g., people walking on redds), redd scour from high flows, and low flows that result in redd dewatering or insufficient water velocity to maintain water quality. The eggs require clean, cold, well-oxygenated water. Without enough swift water moving through the redd to sweep out fine sediment and metabolic waste, the eggs cannot receive sufficient clean, oxygenated water for proper development and mortality often results. In order to evaluate whether the Stanislaus River is providing conditions during egg incubation that will support attainment of the Biological Objectives, Environmental Objectives for water temperature, DO, fine sediment, and contaminants were established. The objectives and supporting rationale for each of these parameters is discussed below. The objectives for water temperature are species-specific and are presented as such, whereas the objectives for DO and water quality do not vary by species, so one set of objectives is presented for all three species. A summary of Environmental Objectives is provided in Table B-4 of Appendix B.

7.2.4.1 Temperature (Egg Incubation)

7.2.4.1.1 Temperature Rationale (Egg Incubation)

Suitable water temperature is necessary for normal behavior, growth, and viability of all life stages of salmonids, including the egg incubation stage. Water temperature and developmental rate are tightly and positively correlated in salmonids (Healey 1991; Quinn 2005); however, above certain temperatures, enzymatic function is compromised and food resources are utilized inefficiently. For example, eggs and alevins incubated at temperatures that are either too cold or too warm produce smaller fry than they would at optimal temperatures (USEPA 2001). Hatching and emergence success decrease as temperatures rise above the threshold for optimum development. Direct egg mortality due to elevated temperatures occurs in the Central Valley (Williams 2006). Temperature-related mortality and habitat limitation will likely become serious problems for Central Valley salmonids in the future because of global climate change (Lindley et al. 2007).

7.2.4.1.2 Temperature Approach (Egg Incubation)

The SEP Group relied on water temperature criteria established by the USEPA Region 10 Guidance for Pacific Northwest State Tribal Temperature Water Quality Standards (2003) to identify optimal, sub-optimal, and detrimental water temperature conditions for Chinook salmon. The USEPA (2003) recommends using the 7DADM metric for evaluating temperature impacts on salmonid life stages. The 7DADM metric is the 7-day average of daily maximum water temperatures. The SEP Group used water temperature ranges for optimal, sub-optimal, and detrimental to describe the objectives for Chinook salmon and *O. mykiss*.

Chinook Salmon

Salmonid eggs and larvae require suitable water temperatures to complete incubation. The length of time it takes for eggs to hatch depends mostly on water temperature. In addition, warm water temperatures can decrease egg survival. The USEPA (2003) found that constant temperatures between 4°C to 12°C (39.2°F to 53.6°F) result in good egg survival and that a narrower range (6°C to 10°C [42.8°F to 50°F]) is optimal. In a review, the USFWS (1999 cited by Myrick and Cech 2004) concluded that temperature-related egg mortality in Chinook salmon increased at temperatures above 13.3°C (55.9°F); this is the limit applied in most regulatory arenas (e.g., NMFS 2009b; SWRCB Order 90-05). A review of research on different populations of Chinook salmon from within and outside of the Central Valley indicated that temperatures between 6°C and 12°C (42.8°F to 53.6°F) were optimal for Central Valley Chinook salmon (Myrick and Cech 2004).

O. mykiss

As with Chinook salmon, *O. mykiss* eggs and larvae require cold water to successfully complete incubation. With the construction of impassable dams, *O. mykiss* eggs incubating in the San Joaquin Valley became dependent on cold-water storage in reservoirs. The accessible supply of cold-water storage limits successful spawning habitat for *O. mykiss* populations in the southern Central Valley. There is a lack of peer-reviewed studies on the temperature tolerances of Central Valley anadromous *O. mykiss* eggs, and additional study of temperature impacts on this species' eggs is needed (Myrick and Cech 2004). Optimal incubation temperatures for *O. mykiss* occur in a narrower range than those for Chinook salmon. Indeed, Myrick and Cech (2004) warned against managing water temperatures for the upper end of the Chinook salmon thermal tolerance range in waterways and during periods when *O. mykiss* are also incubating because incubating *O. mykiss* cannot tolerate such high temperatures. Richter and Kolmes (2005) concluded that egg mortality increased as incubation temperatures exceeded 10°C (50°F) and substantial mortality may occur when temperatures exceed 13.5°C to 14.5°C (56.3°F to 58.1°F). Based on experience at hatcheries in the Central Valley, optimal incubation temperatures appear to be in the 7°C to 10°C (44.6°F to 50°F) range (Myrick and Cech 2004). California's steelhead management plan (McEwan and Jackson 1996) suggests a slightly higher temperature range (from 9°C to 11°C [48.2°F to 51.8°F]).

7.2.4.1.3 Temperature Objectives (Egg Incubation)

Egg incubation temperature objectives are described below for Chinook salmon (Table 37) and *O. mykiss* (Table 38).

Table 37

Temperature Objectives for Chinook Salmon Egg Incubation

<table>
<tr><th>Habitat Type</th><th>Temporal Extent</th><th>Condition</th><th>Range (Metric)</th></tr>
<tr><td rowspan="7">Gravel</td><td rowspan="7">Fall-run:
Late October to March

Spring-run:
Late August to March</td><td rowspan="2">Optimal</td><td>6°C to 12°C (42.8°F to 53.6°F) (Daily Average)</td></tr>
<tr><td>< 12.5°C (< 54.5°F) (7DADM)</td></tr>
<tr><td rowspan="3">Sub-optimal</td><td>4°C to 6°C (39.2°F to 42.8°F) (Daily Average)</td></tr>
<tr><td>12°C to 13.3°C (53.6°F to 55.9°F) (Daily Average)</td></tr>
<tr><td>12.5°C to 13.8°C (54.5°F to 56.8°F) (7DADM)</td></tr>
<tr><td rowspan="2">Detrimental</td><td>> 13.3°C (55.9°F) (Daily Average)</td></tr>
<tr><td>> 13.8°C (56.8°F) (7DADM)</td></tr>
</table>

Table 38
Temperature Objectives for *O. mykiss* Egg Incubation

Habitat Type	Temporal Extent	Condition	Range (Metric)
Gravel	December to June	Optimal	7°C to 10°C (44.6°F to 50°F) (Daily Average)
			< 10.5°C (50.9°F) (7DADM)
		Sub-optimal	4°C to 6.9°C (39.2°F to 44.4°F) (Daily Average)
			10°C to 13.5°C (50°F to 56.3°F) (Daily Average)
			10.5°C to 14.0°C (50.9°F to 57.2°F) (7DADM)
		Detrimental	> 13.5°C (> 56.3°F) (Daily Average)
			> 14.0°C (> 57.2°F) (7DADM)

7.2.4.2 Dissolved Oxygen (Egg Incubation)

7.2.4.2.1 Dissolved Oxygen Rationale (Egg Incubation)

Adequate concentrations of DO in water are critical for salmon and *O. mykiss* survival. In freshwater streams, hypoxia can impact the growth and development of salmon and *O. mykiss* eggs, alevins, and fry as well as the swimming, feeding, and reproductive ability of juveniles and adults. If salmonids are exposed to hypoxic conditions for too long, mortality can result (Carter 2005). Without achieving optimal or some combination of optimal and sub-optimal Environmental Objectives for DO (described below), the Biological Objectives for Chinook salmon and *O. mykiss* productivity will likely not be met.

7.2.4.2.2 Dissolved Oxygen Approach (Egg Incubation)

The SEP Group relied on DO criteria established by the USEPA (1986) and the CVRWQCB (2015a), as well as relevant technical literature (e.g., WDOE 2002), to identify DO objectives that are optimal (no negative effects), sub-optimal (observably negative, though not significantly harmful), and detrimental (clearly harmful) ranges for various salmonid life stages and/or transitions.

The criteria established by the USEPA (1986) and CVRWQCB (2015a) covered cold-water species in one category; separate criteria for Chinook salmon and *O. mykiss* were not provided. This blanket approach of protecting salmon and *O. mykiss* with one set of DO criteria is supported by the available literature, and as such, the SEP Group followed that approach.

The summaries of egg incubation mortality through hatching and incubation growth rates provide rationale for the DO objectives identified in Table 39.

Egg Incubation Mortality through Hatching

The effect of low DO on salmon egg mortality largely depends on incubation temperatures. Under laboratory conditions at favorable incubation temperatures, mortality rates when DO levels greater than or equal to 9 mg/L should be less than 1%, less than 2% at a concentration of 7 mg/L, and between 2% and 6% at a concentration of 6 mg/L (WDOE 2002). Survival rates at oxygen concentrations below 4 mg/L are highly variable. All tests at concentrations below 1.7 mg/L resulted in 100% mortality (WDOE 2002). Mortality rates related to low DO concentrations increase substantially at temperatures that are warmer than ideal. In water at 13.4°C (56.1°F), a decrease in DO from 11 mg/L to 10 mg/L caused a 4% reduction in survival through hatching, and at 7 mg/L, egg survival decreased by 19%. Furthermore, in the laboratory studies that produced these results (WDOE 2002), post-hatch salmon larvae (alevin) did not need to push their way up through gravel substrate to emerge as would wild fish. Optimal fitness will likely be required for optimal emergence from the gravel in natural environments. Thus, the effect of depleted oxygen levels on egg incubation success may be more profound than revealed by simple laboratory studies of egg hatching success. Sub-lethal impacts of high temperatures probably play an important role in overall egg incubation success rates.

Any decrease in the mean oxygen concentration during the incubation period appears to directly reduce the size of newly hatched salmonids (WDOE 2002). At favorable incubation temperatures, the level of this size reduction remained slight (less than or equal to 5%) when mean oxygen concentrations were 10 mg/L or more. At DO concentrations of 9 mg/L, the size of hatched fry was reduced by approximately 8%. Mean concentrations of 7 mg/L and 6 mg/L were associated with 18% and 25% reductions in emergent fry size, respectively.

7.2.4.2.3 Dissolved Oxygen Objectives (Egg Incubation)

DO objectives for egg incubation for Chinook salmon and *O. mykiss* are presented in Table 39.

Table 39
Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Egg Incubation

Habitat Type	Temporal Extent	Condition	Range (Metric)
Gravel (measurement must occur in gravel, not water column)	Fall-run: Late October to March Spring-run: Late August to March *O. mykiss*: December to June	Optimal	> 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	< 6 mg/L (Daily Minimum)

7.2.4.3 Fine Sediment (Egg Incubation)

7.2.4.3.1 Fine Sediment Rationale (Egg Incubation)

High levels of fine sediment in spawning gravels are known to negatively affect spawning success (Kondolf 2000) through suffocation and or entrapment (Jensen et al. 2009). High proportions of fine sediment may reduce the flow of oxygenated water to eggs, thus reducing the removal of metabolic wastes and potentially slowing embryo development (Greig et al. 2005; Jensen et al. 2009). Fine sediment may also entomb the egg and provide a physical barrier to hatching and fry emergence (Franssen et al. 2012). Studies of the effects of fines have often compared levels of fines with percent survival of eggs (e.g., Tappel and Bjornn 1983). There is a great deal of variation in the relationship of fine sediment to egg survival, but Jensen et al. (2009) evaluated many of the studies in an attempt to get a common assessment of the information available. This meta-analysis found that egg survival greatly declined when the proportion of sediment less than 0.85 mm (0.033 in) was greater than 10%. Relationships between egg survival and percent fines were also observed for slightly larger sediment size classes, but the effect was less pronounced. For example, the proportion of sediment less than 4.8 mm (0.189 in) was negatively correlated with survival of eyed eggs; however, the effect threshold was higher at 50% proportion of sediment of less than 4.8 mm. The data Jensen et al. (2009) provide for a fine sediment upper limit of 6.4 mm is largely from Tappel and Bjornn (1983), and with the enormous scatter in survival values, it does not appear to improve the evaluation of limits to define optimum conditions. Combining the data from previous studies, Jensen et al. (2009) were able to produce curves for several species, including Chinook salmon and *O. mykiss*. The data have a large amount of variation in them, but the relationships will allow the development of criteria for maintaining gravel quality for spawning.

7.2.4.3.2 Fine Sediment Approach (Egg Incubation)

The values for fine sediment are largely developed from Jensen et al. (2009). It is important to note that data for very low fine sediment values do not support 100% survival of eggs. The y-intercepts of the relationships given in Jensen et al. (2009) indicate the average survival of between 80% and 95% when fines less than 0.85 mm (0.033 in) are at extremely low values. The y-intercepts for the 4.8 mm (0.189 in) fines also are not at 100% and, in fact, are lower than the values for 0.85 mm (0.033 in), which seems counter-intuitive. Variation in egg survival is enormous at those low levels of fines, ranging from approximately 20% to nearly 100%. Using the data, 80% was set as a baseline value for egg survival under a "no fine sediment" condition. It was assumed that no more than a 10% decline from the baseline should be allowed under optimal conditions; thus, fine sediment that allows for greater than or equal to 70% egg survival is considered optimal. Sub-optimal conditions are assumed to be between 50% and 70% egg survival. Conditions that are equal to or less than 50% survival are assumed to be detrimental.

Using the percent survival above, fine sediment values were extracted from the graphs using direct inspection. The curve for all species egg survival versus fine sediment less than 0.85 mm (0.033 in) was used as the curve includes a 95% confidence interval. The lower 95% bound was used to provide the most conservative (minimum) estimate for percent fines. The inspection results in a 5% fines limit for optimum habitat and a 10% fines limit for sub-optimal habitat. Any higher percentage of fines smaller than 0.85 mm (0.033 in) would be considered detrimental.

The data for sediment smaller than 4.8 mm (0.189 in) are less clear. There are results from studies using green eggs and eyed eggs. The results indicate a very different response by the green and eyed eggs; the eyed eggs exhibit higher survival rates, likely because of their more advanced developmental stage. It is likely that green eggs have lower survival overall because the early developmental stage increases sensitivity to stressful conditions. The effect of fine sediment on overall egg survival mostly occurs during the sensitive green egg stage; thus, the green egg curve was used to set fine sediment thresholds for the 4.8 mm (0.189 in) sediment size class. In addition to variation in egg survival due to developmental stage, egg survival for green and eyed eggs varied among studies conducted using different salmonid species. *O. mykiss* green eggs show higher survival than Chinook green eggs; however, Chinook eyed eggs show higher survival than *O. mykiss*. This was interpreted to mean that the data were highly variable; there is little evidence to support using different survival rates for Chinook and *O. mykiss*. Thus, the *O. mykiss* curve from the green eggs graph was used, giving 5% fines as the upper limit for optimal conditions and 15% as the upper limit for sub-optimal conditions. Anything greater than 15% fines (less than 4.8 mm [0.189 in]) is considered detrimental.

7.2.4.3.3 Fine Sediment Objectives (Egg Incubation)

Table 40 provides fine sediment objectives for Chinook salmon and *O. mykiss* egg incubation.

Table 40
Fine Sediment Objectives for Chinook Salmon and *O. mykiss* Egg Incubation

<table>
<tr><th>Habitat Type</th><th>Temporal Extent</th><th>Condition</th><th>Range (Metric)</th></tr>
<tr><td rowspan="3">Gravel (measurement must occur in gravel, not water column)</td><td rowspan="3">Fall-run:
Late October to March

Spring-run:
Late August to March

O. mykiss:
December to June</td><td>Optimal</td><td>< 5% smaller than 4.8 mm (0.189 in)</td></tr>
<tr><td>Sub-optimal</td><td>5% to 15% finer than 4.8 mm (0.189 in) or
5% to 10% finer than 0.85 mm (0.033 in)</td></tr>
<tr><td>Detrimental</td><td>> 15% smaller than 4.8 mm (0.189 in) or
> 10% smaller than 0.85 mm (0.033 in)</td></tr>
</table>

7.2.4.4 Contaminants (Egg Incubation)

7.2.4.4.1 Contaminants Rationale (Egg Incubation)

Poor water quality has a high potential of impacting the survival and recovery of salmonids. Pesticides, mercury, and selenium have the ability to impact all life stages of salmonids, including the egg incubation stage. Exposure to these contaminants can occur through transfer from the maternal parent or through direct contact in the water or gravel. For example, mercury and selenium exposure to eggs and early-life stages (ELS) will be from maternal transfer because eggs are fairly resistant to these contaminants, and toxicity to mercury and selenium typically occurs from long-term bioaccumulation (Appendix C, Section 1.3.1). Effects to ELS fish from mercury and selenium include developmental deformities, reduced hatch, increased pre-swimup mortality, and behavior abnormalities.

Contrary to mercury and selenium, current use pesticides do not typically bioaccumulate to the same extent, and toxicity to eggs and ELS salmonids can occur from river exposures. In addition to a reduction in fertilized eggs, further evidence supports the theory that pesticides impact salmonid egg to fry development. For example, Du Gas (2008) observed that exposures to herbicides atrazine and chlorothalonil in gravel-bed flume incubators resulted in reduced survival to hatch, increased finfold deformities, reduced condition factors at emergence, and premature emergence in sockeye salmon. Furthermore, another laboratory study that exposed Chinook eyed eggs and alevins to dinosed (herbicide), diazinon (organophosphate insecticide), and esfenvalerate (pyrethroid insecticide) resulted in abnormal swimming behavior, myoskeletal abnormalities, and metabolic disruptions as well as mortality at high concentrations (Viant et al. 2006). Alevins were much more sensitive to pesticide exposures than the eyed eggs, which emphasizes the importance of pesticide exposures to the critical life stages of alevin development and emergence (Viant et al. 2006; Finn 2007; Du Gas 2008).

Nutrient constituents (i.e., ammonia, nitrate, and nitrite) can also cause direct toxicity to incubating eggs. Similar to the previous life stages, excessive nutrients can result in adverse environmental conditions that reduce the fitness and survival of incubating eggs (e.g., low DO or elevated temperatures).

7.2.4.4.2 Contaminants Approach (Egg Incubation)

For discussion of the SEP Group's approach to setting pesticide objectives and objectives for concentrations of nitrogen-based nutrients, see the Contaminants Approach section for Adult Upstream Migration (Section 7.2.1.4.2).

Unlike the evaluation for adult salmonids, selenium and mercury may impact the success of incubating eggs. The SEP Group relied on the draft USEPA National Freshwater Selenium Ambient Water Quality Criterion for Aquatic Life (2014) for the Environmental Objectives to protect salmonid species in the Stanislaus River against adverse effects. The criteria have yet to be promulgated; however, the criteria are consistent with the relevant technical literature on selenium toxicology. The Environmental Objective should be reevaluated once the USEPA selenium criteria are finalized. No criteria have been promulgated for the protection of fish from mercury impacts. However, in recent literature, researchers have developed fish tissue mercury concentration benchmarks that are estimated to be protective of adult and ELS fish (Appendix C, Section 1.3.2.2). The SEP Group relied on these benchmark concentrations as the level that would be fully protective of salmonids during their egg incubation stage. Furthermore, selenium and mercury objectives are presented as the maximum contaminant concentration to be found in eggs and ELS fish tissue, as well as the maximum tissue concentration allowable in maternal salmonids to prevent the toxicological transfer of mercury and selenium. This is because egg and ELS fish exposure to mercury and selenium is through maternal transfer (Wiener and Spry 1996; Presser and Luoma 2013; USEPA 2015).

7.2.4.4.3 Contaminants Objectives (Egg Incubation)

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and *O. mykiss* egg incubation are expected to be similar. Based on the described approach of pesticide Environmental Objectives, the optimal condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 23) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2014).

It is estimated that salmon exposed to pesticides at a frequency of 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has similar impact on salmonid physiology and responses across all life stages, then exposures of pesticides greater than 30% (Bin 7 – 10, Table 23) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2 – 6, Table 23. See Appendix C, Section 1.3.3.1 for more information.

Mercury objectives for the egg incubation life stage are presented in Table 41. The objectives apply to the mercury concentrations in the eggs themselves as well as the concentrations in the maternal fish to prevent the transfer of mercury at toxicological levels.

Table 41
Mercury Objectives for Chinook Salmon and *O. mykiss* during the Egg Incubation Life Stage

Condition	Egg and Maternal Ovary mg/kg (wet weight)	Maternal Fish mg/kg whole body (wet weight)
Optimal	< 0.02	< 0.20
Sub-optimal	0.02 to 0.10	0.20 to 1.0
Detrimental[1]	> 0.1	> 1.0

Note:
1 Sub-lethal impacts to fish are estimated to occur above optimal conditions. Detrimental impacts are assumed to occur at mercury tissue concentrations that are expected to create 25% or greater injury to the fish. A 25% effect, or EC25 metric, is a consistent threshold to determine chronic toxicity assessments for regulatory compliance (SWRCB 2012).

Selenium objectives for the egg incubation life stage are presented in Table 42. The objectives apply to the selenium concentrations in the eggs themselves as well as the concentrations in the maternal fish to prevent the transfer of selenium at toxicological levels. In addition, aqueous selenium objectives are presented for lentic and lotic systems to protect aquatic life from bioaccumulating toxic levels of selenium.

Table 42
U.S. Environmental Protection Agency Draft National Freshwater Selenium Ambient Water Quality Criterion for Aquatic Life

Media Type	Fish Tissue		Water Column	
Criterion Element	Egg/Ovary	Fish Whole Body or Muscle	Monthly Average Exposure	Intermittent Exposure
Magnitude	15.8 mg/kg (dry weight [wt.])	8.0 mg/kg whole body or 11.3 mg/kg muscle (skinless, boneless filet; dry wt.)	1.2 micrograms per liter (µg/L) in lentic aquatic systems 3.1 µg/L in lotic aquatic systems	$WQC_{int} = \dfrac{WQC_{30\text{-}day} - C_{bkgrnd}(1 - f_{int})}{f_{int}}$
Duration	Instantaneous measurement	Instantaneous measurement	30 days	Number of days per month with an elevated concentration
Frequency	Never to be exceeded	Never to be exceeded	Not more than once in 3 years on average	Not more than once in 3 years on average

Notes:
From USEPA 2015. These draft criteria are presented to give a relative magnitude of selenium levels above which could pose risks to aquatic life. In addition, the criteria are presented as an example of the type of approach that could be used to assess selenium impacts to aquatic life.
WQC = Water Quality Criterion

Ammonia, nitrate, and nitrite concentrations necessary to protect salmonid incubating eggs are provided in Table 24.

7.2.5 Juvenile Rearing and Migration

The juvenile rearing and migration life stage encompasses all of those developmental stages, life history strategies and associated behaviors and phenotypic expressions that occur subsequent to emergence and prior to either ocean entry (for anadromous forms) or sexual maturation (for resident forms; principally applicable to *O. mykiss*). Depending on the species, these may include the following:

- Fry, parr, smolt, and yearling developmental stages;
- Anadromous, resident, and estuarine migratory behaviors; and
- Habitat areas
  - Within the bank-full channel (in-channel); and

- Adjacent to it on higher gradient, shorter inundation off-channel floodplains, floodplain terraces, backwaters, and intermittent side channels (short-inundation floodplains); and
- Lower gradient, longer inundation valley floodplains and wetlands (long-inundation floodplains).

There is evidence that salmon production in the Stanislaus River is limited by carrying capacity constraints, particularly in dry years (Figure 3). The apparent limit on juvenile production in dry years may indicate that the Stanislaus River currently only provides enough high-quality juvenile rearing habitat to support production of a limited number of juveniles. Rearing habitat limitation is consistent with the observation that the number of juveniles produced per spawner increases dramatically in years with higher winter-spring flows (Figure 3).

Generally, optimal conditions for juvenile salmonid rearing involve a balance of the following—a) water quality conditions (e.g., temperature, DO, contaminant concentrations); b) physical attributes of habitat (water depth, suitable cover, and substrate); c) extent of available habitat relative to fish territory size (as a function of fish size, fish density, prey density, and habitat structure); d) ecosystem and food web conditions (e.g., prey availability, predator density, and competition); and e) activity levels (as a function of the interaction of a, b, c, and d with water velocity)—such that juvenile salmonids can sustain metabolic needs while maximizing growth (Quinn 2005). However, these conditions vary across a range of sub-habitat types within the riverine landscape used by juvenile salmonids. Various sub-habitats may also be used differently by each salmonid species, specific life history stages of a given salmonid species (Roper et al. 1994; Bradford et al. 2001; Merz et al. 2015), and individuals within a life history stage that are developing at different rates (e.g., "young"/small smolts may utilize habitats differently than older/larger ones). In the San Joaquin River basin's Mokelumne River, juvenile Chinook salmon have been shown to prefer off-channel floodplain habitat for rearing, while juvenile *O. mykiss* prefer in-channel riffle habitat (Merz et al. 2015).

For a given species, the interaction of different life history stages with different sub-habitats can additionally reinforce cohort and population-level life history diversity and associated resilience (McClure et al. 2008; Zimmerman et al. 2015). For example, juvenile Chinook salmon rearing on floodplains can experience greater maximum size, diversity in growth, and exposure to environmental pollutants than juvenile salmon reared in the associated river channel (Sommer et al. 2001, 2005; Jeffres et al. 2008; Henery et al. 2010). For juvenile *O. mykiss*, in-channel rearing habitat with more variable flow has been associated with higher levels of anadromy (Pearsons et al. 2008; Kendall et al. 2014). In characterizing optimal rearing habitat conditions, it is appropriate to do so by sub-habitat and species.

Depending on the salmonid species and life history stage, there may not be a clear delineation between those sub-habitats used for rearing and for migration. For example, the same channel reach may theoretically be used by juvenile *O. mykiss* for rearing at the same time as it is being used for juvenile Chinook salmon as a migration corridor. Similarly, the same valley floodplain area may be used as a migration pathway by an outmigrating juvenile Chinook salmon smolt and a primary rearing area for a Chinook salmon parr. Juvenile Chinook salmon and *O. mykiss* may also continue to rear as they move downstream, whereas Central Valley steelhead seem to move downstream relatively quickly once they begin their emigration from upstream rearing areas.

For the purposes of Environmental Objectives development, the SEP Group characterizes migration as downstream movement in outmigrating anadromous or estuarine juveniles. Migration objectives include physical habitat conditions (e.g., temperature) that support smoltification, allow for passage (e.g., depth, free flowing rivers not obstructed by barriers, partial barriers, or water diversions), and facilitate movement (e.g., velocity) as well as habitat heterogeneity and distribution that support distributed velocity refugia, downstream rearing behavior, and predator avoidance (e.g., turbidity). Rearing and migration habitat are differentiated based on the primary function it is serving to a given individual or species during the time they are occupying it. In cases where a habitat is serving as both rearing and migration functions simultaneously for a given species, optimal conditions for rearing are prioritized. The SEP Group recognizes that the natural, historic overlap in these functions speaks to their inherent alignment, and within the appropriate range, diversity in conditions within a given sub-habitat type supports life history diversity and resilience in the population.

7.2.5.1 *Temperature*

7.2.5.1.1 Temperature Rationale (Juvenile Rearing and Migration)

Juvenile salmonid growth, life stage duration, and metabolic efficiency are directly influenced by water temperature (Quinn 2005). Several authors have hypothesized that Central Valley populations of Chinook salmon and steelhead may tolerate warmer temperatures than those of other populations (e.g., Myrick and Cech 2004). In the San Joaquin River basin's Tuolumne River, there is limited evidence of this warm temperature tolerance in *O. mykiss* populations (Farrell et al. 2015). For juvenile salmonids who are actively feeding over a certain range of temperatures, growth increases with increasing temperatures as long as food is readily available; increasing temperatures may lead to decreased growth or death when food supplies are not sufficient to support increases in metabolic rate. Temperatures ultimately limit growth and survival at thresholds that are species-, population-, and individual-specific.

Temperatures that produce mortality among Pacific salmon depend, to some extent, on acclimation temperatures—higher acclimation temperatures produce higher IULT (Myrick and Cech 2004). Various sources indicate an IULT for Chinook salmon in the range of 24°C to 25°C (75.2°F to 77°F; e.g., Myrick and Cech 2004). Baker et al. (1995) found that Central Valley Chinook salmon had an IULT between approximately 22°C to 24°C (71.6°F to 75.2°F). Negative sub-lethal effects (those that may increase susceptibility to other mortality mechanisms) begin to occur at temperatures lower than the IULT. In the laboratory, when fish have access to full rations, growth of juvenile salmonids increases with temperature up to their physiological limits; however, when food supply is limited (as it often is under normal conditions in the field), optimal and sub-optimal growth and mortality occur at lower temperatures. For example, Mesa et al. (2002) detected increased levels of heat shock proteins (an indicator of stress) after several hours of exposure to 20°C (68°F) for Columbia River fall-run Chinook salmon.

7.2.5.1.2 Temperature Approach (Juvenile Rearing and Migration)

Chinook Salmon

Among juvenile fall-run Chinook salmon from California's Central Valley population, Marine and Cech (2004) found decreased growth, reduced smoltification success, and impaired ability to avoid predation at temperatures above 20°C (68°F). They also reported that fish reared at temperatures of 17°C to 20°C (62.6°F to 68°F) experienced increased predation relative to fish raised at 13°C to 16°C (55.4°F to 60.8°F), although they found no difference in growth rate among fish reared in these two temperature ranges (Marine and Cech 2004). The finding of decreased performance at temperatures above 17°C (62.6°F) is consistent with several studies that suggest, when food supplies are not super-abundant, optimal growth and survival among Chinook salmon occurs at temperatures somewhat lower than 17°C (62.6°F). The USEPA (2003) identifies constant temperatures of 10°C to 17°C (50°F to 62.6°F) and 7DADM less than 18°C (64.4°F) as being optimal conditions for juvenile Chinook salmon when food supplies are limiting. The USEPA (2003) recommends 16°C (60.8°F) 7DADM as a maximum criterion for the following:

- Safely protecting juvenile salmon and trout from lethal temperatures;
- Providing upper optimal conditions for juvenile growth under limited food during the period of summer maximum temperatures and optimal temperatures for other times of the growth season;
- Avoiding temperatures where juvenile salmon and trout are at a competitive disadvantage with other fish;
- Protecting against temperature-induced elevated disease rates; and
- Providing temperatures that studies show juvenile salmon and trout prefer and are found in high densities.

Based on this recommendation, 16°C (60.8°F) 7DADM or less has been established as the optimal water temperature for juvenile rearing and migration in the river channel.

As indicated, the temperatures that can be tolerated by rearing juvenile Chinook salmon depend largely on food availability. The USEPA (2003) indicates that, when food supplies are unlimited, temperatures from 13°C to 20°C (55.4°F to 68°F; constant) may be optimal. Recent studies on Central Valley Chinook salmon rearing on inundated floodplains reveal excellent survival and growth rates at even higher temperatures. Growth and survival for limited periods have been recorded at temperatures as high as approximately 25°C (77°F) (Katz, unpublished data; Jeffres, unpublished data). The increased tolerance for high temperatures in these fish is believed to be related to the high prey densities and food quality available on floodplains, coupled with low activity costs (Sommer et al. 2001; Henery, unpublished data) and suggests that when food is not limiting, Chinook salmon can tolerate and even thrive at temperatures approaching the physiological limits observed in the laboratory (i.e., IULT). As a result, the SEP Group assumed that following successful restoration of floodplain habitats (and during periods when juvenile Chinook salmon actually occupy inundated floodplains), rearing Chinook juvenile salmon could survive temperatures approaching 25°C (77°F) for limited periods of time. Based on these distinctions, temperatures greater than 25°C (77°F) were established as detrimental for salmon rearing on long-inundation floodplains only. However, the SEP Group also recognizes that exposure to such warm water temperatures greatly increases disease risk, and stress from other water quality factors (e.g., DO or contaminants) likely reduces thermal tolerance. When Chinook salmon are not in habitats that support super-abundant food resources (e.g., in-channel habitats), lower temperatures are required to avoid negative sub-lethal effects.

Elevated water temperatures can inhibit the parr-smolt metamorphosis (smoltification) in salmonids. Chinook salmon can smolt at temperatures ranging from 6°C to 20°C (42.8°F to 68°F; Myrick and Cech 2004). However, salmon that undergo smoltification at higher temperatures (greater than 16°C [60.8°F]) tend to display impaired smoltification patterns and reduced saltwater survival (Myrick and Cech 2004). Marine and Cech (2004) found that Central Valley Chinook salmon rearing in temperatures greater than or equal to 20°C (68°F) suffered altered smolt physiology, and other studies from within this ecosystem suggest that negative effects of temperature on the parr-smolt transition may occur at temperatures less than 20°C (68°F). Richter and Kolmes (2005) cite two studies that indicated negative impacts on Chinook salmon smoltification success at temperatures greater than 17°C (62.6°F). USEPA (2003) indicates that smoltification impairment may occur at temperatures between 12°C to 15°C (53.6°F to 59°F).

O. mykiss

Laboratory studies show that incipient lethal temperatures for juvenile *O. mykiss* occur in a range between 27.5°C to 29.6°C (81.5°F to 85.3°F), depending on acclimation temperatures (Myrick and Cech 2005). Temperature influences growth and lipid content in *O. mykiss* (McMillan et al. 2012). Optimal temperatures for *O. mykiss* juvenile growth occur between 15°C to 19°C (59°F to 66.2°F; Moyle 2002; Richter and Kolmes 2005). In addition to growth, temperature may also influence *O. mykiss* ecological interactions and life history (Reese and

Harvey 2002; Kendall et al. 2014). For example, *O. mykiss* juveniles suffer adverse impacts of competition with pikeminnow at temperatures greater than 20°C (68°F), though no competitive impact is detectable at lower temperatures (Reese and Harvey 2002). Temperature has been correlated with anadromy versus residency in juvenile *O. mykiss* (Kendall et al. 2014), with warmer temperatures associated with anadromy in some cases (Sogard et al. 2012; Benjamin et al. 2013; Doctor et al. 2014). The variable nature of these correlations does not support the use of temperature objectives in isolation as a mechanism for promoting anadromy.

Steelhead may be particularly sensitive to high temperatures during the smoltification process. The USEPA (2003) indicates that temperatures greater than 12°C (53.6°F) inhibit steelhead metamorphosis into smolt. Richter and Kolmes (2005) and USEPA (1999) cited studies that present a range of temperatures between 11°C to 14°C (51.8°F to 57.2°F) that may inhibit steelhead smoltification. Myrick and Cech (2005) cautioned that smolting steelhead in the Central Valley must experience temperatures less than 11°C (51.8°F) to successfully complete this metamorphosis. The critical temperature at which smoltification becomes inhibited may vary from run to run (Richter and Kolmes 2005).

7.2.5.1.3 Temperature Objectives (Juvenile Rearing and Migration)

Temperature objectives for juvenile rearing and migration life stages for Chinook salmon and *O. mykiss* are provided below in Table 43.

Table 43
Temperature Objectives for Chinook Salmon and *O. mykiss* Juvenile Rearing, Migration, and Smoltification

Habitat Type	Temporal Extent	Condition	Range (Metric)
Channel	Fall-run: Last week of January to 2nd week of June	Optimal	6°C to 16°C (42.8°F to 60.8°F) (7DADM)
		Sub-optimal	16°C to 20°C (60.8°F to 68°F) (7DADM)
		Detrimental	> 20°C (> 68°F) (7DADM)
Floodplain – Short Inundation	Spring-run: Last week of December to 2nd week of June	Optimal	10°C to 18°C (50°F to 64.4°F) (7DADM)
		Sub-optimal	18°C to 20°C (64.4°F to 68°F) (7DADM)
		Detrimental	> 20°C (> 68°F) (7DADM)
Mainstem	*O. mykiss*: January to December (year-round)	Optimal	15°C to 19°C (59°F to 66.2°F) (Daily Average)
			16.5°C to 21.5°C (61.7°F to 70.7°F) (7DADM)
		Sub-optimal	20°C to 25°C (68°F to 77°F) (Daily Average)
			21.5°C to 26.5°C (70.7°F to 79.7°F) (7DADM)
		Detrimental	> 25°C (> 77°F) (Daily Average)
			26.5°C (79.7°F) (7DADM)
			> 27.5°C (> 81.5°F) (Instantaneous)

7.2.5.2 Dissolved Oxygen (Juvenile Rearing and Migration)

7.2.5.2.1 Dissolved Oxygen Rationale (Juvenile Rearing and Migration)

Adequate concentrations of DO in water are critical for salmon and *O. mykiss* survival. In freshwater streams, hypoxia can impact the growth and development of salmon and *O. mykiss* fry as well as the swimming, feeding, and reproductive ability of juveniles. If salmonids are exposed to hypoxic conditions for too long, mortality can result (Carter 2005). Factors affecting DO levels may vary among sub-habitats used during juvenile rearing and migration. On floodplains, DO levels may be spatially variable and driven by factors such as temperature, wind mixing, and BOD. In channel, DO is typically less spatially heterogeneous (relative to salmonid needs) and presumed to be driven principally by temperature, with potential influence from groundwater, mixing, and BOD lower in the system.

7.2.5.2.2 Dissolved Oxygen Approach (Juvenile Rearing and Migration)

Salmonids may be able to survive when DO concentrations are low (less than 5 mg/L), but growth, food conversion efficiency, and swimming performance will be adversely affected (Bjornn and Reiser 1991). Davis (1975) reviewed numerous studies and reported no impairment to rearing salmonids if DO concentrations averaged 9 mg/L, while at oxygen levels of 6.5 mg/L, "the average member of the community will exhibit symptoms of oxygen distress," and at 4 mg/L, a large portion of salmonids may be affected. The WDOE (2002) concludes that a monthly or weekly average concentration of 9 mg/L and a monthly average of the daily minimum concentrations should be at or above 8.0 to 8.5 mg/L to have a negligible effect (5% or less) on growth and support healthy growth rates. The USEPA (1986) states that due to the variability inherent in growth studies, the reductions in growth rates seen above 6 mg/L are not usually statistically significant, while reductions in growth at DO levels below 4 mg/L are considered severe. The WDOE (2002) recommended that DO levels below 5 to 6 mg/L should be considered a potential barrier to the movement and habitat selection of juvenile salmonids. Given that recommendation, the SEP Group has established that DO levels below 6.0 mg/L are detrimental for juvenile salmon.

7.2.5.2.3 Dissolved Oxygen Objectives (Juvenile Rearing and Migration)

The DO objectives for Chinook salmon and *O. mykiss* juvenile rearing and migration are provided in Table 44. It is not necessary to separate DO objectives by habitat type because juvenile salmon and *O. mykiss* are affected by DO the same whether they are in the main river channel or in the floodplain.

Table 44
Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Juvenile Rearing and Migration

Habitat Type	Temporal Extent	Condition	Range (Metric)
River channel or Floodplain (water column measurement)	Fall-run: Last week of January to 2nd week of June Spring-run: Last week of December to 2nd week of June *O. mykiss*: January to December (year-round)	Optimal	> 8 mg/L (Daily Minimum)
		Sub-optimal	6 to 8 mg/L (Daily Minimum)
		Detrimental	< 6 mg/L (Daily Minimum)

7.2.5.3 Contaminants (Juvenile Rearing and Migration)

7.2.5.3.1 Contaminants Rationale (Juvenile Rearing and Migration)

Like the other life stages, contaminants have the high potential to impact juvenile rearing and migration. In fact, the greatest impact that contaminants may have is to the health and survival of the juvenile rearing and migration life stages. For example, herbicides and insecticides are designed to target the organisms at the base of the food web that rearing salmonids rely on. In addition, pesticides have been found to disrupt fish behaviors and biochemistry necessary for survival at this life stage (e.g., predator avoidance, feeding, metabolism, growth, osmoregulation, and orientation) (Beyers et al. 1999; Coghlan and Ringler 2005; Potter and Dare 2003; Scott and Sloman 2004). Furthermore, the nearshore, low-flow habitats that provide the greatest benefit to rearing and migratory juveniles typically have higher concentrations and loads of pesticides, which compounds the impact on salmonids in their preferred habitat (NMFS 2008, 2009c, 2011c). Finally, juvenile salmonids exposed to pesticides and other olfactory inhibiting contaminants during development may fail to imprint to their natal waters, which can lead to increased adulthood straying (NMFS 2009c).

Because of the short time period and the type of food web that juvenile salmonids use during rearing and migration, there is typically low risk to mercury and selenium toxicity. However, there are some instances where environmental condition may stimulate methylmercury production and pose toxicological risks to rearing and migrating juveniles. For example, in 2006, episodic flooding in the San Joaquin River watershed, Delta, and other Central Valley river basins created conditions where YOY fish methylmercury concentrations increased 4- to 5-fold higher than typical concentrations and to levels that could pose risks to fish health (Slotton et al. 2007).

Nutrient constituents (i.e., ammonia, nitrate, and nitrite) can also cause direct toxicity to rearing and migrating juveniles. Similar to the previous life stages, excessive nutrients can result in adverse environmental conditions that reduce the fitness and survival of incubating eggs (e.g., low DO or elevated temperatures). (See Appendix C, Section 1.3 for more detailed information on effects of pesticides, nutrients, mercury, and selenium.)

7.2.5.3.2 Contaminants Approach (Juvenile Rearing and Migration)

For discussion of the SEP Group's approach to setting pesticide objectives and objectives for concentrations of nitrogen-based nutrients, see the Contaminants Approach section for Adult Upstream Migration (Section 7.2.1.4.2). The approaches for selenium and mercury Environmental Objectives are similar to egg incubation life stages (see Section 7.2.4.4.2).

7.2.5.3.3 Contaminants Objectives (Juvenile Rearing and Migration)

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and *O. mykiss* juvenile rearing and migration are expected to be similar. Based on the described approach of pesticide Environmental Objectives, the optimal condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 23) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2014).

It is estimated that salmon exposed to pesticides at a frequency of 30% of the time would reduce juvenile growth through olfaction disruption enough to reduce intrinsic population growth by 2% (1.08 versus the 1.10 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Consequently, exposures of pesticides greater than 30% (Bin 7 – 10, Table 23) would represent detrimental conditions. Accordingly, sub-optimal conditions would include Bins 2 – 6, Table 23. (See Appendix C, Section 1.3.3.1 for more information.)

Mercury objectives for juvenile rearing and migration for Chinook salmon and *O. mykiss* are presented in Table 45. (See Appendix C, Section 1.3.3.2 for more information.)

Table 45

Mercury Objectives for Chinook Salmon and *O. mykiss* for Juvenile Rearing and Migration

Condition	Juvenile Fish mg/kg whole body (wet weight)
Optimal	< 0.20
Sub-optimal	0.20 to 1.0
Detrimental[1]	> 1.0

Note:
1 Sub-lethal impacts to fish are estimated to occur above optimal conditions. Detrimental impacts are assumed to occur at mercury tissue concentrations that are expected to create 25% or greater injury to the fish. A 25% effect, or EC25 metric, is a consistent threshold to determine chronic toxicity assessments for regulatory compliance (SWRCB 2012).

Selenium objectives for the rearing and migration life stage are presented in Table 42. The objectives apply to the selenium concentrations in the juvenile fish tissue. In addition, aqueous selenium objectives are presented for lentic and lotic systems to protect rearing and migrating juvenile salmonids from bioaccumulating toxic levels of selenium.

Ammonia, nitrate, and nitrite concentrations necessary to protect salmonid juveniles are provided in Table 24.

7.2.5.4 Physical Characteristics of Rearing Habitat (Juvenile Rearing and Migration)

Physical attributes of rearing habitat include the following:

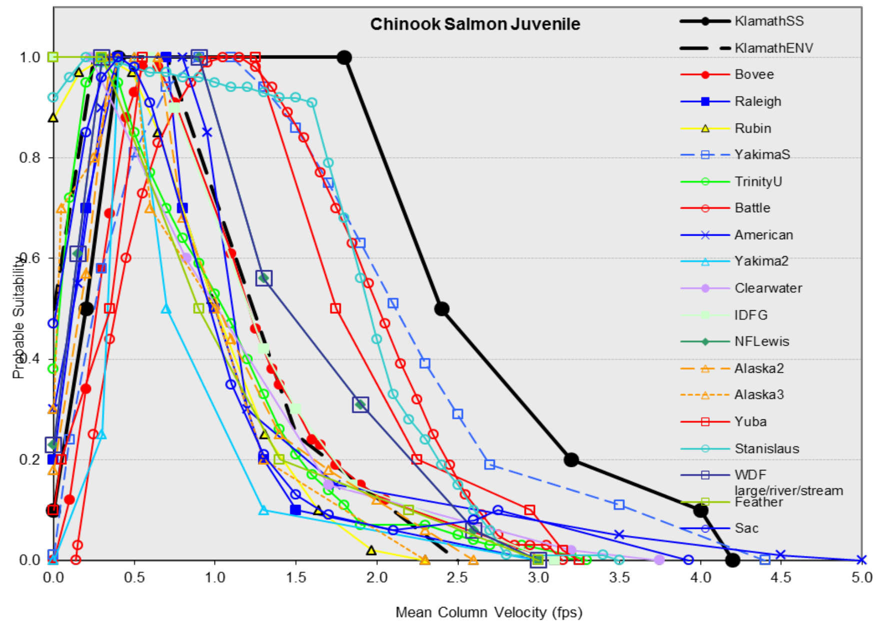
- Water depth and velocity, and
- Cover, structure, and substrate.

The rationale and approach to defining objectives for attributes in each of these groups are described separately below, and objectives are summarized in Table 47 (located in Section 7.2.5.4.5).

7.2.5.4.1 *Water Depth and Velocity Rationale (Juvenile Rearing and* Migration)

Depth and velocity of flow play a critical role in habitat quality for juvenile salmonids. Water depth and water velocity are parameters commonly applied to habitat suitability models for juvenile salmonids, and different combinations of water velocity and depth can contribute to habitat physical and ecological functions as well as heterogeneity within and across habitat types. For juvenile salmonids, water velocity is a key driver of activity level, which interacts with temperature, DO, and prey availability-driven consumption rate to affect growth rate (see Section 1.3.5.3), and suitable depths support foraging behavior and predator avoidance (Gregory 1993). Optimal depth and velocity for juvenile salmonids can vary significantly between systems and for fish of different sizes (Figure 8). Research on juvenile Chinook salmon rearing on flooded rice fields in the Yolo Bypass found no significant correlation between depth and growth for depth ranges of approximately 0.15 m to 0.61 m (6 in to 2 ft) at low velocities and a consistent prey density (Katz, unpublished data).

A) Velocity



B) Depth

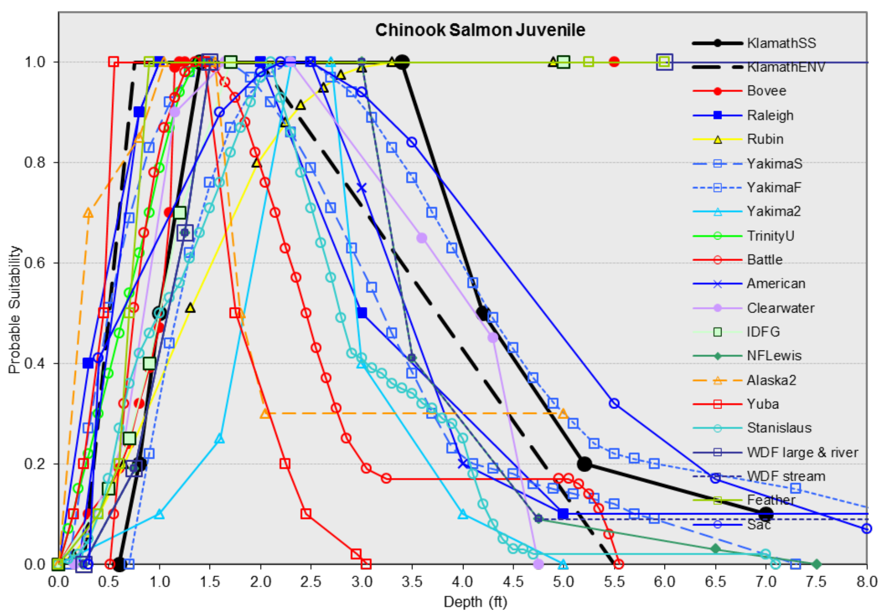


Figure 8

Habitat Suitability Index Values for A) Velocity and B) Depth for Juvenile Chinook Salmon on Multiple Rivers

Note:
Compiled by SJRRP (2012) from multiple published and unpublished empirical (when available) and modeled datasets. The Stanislaus River is indicated by the teal circles.

7.2.5.4.2 Water Depth and Velocity Approach (Juvenile Rearing and Migration)

Juvenile Chinook salmon habitat suitability models for depth and velocity have been developed previously for the Stanislaus River (Aceituno 1990) and applied to floodplain habitat estimates for the San Joaquin River (SJRRP 2012). These estimates suggest optimal depth values between 0 m and 1.4 m (0 ft and 4.5 ft) in floodplain or off-channel conditions (Aceituno 1990; SJRRP 2012). The same studies assigned optimal velocity values for those habitat types at between 0 m/s and 0.91 m/s (0 ft/s and 3 ft/s; Aceituno 1990). These values are based on the velocity requirement for Chinook salmon. While the needs of *O. mykiss* may be different and may use short inundation off-channel habitats for rearing under certain circumstances, research suggests that their primary rearing habitat is in-channel (Merz et al. 2015). Therefore, the SEP Group has used values supporting Chinook salmon as the basis for floodplain objectives. Depth and velocity objectives have been defined consistently across short and long inundation floodplains, with the additional guidance that shorter inundation floodplains may exhibit higher velocities as a function of gradient and more confined channel geometry. Productivity on longer inundation floodplains, by contrast, may benefit from slower velocities often associated with longer hydraulic residence times.

Water velocity in-channel is generally assumed to be greater than in off-channel habitats. Velocity is flow-dependent and variable within and across years as well as at a sub-habitat scale as a function of habitat structure. Additionally, in-channel habitat may be used simultaneously by multiple species and life history stages. As such, no single velocity or velocity range objective was defined for in-channel habitat. Increased flow variability during the summer has been correlated with higher levels of anadromy in juvenile *O. mykiss* (Pearsons et al. 2008; Kendall et al. 2014), whereas increased residency has been hypothesized (Pearsons et al. 1993; Cramer et al. 2003; McMillan et al. 2007) to be linked with more stable summer high flows and correlated with increased summer flows in females (Berejikian et al. 2013). Flow variability in the Stanislaus River has declined significantly from historic unimpaired conditions under reservoir operations. To support anadromy in juvenile *O. mykiss*, the SEP Group has additionally defined a flow variability objective for in-channel habitat.

7.2.5.4.3 Cover, Structure, and Substrate Rationale (Juvenile Rearing and Migration)

Cover, structure, and substrate are core components of the physical habitat for juvenile salmonids that can interact with other physical habitat components (e.g., water velocity and depth) and ecosystem dynamics (e.g., primary and secondary productivity, predator-prey interactions) to influence habitat use by juvenile salmonids. Cover and structure, specifically, have been correlated with the density in juvenile salmonids (McMahon and Hartman 1989), and substrate remediation in the form of gravel augmentation has been correlated with increased habitat use by juvenile salmonids in the Merced River (Selheim et al. 2015).

7.2.5.4.4 Cover, Structure, and Substrate Approach (Juvenile Rearing and Migration)

As concepts, cover and structure have significant overlap—encompassing a range of common physical elements and differing primarily based on the function they serve for juvenile salmonids. For example, a root wad might be considered cover when its function is to provide juveniles with refuge from predators or high flows; a root wad might be considered structure when its function is to increase habitat complexity, regulate territory size, or provide a base for invertebrate prey to attach. Similarly, for juvenile fish, substrate of a certain size (e.g., large cobble or boulders) can provide cover and structure.

Many studies have examined a range of physical structures definable as “cover” in terms of the extent to which they support suitable habitat for juvenile salmonids (Raleigh 1986; Hampton 1988; WDFW and WDOE 2004; Sutton 2006). Physical structures constituting cover and suitability scores for common cover types are not addressed consistently across these studies. In 2012, the San Joaquin River Restoration Program developed a summary of habitat suitability scores for cover from multiple sources for use in modelling suitability of floodplain rearing habitat (Table 46; SJRRP 2012). Average HSI scores from this summary were applied as the basis for floodplain rearing habitat cover objectives.

Table 46
Summary of Habitat Suitability Index Scores for Juvenile Salmon Cover

Cover Type	HSI score for each cover type				Average HSI Value
	Raleigh 1986	Sutton 2006	WDFW and WDOE 2004	Hampton 1988	
No Cover	0.01	N/A	0.1	0.1	0.07
Woody Debris	0.9	0.6	N/A	0.7	0.73
Cobble/Boulder	0.2	0.5	N/A	0.18	0.29
Grass	N/A	0.5	0.48	N/A	0.49
Gravel	0.25	0.3	N/A	N/A	0.28
Willow	N/A	0.8	N/A	N/A	0.80
Undercut Bank	1	1	1	1	1.00
Aquatic Vegetation	0.3	0.6	1	0.5	0.60
Overhanging Vegetation	0.38	0.8	1	0.1	0.57
Root Wad	N/A	0.7	1	0.7	0.80

Note:
Summary of HSI scores for juvenile salmon from a range of sources developed for application to assessment of floodplain habitat quality by the SJRRP (2012)

Substrate objectives were defined separately for short inundation floodplain, long inundation floodplain, and in-channel habitat types. Substrate objectives are defined broadly to comport with the habitat gradient and target velocity range as well as support vegetative cover establishment and the assumed productivity mechanisms. For in-channel habitats areas, to the extent that spawning and rearing areas overlap spatially, substrate should be defined based on needs for spawning and egg incubation and emergence. However, substrate objectives for in-channel rearing habitat have additionally been provided here and are applicable to those in-channel areas not targeted for spawning.

7.2.5.4.5 Physical Characteristics of Rearing Habitat Objectives (Juvenile Rearing and Migration)

Objectives defining the physical characteristics of rearing habitat for Chinook salmon and *O. mykiss* juveniles are provided in Table 47.

Table 47

Physical Rearing Habitat Objectives (Including Metrics for Cover, Substrate, Depth, and Velocity) for Juvenile Chinook Salmon and *O. mykiss*

Habitat Type	Parameter	Condition	Range (Metric)
Floodplain – Short Inundation	Substrate	Optimal	> 5% fines to support vegetation recruitment
	Cover	Optimal	Average HSI score of ≥ 0.5 for all cover types Or: HSI for individual cover types: Woody debris ≥ 0.9 Cobble boulder ≥ 0.5 Overhanging vegetation ≥ 0.8 Root wad ≥ 1
	Depth	Optimal	0.15 m to 1.22 m (0.5 ft to 4 ft) Averaged spatially
		Sub-optimal	1.23 m to 2.13 m (4 ft to 7 ft) Averaged spatially
	Velocity	Optimal	0 m/s to 0.9 m/s (0 ft/s to 3 ft/s)
		Sub-optimal	> 0.9 m/s (> 3 ft/s)
Floodplain – Long Inundation	Substrate	Optimal	> 5% fines to support vegetation recruitment
	Cover	Optimal	Average HSI score of ≥ 0.5 for all cover types
	Depth	Optimal	0.15 m to 1.22 m (0.5 ft to 4 ft) Averaged spatially
		Sub-optimal	1.23 m to 2.13 m (4 ft to 7 ft) Averaged spatially
	Velocity	Optimal	0 m/s to 0.9 m/s (0 ft/s to 3 ft/s) s
		Sub-optimal	> 0.9 m/s (> 3 ft/s)
Channel	Substrate	Optimal	See spawning habitat requirements
	Cover	Optimal	Average HSI score of ≥ 0.5 for all cover types Or: HSI for individual cover types: Woody debris ≥ 0.9 Cobble boulder ≥ 0.5 Overhanging vegetation ≥ 0.8 Root wad ≥ 1
	Flow variability	Optimal	Summer flow variability that mimics the natural hydrograph; intended to contribute to the expression of anadromy

Notes:
Cover metrics are defined by HSI values for various cover types (averaged either across cover types or for individual cover types). Rearing habitat objectives apply year-round for *O. mykiss*, last week of January to second week of June for fall-run Chinook salmon, and last week of December to second week of June for spring-run Chinook.

7.2.5.5 *Rearing Habitat Accessibility and Extent: Inundation Timing, Frequency, and Duration (Juvenile Rearing and Migration)*

The preceding sections described the water quality and physical elements of high-quality rearing habitats. Some rearing habitats are ephemeral and the temporal overlap between the juvenile rearing period and the existence of the different rearing habitats determines, in part, the benefits attributable to these habitats. In addition, timing and duration of inundation of certain shallow water rearing habitats affect their value to rearing juvenile salmonids. Finally, the area of inundated habitat must be sufficient to achieve Biological Objectives for the focal salmonid populations.

7.2.5.5.1 *Habitats, Timing, and Associated Parameters (Juvenile Rearing and Migration)*

Timing of rearing and migration can be presumed to occur year-round when considering all three salmonid species covered in this report, although the timing varies by species and across years,. For juvenile fall-run Chinook salmon (fry, parr, and smolt), the rearing and migration period has been defined as extending from the last week of January through the second week of June. For spring-run Chinook salmon, this period extends from the last week of December through the second week of June. For *O. mykiss*, the juvenile rearing period is considered to be year-round. As such, a separate rearing period for yearlings has not been defined. However, a specific period has also been identified with different objectives to support smoltification in anadromous life history forms of *O. mykiss* that extends from December through March.

Rearing and migration Environmental Objectives have been defined for three primary habitat types as follows:

1. **Floodplain – long inundation**: This habitat type serves the specific functions of rearing habitat for juvenile Chinook salmon and migration “rest stop” and predator avoidance pathway for juvenile Chinook salmon and *O. mykiss*. It is applicable to the lower section of the river (downstream of Ripon) and characterized by lower gradients and longer seasonal inundation event durations (10 to 21 days) that allow for autochthonous primary and secondary production and result in high prey densities. This productivity is supported by a substrate with a higher proportion of

fines, shallower water depths, and lower velocities. As a result of the low velocities and high prey densities, the optimal temperature range and maximum temperature threshold for this habitat are higher.

2. **Floodplain – short inundation**: This habitat type serves the specific functions of rearing habitat for juvenile Chinook salmon and *O. mykiss* and migration "rest stop" and predator avoidance pathway for juvenile Chinook salmon and *O. mykiss*. It is applicable to the portions of the river upstream of Ripon and characterized by higher gradients and shorter seasonal inundation events (1 to 9 days) that support elevated prey densities primarily through allochthonous input of displaced terrestrial invertebrates and, to a lesser extent, benthic invertebrate drift. As a function of the gradient, velocities are generally higher and substrate coarser, though depths remain lower than in-channel. Optimal temperature range is similar to that of in-channel habitats.
3. **In-channel**: This habitat type serves the specific functions of rearing habitat for juvenile *O. mykiss* and migration pathways for juvenile Chinook salmon and *O. mykiss*. It is applicable to all portions of the river (including side channels and braided channels) and characterized by perennial flows and a greater range of depths and velocity than off-channel habitats. Prey densities are generally lower than off-channel habitats and velocities are greater, resulting in a lower temperature range and maximum temperature threshold than long-inundation floodplain habitats. Colder temperatures in this habitat also support smoltification during certain times of year, and variability in flow and temperature support anadromy in *O. mykiss* (Pearson et al. 2008; Soggard et al. 2012; Benjamin et al. 2013; Kendall et al. 2014).

Several of the critical parameters applied to quantify desired conditions are common to multiple habitat types. Sections 7.2.5.5.2 through 7.2.5.5.6 provide a breakdown of desired conditions for each species, organized by parameter, for each applicable habitat type. Tables B-5a through B-5d in Appendix B provide a summary of these Environmental Objectives.

7.2.5.5.2 Inundation Duration and Frequency Rationale (Juvenile Rearing and Migration)

The flood pulse and seasonal inundation of floodplains drive key hydrologic and geomorphic processes that provide substantial habitat and trophic benefits to river ecosystems and fish (Junk 1989; Junk et al. 2004; Poff et al. 2010). The action of floodplain inundation and the extension of the photic zone it creates have been shown to enhance phytoplankton biomass (Schemel et al. 2004; Sommer et al. 2004; Ahearn et al. 2006), zooplankton growth (Müller-Solger et al. 2002; Grosholz and Gallo 2006), and drift invertebrate biomass (Sommer et al. 2001a, 2001b; Benigno and Sommer 2008). Greater frequency of inundation has also been linked to higher levels of invertebrate productivity (Grosholz and Gallo 2006). It is therefore not surprising that juvenile Chinook salmon rearing on floodplains and other off-channel habitats tend to be larger and in better physical condition than those that rear in the main channel of rivers (Sommer et al. 2001; Jeffres et al. 2008; Limm and Marchetti 2009; Henery et al. 2010).

In higher gradient off-channel and floodplain habitats, short duration inundation can displace terrestrial invertebrates from soil and vegetation, and drive terrestrial invertebrate distribution by modifying heterogeneity of organic matter (Langhans 2006). In low gradient floodplains, longer inundation times and extended solar exposure can stimulate autochthonous primary and secondary production that can drive high prey densities and fish production (Grosholz and Gallo 2006). Research from the Cosumnes River floodplain found that secondary productivity began to increase in as little as 10 days after inundation (Jeffres, unpublished data) and reached high levels at approximately 14 days (Grosholz and Gallo 2006). A similar pattern was observed in the Yolo Bypass floodplain (Katz, unpublished data). Research in the Yolo Bypass further indicates that after approximately 21 days, productivity levels have stabilized or are in decline (Katz, unpublished data), and Grosholz and Gallo (2006) recommend a 2- to 3-week flooding duration and frequency to best support native fish.

The timing of inundation, both on its own and through its interaction with duration and frequency, also exerts significant influence over floodplain habitat quality for salmonids. On an annual time scale, under unimpaired flow conditions, inundation event frequency is often tied closely with water year type, and many habitats may not inundate during dryer years.

In order for rearing habitat benefits to be realized for a given cohort, inundation must occur in 1 out of every 2 years (assuming a yearling strategy in some percentage of outmigrants). At a daily time scale, for short duration inundation events, where displacement of terrestrial invertebrates is a main prey source, the frequency of inundation drives the timing of both habitat availability and increased prey density. For longer inundation events, autochthonous production may continue to increase during a single event, primarily as a function of duration (Grosholz and Gallo 2006). Research from the Yolo Bypass and Cosumnes floodplains, however, indicates that drawdown between events can reset the productivity cycle once productivity rates have begun to stabilize or decline (Grosholz and Gallo 2006; Katz, unpublished data).

7.2.5.5.3 Inundation Duration and Frequency Approach (Juvenile Rearing and Migration)

Inundation objectives presented here apply habitat type-specific inundation event duration and timing as a surrogate for mechanism and extent of food production and availability (assuming other identified parameters/conditions, including temperature, water quantity, and substrate type). Specifically, short-duration inundation events are assumed to have elevated levels of invertebrate drift (benthic and terrestrial) as primary prey source, whereas long-inundation events are assumed to have autochthonous secondary productivity as a primary prey source, with terrestrial and benthic invertebrate drift as a secondary source. Duration of discrete events is measured based on a period following a minimum drawdown time. Minimum annual frequency has been established based on the potential for floodplain rearing benefits to have been experienced by adults in any given year, assuming a mix of primarily 2- and 3-year-old retuning adults.

7.2.5.5.4 Inundation Duration and Frequency Objectives (Juvenile Rearing and Migration)

Specific objectives for inundation for juvenile Chinook salmon and *O. mykiss* rearing are provided in Table 48.

Table 48
Environmental Objectives for Inundation for Juvenile Chinook Salmon and *O. mykiss* Rearing

Habitat Type	Temporal Extent	Parameter	Range (Metric)
Floodplain – Long Inundation	Fall-run: Last week of January to 2nd week of June Spring-run: Last week of December to 2nd week of June *O. mykiss*: January to December (year-round)	Duration	10 to 21 wetted acre days
		Frequency	Minimum of 1 in 3 years recurrence interval; Minimum of 1 week drawdown to distinguish discrete event
Floodplain – Short Inundation		Duration	1 to 9 wetted acre days
		Frequency	Minimum of 2 in 3 years recurrence interval during all years (minimum of 1 week drawdown to distinguish discrete event); Minimum of 1 event per year in wet years/years where inundation occurs

7.2.5.5.5 Habitat Spatial Extent and Distribution Rationale (Juvenile Rearing and Migration)

In order for Biological Objectives to be achieved, spatial extent of rearing habitat must be sufficient to support the combined habitat needs of all rearing juveniles within the system necessary to achieve Biological Objectives.

Juvenile Chinook salmon either defend or rely on food from an area of territory (Cramer and Ackerman 2009), even when schooling (Neuswanger 2014). Additionally, territory size is thought to limit the density and production of stream-dwelling salmonids (Chapman 1966; Allen 1969; Grant and Kramer 1990). Territory size requirements of individual fish of a given size tend to be constant regardless of the local numbers of fish abundance (Grant and Kramer 1990; Cramer and Ackerman 2009), and in natural systems result in competition for space and displacement of smaller/weaker individuals (Titus 1990; Keeley 2001; Keeley 2003; Cramer and Ackerman 2009). Smaller/weaker individuals in turn occupy sub-optimal territories (Titus 1990; Keeley 2001) and are likely to experience increased stress, which may reduce growth and fitness, and increased mortality. Providing adequate quantity and quality of territory during rearing and emigration may therefore reduce the negative effects associated with competition for space (SJRRP 2012).

An important component of territory size is the relationship between territory size and fish body size, also known as the "allometry of territory size" (Grant and Kramer 1990). Because salmonids in streams defend territories, from small (post-emergent) juveniles until they either become ocean-ready fish (smolts) or become sexually mature, they must increase the area they defend to meet increasing food and energy (energetic) requirements as they grow (Keeley and Slaney 1996). The result is a dynamic where territory requirements expand through time for growing fish, while fish numbers are diminishing. The required extent and distribution of rearing and migration habitat for juvenile salmonids can therefore be conceptualized as a function of their abundance, size, emigration speed, and survival rate. From this perspective, rearing habitat needs vary based on location and time, where the rearing habitat extent necessary in any one location is equivalent to that which is required by the maximum number of juvenile fish that will occupy that habitat on any day during the rearing and emigration period.

Grant and Kramer (1990) provided a general, multi-species (interspecific) regression model for allometric territory size that attempted to account for variability among species. Following the rational above, allometric territory size relationships may be applied as a predictor of space requirements and maximum densities of juvenile salmonids in streams.

7.2.5.5.6 Habitat Spatial Extent and Distribution Approach (Juvenile Rearing and Migration)

To establish objectives for spatial extent and distribution of rearing habitat, the Emigrating Salmonid Habitat Estimation (ESHE) model, developed by Cramer Fish Sciences and The Nature Conservancy (SJRRP 2012), was applied. The ESHE model simulates stationary growth (rearing) and downstream movement (emigration) of individual, daily groups (cohorts) of juvenile spring-run and fall-run Chinook salmon. The model tracks their numbers (abundance), average speed, size, the amount of territory needed per fish (territory size), and the amount of suitable habitat required to sustain the number of juvenile salmon present within a model reach. Model outputs provide daily estimates of the number of juvenile spring-run and fall-run Chinook salmon present in each model reach and the required area of suitable habitat needed to support them throughout the rearing and emigration period. A detailed description of the ESHE model is presented in Appendix D.

The ESHE model applies multiple parameters (and associated functions) in order to calculate juvenile salmon abundance and habitat needs of daily cohorts, including the following:

- **Initial abundance**: the number of juvenile Chinook salmon entering the model based on the target number of reproducing parent fish;
- **Initial timing and size**: the number of fish on each day that exit the spawning grounds and the average size of the fish exiting the spawning grounds;
- **Migration speed**: the daily downstream movement of juvenile salmon in each reach;
- **Survival rate**: the number of fish that avoid death each day in each reach;
- **Growth**: the daily growth and resulting size of juvenile salmon in each reach;
- **Territory size**: territory size requirements of juvenile salmon in each reach based on their size; and
- **Required suitable habitat**: the required suitable habitat needed to support the juvenile salmon present in each reach.

The values for each of the parameters described above were populated based on a combination of measured and modeled data. Whenever possible and appropriate, preference was given to measured data from the Stanislaus River. A summary of key model inputs is provided in Table 49.

Table 49
Summary of Key Emigrating Salmonid Habitat Estimation Model Inputs along with Sources and Notes

Parameter	Value
Number of Reproducing Fish	Target: 13,200 (Fall-run); 13,200 (Spring-run) Current: 2,150 (Fall-run)
Female Fish Percentage	60%
Number of eggs per fish (fecundity)	5,813
Egg Survival to Emergence	0.68
Yearlings Percentage	15%
Entry Numbers and Location	RM 58 – 54 (25.64%) RM 53 – 49 (40.98%) RM 53 – 49 (13.46%) RM 43 – 39 (8.77%) RM 38 – 34 (11.15%)
Migration Speed – Pre-smolts	4.14, 12.62, or 24.91 km/day (2.57, 7.84, or 15.48 miles/day)
Migration Speed – Smolts	7.11, 18.55, or 35.13 km/day (4.42, 11.53, or 21.83 miles/day)
Egg to Smolt Survival	10.18%
Egg Survival (Current)	33%
Egg Survival (Target)	68%
Habitat Quality	100%

To provide habitat spatial extent and distribution objectives that would account for differences in rearing and migration behavior across wet and dry years and be applicable to cohort abundance consistent with existing and target population sizes, separate ESHE model runs were completed for current and target population levels under slow and fast outmigration scenarios (four total model runs). Results from the model runs are presented in Table 50.

Table 50
Summary of Key ESHE Model Inputs Along with Sources and Notes

ESHE Results			
Abundance	**Migration Type**	**Habitat Area (m^2)**	**Habitat Area ($Acres^2$)**
Current	Fast	25,055	6.19
Current	Slow	278,346	68.78
Target	Fast	330,541	81.68
Target	Slow	2,861,357	707.05
Estimated Inundated Area (Example)			
Habitat Quality	**Abundance**	**Migration**	**Inundated Area (Acres)**
7% to 30% (SJRRP 2012)	Target	Slow	2,356.8 – 10,100.7

Notes:
– Rearing habitat need outputs from the ESHE model for slow current and target Chinook salmon populations at slow and fast emigration rates.
– Habitat area needs estimates assume 100% suitability.
– The Estimated Inundated Area (Example) applies the measured range of on-the-ground habitat suitability from the San Joaquin River to the highest output (Target/Slow) from the four modeled scenarios as an example of how ESHE-estimated habitat extent objectives translate into habitat extent need on the ground.

It is important to note that model results assume 100% habitat suitability. However, actual habitat suitability within a given area of rearing habitat may be significantly lower. As a component of their floodplain habitat needs analysis, the San Joaquin River Restoration Program compiled and examined on-the-ground information on habitat condition from the San Joaquin River basin and found that floodplain habitat suitability ranged from 7% to 30% (SJRRP 2012). Relating the estimated habitat area need provided by ESHE to the percentage of habitat suitability on-the-ground yields the required rearing habitat area. An example to this effect is provided in Table 50.

In order to account for differences among years, rearing habitat spatial extent objectives were established based on the range of 100% suitable habitat area needs estimated across the four modeled scenarios. Calculating on-the-ground habitat spatial extent needs for the Stanislaus River will require the application of this range to applicable on-the-ground percent habitat suitability. Habitat distribution objectives were similarly presented as a range, describing the range in percent of the total habitat area necessary in any given reach. Rearing habitat spatial extent and distribution needs were calculated based on targets for spring- and fall-Chinook salmon and are intended to apply primarily to floodplain rearing habitat.

8 STRESSORS

Stressors are conditions (physical, biological, or ecological) within the system that limit or inhibit the attainment, existence, maintenance, or potential for desired conditions, as characterized by the Biological and Environmental Objectives. Identification of stressors is critical in order to:

- Highlight components of desired conditions that are not being achieved; and
- Identify the specific obstacles (i.e., stressor[s]) inhibiting desired conditions.

As a complement to the identification of stressors, ranking stressors accomplishes the following:

- Enables the development of specific actions to achieve desired conditions by resolving stressors; and
- Facilitates the prioritization and sequencing of those actions to maximize benefit by addressing the most significant stressors first.

In cases where other prioritization considerations (e.g., financial and political) prevent stressors from being addressed in order of importance, stressor ranking also helps to correctly set expectations about the extent of progress towards desired conditions that a given action will achieve, and/or the suite and scale of actions necessary to achieve or make progress towards desired conditions.

8.1 Stressor Identification and Ranking Approach

The process for identifying and ranking stressors includes the following four key steps:

1. **Identification of the range of stressors affecting each life history stage.**
   For each life stage, stresses that limit the success of that life stage were identified (e.g., lack of suitable holding habitat for migrating adult salmonids). Stressors, or drivers of stresses, were framed in terms of parameters specified in Environmental Objectives (e.g., temperature and DO). Stressors not specifically addressed in the objectives that could impact Biological or Environmental Objectives were also included (e.g., predation). In some cases, stressors may be interrelated both for a given life history stage (as when two lower magnitude stressors cumulatively result in a third

higher magnitude stressor) or across life history stages (as when a stress to one life history stage results in a different stress to one or more subsequent life history stages).

- Assignment of stressors for each life history stage as relevant to current and future scenarios. Stressors were considered as relevant to 1) current population and conditions, 2) target population and conditions, or 3) both.
  - In the first case, the stressor affects the species or ecosystem under current conditions, and/or at the current species population levels.
  - In the second case, the stressor, although not currently impacting populations or ecosystem conditions, is predicted to become impactful once populations approach recovery; when ecosystem conditions progress towards desired conditions; or as a function of some other trend, transition, or tipping point occurring in the future.
  - In the third case, a stressor is currently having an impact on the species, and it is expected that the magnitude or nature (e.g., scale and predictability) of that impact will change as populations increase, progress towards Environmental Objectives is made, or some other future condition comes into being.

2. **Scoring of coarse scale stress and component fine scale stressors, by life history stage for current conditions and target of future conditions as applicable.**
   Stressors are assigned a score of 1 to 4 points (1 being lowest and 4 being highest) in two categories: magnitude and certainty. Magnitude scores are based on the scale and severity of the impact to populations from the stress. Certainty scores are based on the understanding of a stressor's related impact as a function of the available information base as well as the predictability of that impact. In combination, magnitude and certainty scores generate an overall score, guide stressor ranking, and provide indication about the appropriate stressor response. Although stressors are scored separately for each life history stage, score definitions for magnitude and certainty are common to all life history stages, allowing for ranking of stressors across life history stages. The highest score for any stressor is then assigned to the life stage stress; a life stage stress cannot be scored lower than any of the stressors. Scores for each life stage were adjusted upward from the highest component stressor score based on professional judgement if the SEP Group felt there were synergistic effects among

component stressors. Additional details about the stressor scoring process are provided in the next section.

3. **Stressor ranking and prioritization across life history stages.**
   Once scored, stressors for individual life history stages are combined for each of the three species (fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss*). Stressors are then sorted and ranked based on their magnitude and certainty scores, and assigned a stressor response type also based on scoring. In addition to the severity of the stress, a high magnitude score indicates the potential need for a major action, depending on certainty. A low magnitude score, depending on certainty, suggests a need for either 1) monitoring to ensure the magnitude does not increase, or 2) research to confirm the low magnitude score and potentially inform adaptive management. Because stressor ranking is intended to guide and prioritize the development of actions to advance objectives and achieve desired conditions, stressors with high magnitude and high certainty are considered the highest priority.

8.1.1 Stressor Identification

The SEP Group identified stressors by examining the Environmental Objectives for each life stage and identifying the following:

- Which Environmental Objectives were not being achieved under current conditions,
- Any aspects of Biological Objectives that were not being achieved under current conditions and would not be addressed by meeting the Environmental Objectives, and
- Any specific factors that were currently inhibiting achievement of Environmental Objectives and Biological Objectives.

In many cases, a stressor is directly related to an Environmental Objective. For example, the lack of suitable habitat for spring-run Chinook salmon holding is a stressor that is directly related to the Environmental Objective for spring-run adult holding habitat. However, in other cases, a stressor is a category that may encompass multiple Environmental Objectives. For example, lack of suitable migratory conditions for fall-run Chinook salmon is a stressor for the juvenile rearing and migration life stage that addresses multiple Environmental Objectives and biological processes, including water quality, flow, habitat, and predation. In general, the SEP Group used expert opinion to develop stressors that the group felt prevented attainment of Environmental Objectives and Biological Objectives in the Stanislaus River. The collective knowledge and experience of the SEP Group was used to develop a comprehensive list of stressors. The process of stressor scoring and ranking was informed and supported by the quality and quantity of existing information (data and literature).

8.1.2 Assignment of Stressors to Current and Future Conditions

The SEP Group assigned stressors according to the potential to achieve Biological Objectives under two scenarios:

1. Current conditions; and
2. Twenty years in the future and assuming the attainment of the Biological Objectives (i.e., fish populations approaching goals for the Stanislaus River) and increased air temperatures.

The assumption of a restored population under Scenario 2 implied that habitat requirements would be greater than under current conditions and sufficient to support population goals for the Stanislaus River. The assumption of increased air temperatures under Scenario 2 implied that temperature would be more of a stressor in the future compared with current conditions.

8.1.3 Stressor Scoring

8.1.3.1 Scoring Framework Adapted from DRERIP

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP), the first of four regional plans intended to implement the CALFED Ecosystem Restoration Program, developed specific guidance for the evaluation of actions and stressors to assess performance and guide adaptive management.[8] The DRERIP includes a scoring framework for ranking the effect of different actions to achieve an objective. The framework applies magnitude and certainty scores as a basis for a balanced ranking sensitive to spatial and temporal scale. The

[8] Available from: http://www.delta.dfg.ca.gov/erpdeltaplan/science_process.asp

stressor ranking the SEP Group used applies an adapted version of the DRERIP framework, leveraging the same balanced and replicable approach to scoring, but with minor modifications to accommodate the application of the framework to the ranking of stressors limiting desired conditions as opposed to actions to achieve them.

8.1.3.2 Key Concepts and Terminology

8.1.3.2.1 Magnitude

Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.

8.1.3.2.2 Certainty

Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.

8.1.3.2.3 Other Key Component of Scoring

The terms importance, predictability, and understanding are used in the magnitude and certainty scoring definitions to characterize conceptual model linkages between a driver (i.e., stressor) and an outcome (stress).

Importance
The degree to which a stressor-stress linkage controls an outcome or impact relative to other stressors and linkages affecting that same outcome. The stressor analysis was designed to encompass all known potential stressors, linkages, and outcomes, but this concept recognizes that some are more important than others in determining how the system works.

Predictability
The degree to which the performance or the nature of the outcome can be predicted from the stressor. Predictability seeks to capture the variability in the stressor-stress relationship. Predictability can encompass temporal or spatial variability in conditions of a stressor,

variability in the processes that link the stressor to the outcome, or variability in the level of understanding about the cause-effect relationship. Any of these forms of variability can lead to difficulty in predicting change in an outcome based on changes in a stressor.

Understanding

A description of the known, established, and/or generally agreed upon scientific understanding of the cause-effect relationship between a single stressor and a single outcome (i.e., stress). Understanding may be limited due to the following: lack of knowledge and information; disagreements in the interpretation of existing data and information; the basis for assessing the understanding of a linkage or outcome is based on studies done elsewhere and/or on different organisms; or conflicting results have been reported. Understanding should reflect the degree to which the stressor analysis and scoring does, in fact, represent conditions in the system.

8.1.3.3 Specific Scoring Criteria

8.1.3.3.1 Criteria for Scoring Magnitude

4-High

Expected sustained major population-level effect, e.g., natural productivity, abundance, spatial distribution and/or diversity (both genetic and life history diversity) or a landscape scale habitat effect, including habitat quality, spatial configuration and/or dynamics; this requires a large-scale action.

3-Medium

Expected sustained minor population effect or effect on large area (regional) or multiple patches.

2-Low

Expected sustained effect limited to small fraction of a population, addresses productivity and diversity in a minor way, or limited spatial (local) or temporal habitat effects.

1-Minimal

Little effect.

8.1.3.3.2 Criteria for Scoring Certainty: Understanding and Predictability

Scoring for certainty hinges on the level of a) understanding, b) predictability, and to a lesser extent c) importance. Certainty is based on the understanding score, which is modified (shifted up or down) by the associated predictability that accompanies the understanding, as shown in Figure 9.

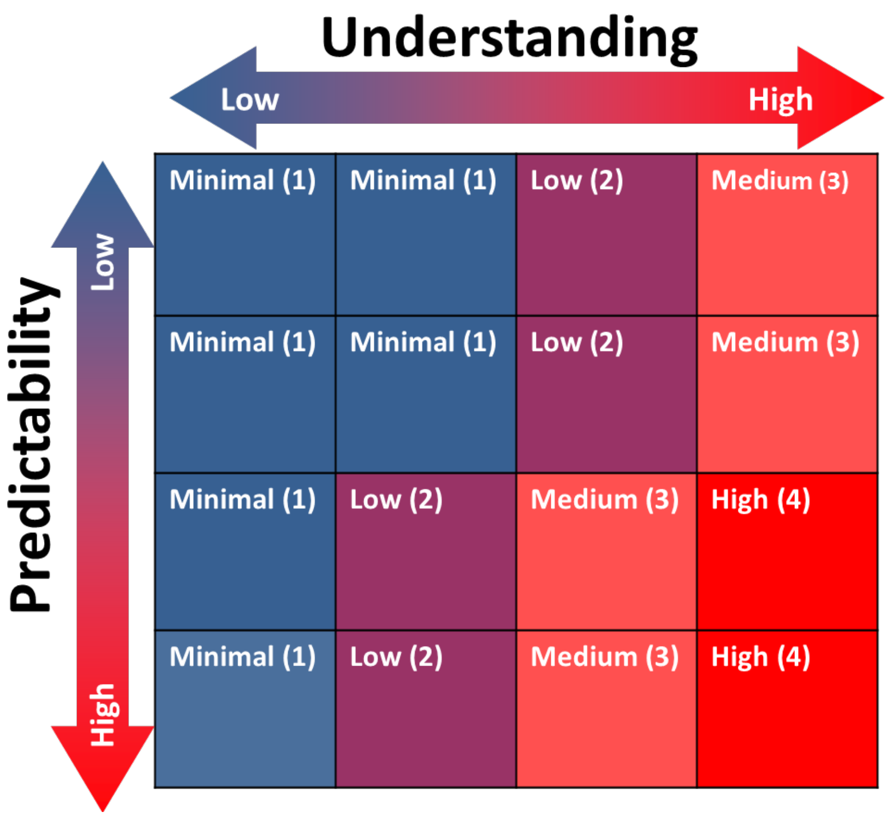


Figure 9

Matrix Depicting Certainty Scoring Based on a Combination of Understanding and Predictability

Note:
Understanding and predictability have specific definitions that determine the resulting score on the certainty matrix. See text for definitions.

8.1.3.3.3 Scoring Understanding (as a Component of Certainty Scoring)

Understanding is "**high**" based on:

- Near-term condition:
  - Either:
    - Recent (i.e., within the last 10 years) and robust (e.g., multiple years spanning wet and dry conditions) agency data on the system for the stressor/variable of interest; or
    - More than one peer-reviewed paper of conditions on the system from within the last 20 years generally support the score.
- Long-term condition:
  - In general, future conditions are expected to be less certain than the near-term condition (because data or published papers are not yet available). A "high" certainty in the long term is warranted when:
    - There is an established (high understanding per above) trend suggesting that the near-term conditions are highly likely to maintain the certainty over the next 20+ years, or
    - There is a well-understood relationship between increased abundance of salmonids (the operating assumption of the long-term condition) and the certainty of the stressor.

Understanding is "**medium**" based on:

- Near-term condition:
  - Either:
    - There are agency data on the system for the stressor/variable of interest, but the data are not as recent and/or not as abundant/robust as described for the high score, or
    - One peer-reviewed paper from the scientific literature and/or grey literature reports on the system from multiple disparate sources (i.e., different projects, not periodic interim reports from the same project) from within the last 20 years generally support the score.
- Long-term condition:
  - A "medium" certainty in the long term is warranted when:

  - o There is some evidence suggesting that the near-term conditions are highly likely to continue or to increase the certainty of the score over the next 20+ years, or
  - o There is evidence to suggest a relationship between increased abundance of salmonids in the system (the operating assumption of the long-term condition) and the certainty of the stressor.

Understanding is “**low**” based on:

- Near-term condition:
  - No recent or robust data are available and score is supported by one scientific grey literature report on the system from within the last 20 years.
- Long-term condition:
  - There is little or no evidence suggesting that the near-term conditions are predictive of conditions 20+ years into the future and little evidence suggesting that increases in salmonid abundance will make the stressor score more certain in the future.

8.1.3.3.4 Scoring Certainty

4-High:

- Understanding is “high,” and
- Nature of outcome (i.e., stress) is either: a) predictable (i.e., largely unconstrained by variability in ecosystem dynamics, other external factors, or b) is expected to confer effects under conditions or times of greatest importance (i.e., control over the outcome relative to other drivers and linkages affecting that same outcome).

3-Medium:

- Understanding is “high” (see scoring for 4) but nature of outcome is somewhat unpredictable, **or**
- Understanding is “medium” and nature of outcome (i.e., stress) is predictable (i.e., largely unconstrained by variability in ecosystem dynamics or other external factors).

2-Low:

- Understanding is "medium" but nature of outcome is somewhat unpredictable, **or**
- Understanding is "low" and nature of outcome (i.e., stress) is predictable (i.e., largely unconstrained by variability in ecosystem dynamics or other external factors).

1-Minimal:

- Understanding is lacking, **or**
- Understanding is "low" and nature of outcome (i.e., stress) is unpredictable (i.e., greatly dependent on highly variable ecosystem processes or other external factors).

8.1.3.4 Scoring Stress Based on Contributing Stressors

Once all the fine scale component stressors had been scored, each coarse scale life stage stress was given the highest score for any fine scale stressor; a life stage stress cannot be scored lower than any of the component stressors. Scores for each life stage were adjusted upward from the highest component stressor score based on professional judgement if the SEP Group felt there were synergistic effects among component stressors.

8.1.4 Stressor Ranking and Prioritization

Stressor prioritization is a function of the combination of scores for magnitude and certainty. Scores in these categories not only combine to produce the overall stressor ranking, but also provide insight into the appropriate stressor response where:

- High magnitude → Action
- Low magnitude → No action
- Hi certainty → Monitoring
- Low certainty → Research

In combination, magnitude and certainty scores reveal even greater detail about appropriate stressor response and prioritization where:

- High magnitude + High certainty → High priority action response
- High magnitude + Low certainty → High priority research response

- Low magnitude + High certainty → Low priority monitoring response
- Low magnitude + Low certainty → Low priority research response

Additionally, upper mid-range certainty scores, although still strong enough to warrant action (as opposed to research), indicate the likely need for adaptive management of the action and/or subsequent associated actions in order to achieve the desired stressor reduction. Similarly, low mid-range certainty scores indicate a high research priority with a focus on clarifying the design of specific action(s) to respond to and resolve the stressor. Figure 10 presents the full range of stressor responses associated with different magnitude and certainty score combinations.

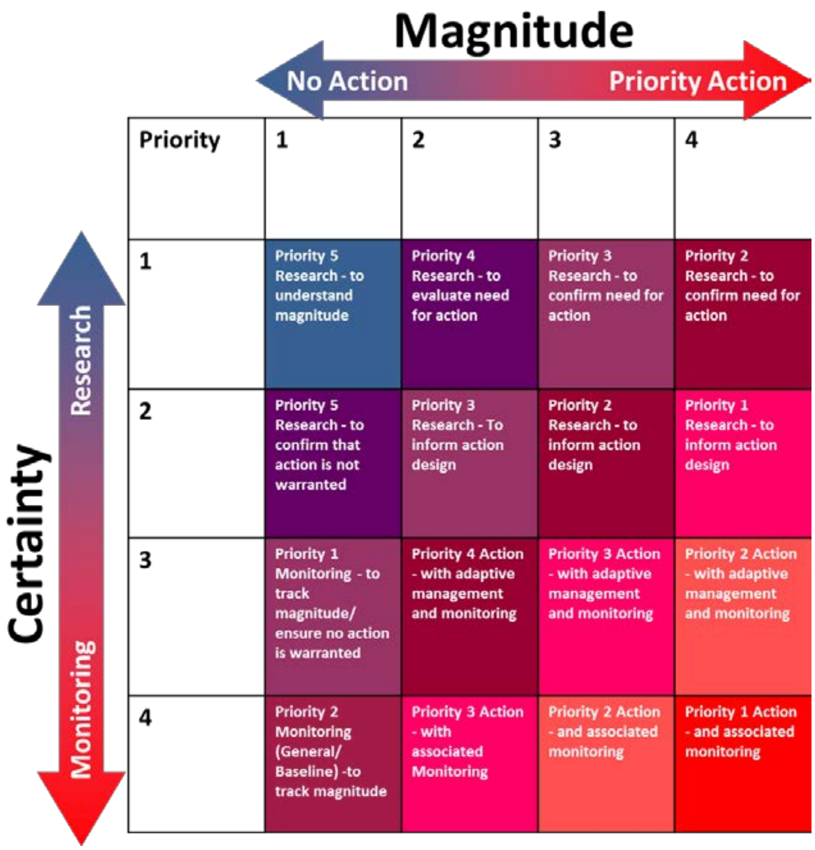


Figure 10
Stressor Response Priorities Based on Combined Magnitude (Horizontal) and Certainty (Vertical) Scores

Note:
Magnitude and certainty have specific definitions that determine the resulting score on the Priority matrix. See text for definitions.

To develop the overall stressor response prioritization for each species, stressor magnitude and certainty scores for all life history stages were combined. Stressor response priorities were then assigned to the coarse scale multi-variate stressors and the fine scale individual variable driven stressors. They were then grouped based on those applicable to near-term conditions (i.e., current and recovering populations) and long-term conditions (i.e., target populations). The results of this synthesis are summarized in Figures 23 through 29.

8.2 Stressors on Adult Migration

Adult migration through freshwater represents one of the last stages in the Chinook salmon life cycle and a key (and most often terminal) stage in the anadromous *O. mykiss* life cycle. Individuals that reach this stage have avoided mortality in earlier life stages and therefore have very high value from a life history perspective.

The SEP Group evaluated two categories of stress in the near term and long term for adult salmonids migrating into the San Joaquin and Stanislaus rivers, including the following:

- Failure to reach the natal stream due to straying or direct mortality, and
- Indirect lethal and sub-lethal impacts to migrating salmon (those that affect their subsequent holding or spawning success).

In addition, for fall-run Chinook salmon, the stress arising from late access to the spawning grounds was evaluated. Measuring any of these effects presents challenges: delays and direct mortality of migrating adults may go unnoticed if it occurs downstream of the first monitoring station in freshwater, and detecting reduced gamete viability generally requires directed studies of incubation success (e.g., in a hatchery).

Water temperature, DO, in-river predation/poaching, physical and biological passage barriers, toxic chemicals, and attraction flows are among the factors (stressors) that contribute to stress on the target populations during their adult migrations (Tables 52 through 54). Near-term stresses reflect those that would impede attainment of

Environmental or Biological Objectives under current conditions, including densities of target populations that may occur on the path to attainment of near-term objectives. Evaluation of stress in the long term assumed that adult salmon densities would increase substantially and that regional warming trends occur as anticipated (Cayan et al. 2008; Dettinger et al. 2004).

Complete blockage of salmonid migration due to impassable barriers (i.e., dams) is a stress that occurs during adult migration. Note that the population impact associated with this stress was assessed in the life stages following adult migration as a function of the amount and quality of holding, spawning/incubation, and juvenile rearing habitats below the dams. In other words, the effect of impassable barriers is captured by the stress associated with inadequate habitat available in subsequent life stages. As long as the extent of quality habitats for any freshwater life stage is limited below the dam and additional acreage of those high quality habitats are available above impassable dams, the dams will represent a stressor that impairs the ability of salmonid populations on the Stanislaus River to attain the Biological Objectives described in this report. Whether the stress created by inadequate habitat availability in any life stage is best alleviated by allowing for adult migration beyond the dams or by creating new habitat below the dam is a question that will be evaluated by comparing different conservation proposals (i.e., it is beyond the scope of this report).

8.2.1 Current Migration Timing Pattern

Scoring of stress is based on the potential exposure to stressors along the full migration pathway in the San Joaquin and Stanislaus rivers and across the range of each population's adult migration timing window (see Figure 7). For comparison, current temporal distribution of fall-run Chinook salmon adult migration into the Stanislaus River was estimated from passage data collected at the counting weir located near the City of Riverbank (approximately RM 31.5). Some adult migration occurs through most of the target migration window for fall-run Chinook salmon in all years (Table 51); migration typically begins in late September and the run is largely completed by late December. Typically, 50 % of the annual escapement of fall-run Chinook salmon has occurred by the end of October, although in some years this milestone is not attained until early November. The distribution of returning adults appears coincident with fall pulse flows (engineered releases from reservoirs) that are intended to stimulate upstream migration (Figure 11).

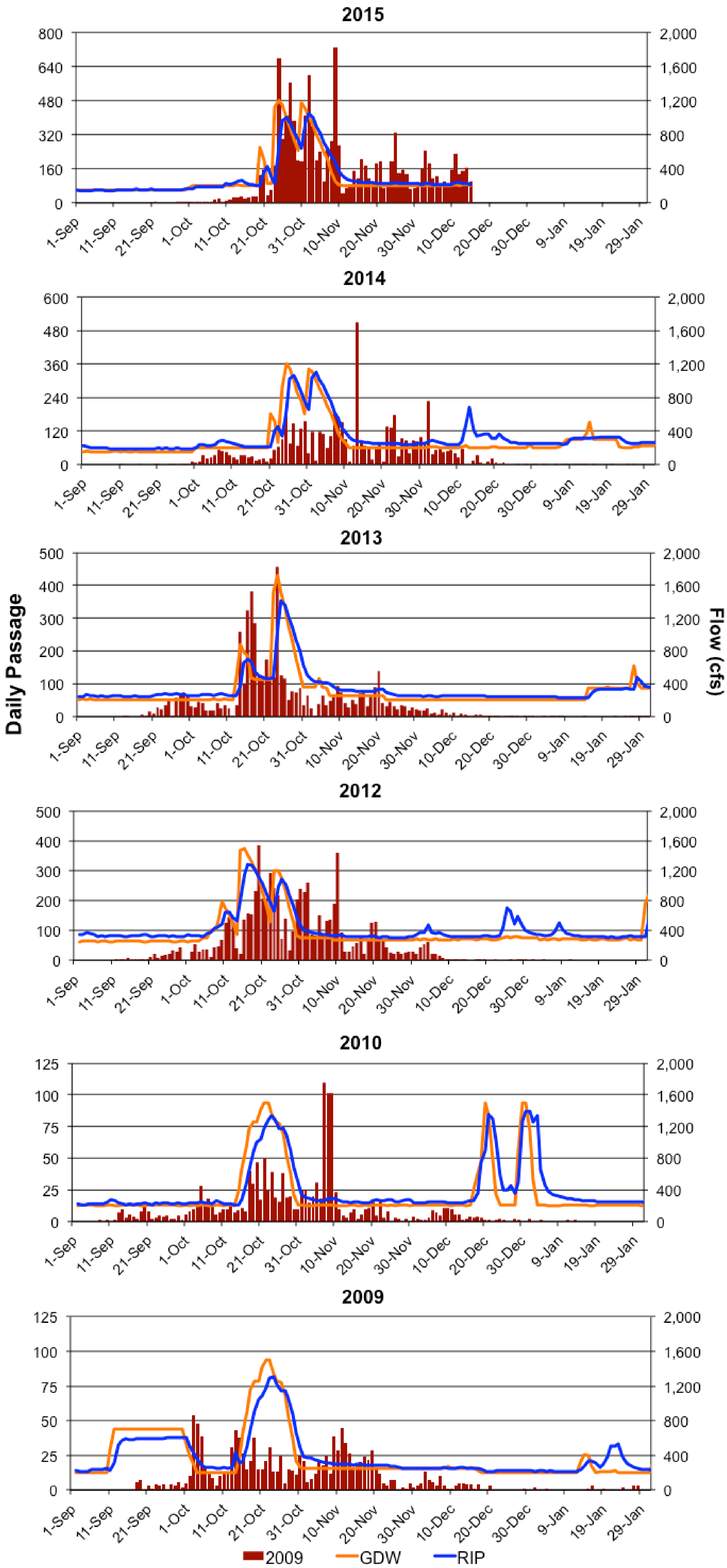


Figure 11

Daily Adult Fall-run Chinook Salmon Passage

Notes:
Daily adult fall-run Chinook salmon passage (red bars; left axis) measured at the Stanislaus River weir with respect to river flow measured at Goodwin Dam (GDW; orange line; right axis) and Ripon (RIP; blue line, right axis). Years 2009 – 2015 are shown, except for 2011 because high river flows made weir counts unreliable in that year.
Source: FISHBIO, unpublished data. Provided by J.D. Wikert, US Fish and Wildlife Service, December 2015.

Spring-run Chinook salmon and steelhead migrations in the Stanislaus River are not well monitored at this time, so the SEP Group's knowledge of adult movements in these two populations is based on ad hoc observations.

Table 51

Cumulative Timing of Adult Fall-run Chinook Salmon Migration Past the Stanislaus River Weir, 2003 – 2014

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Sep 29 –Oct 5						10%	10%	10%	Weir Data Unreliable		10%	
Oct 6 – 12	10%, 25%	10%		10%	10%	25%				10%		
Oct 13 – 19			10%				25%	25%		25%	25%	10%
Oct 20 – 26		25%	25%		25%	50%					50%	
Oct 27 – Nov 2	50%	50%		25%	50%		50%	50%		50%		25%
Nov 3 – 9			50%	50%		75%		75%		75%	75%	
Nov 10 – 16	75%	75%	75%	75%	75%		75%			90%		50%
Nov 17 – 23		90%					90%	90%			90%	75%
Nov 24 – 30	90%		90%	90%	90%	90%						
Dec 1 – 7												90%

Note:
Numbers and shading represent percentiles of total returns for each year. Escapement timing in 2011 is not shown because flows during that year made weir counts unreliable for much of the migration season.
Source: FISHBIO, unpublished data. Provided by J.D. Wikert, US Fish and Wildlife Service, December 2015

8.2.2 Stress: Failure to Reach Holding or Spawning Habitat in the Natal Stream (Stanislaus) due to Direct Action of Stressors (e.g., Mortality, Straying, and Extreme Delays) (Adult Migration)

Direct mortality and straying rates for Stanislaus-natal fish are currently unknown because adult salmon presence is not monitored regularly in the Delta, San Joaquin River, or lower Stanislaus River. However, straying of San Joaquin River Chinook salmon is believed to be high, especially when elevated Delta export and reduced San Joaquin River inflow levels alter hydrodynamic patterns in a way that affects homing ability (Marston et al. 2012). Current environmental conditions in the lower San Joaquin (below the Stanislaus confluence) and lower Stanislaus rivers are expected to have a direct, negative influence on successful migration into the Stanislaus in a way that would inhibit Stanislaus River productivity.[9]

Various factors, acting alone and in combination, may result in failure of adult salmon to reach the Stanislaus River; data associated with these factors differ in quantity and quality. Hourly measures of temperature and DO are available from year-round, long-term monitoring at several locations in the migratory corridor of Chinook salmon and steelhead returning to the Stanislaus River. Toxin concentrations also factor into this stress, but available data quality and quantity, as well as the spatial and temporal distribution of data, vary over a range of compounds. In-river fishing mortalities (legal and illegal) are not well monitored, so certainty regarding their effect is minimal. Improved monitoring of certain environmental conditions as well as study of the timing of salmonid migration into the San Joaquin basin and Stanislaus watershed will be needed to fully understand the population-level effects of this stress.

8.2.2.1 Fall-run Chinook Salmon

Failure of Stanislaus-bound fall-run Chinook salmon to reach the Stanislaus River in the near term as a direct result of poor environmental conditions was scored as a "medium" magnitude stress (Table 52) with a minimal degree of certainty. Certainty could be improved with additional monitoring of migrating adult salmon lower in the watershed (e.g., near where the San Joaquin River enters the Delta and/or the confluence of the Stanislaus River and San Joaquin River).

[9] The SEP Group currently has no Biological Objective pertaining to adults failing to reach the Stanislaus River or straying into the Stanislaus from other natal watersheds (but see Biological Objective regarding genetic effects of hatchery strays). Without additional monitoring for adult salmon entering the lower San Joaquin River, such an objective would not be measureable. Management of the Stanislaus River is only partially responsible for conditions in the lower San Joaquin River. Additional objectives for migration success and associated Environmental Objectives will be incorporated into the SEP's report on objectives and stressors for the San Joaquin Basin as a whole. Stresses impacting adult migration into the Stanislaus from the San Joaquin are documented here because they may affect Biological Objectives for other life stages and as a placeholder for issues that must be addressed in a basin-wide assessment of stressors.

Without corrective action, failure of Stanislaus-bound fall-run Chinook salmon to reach spawning grounds as a direct response to poor environmental conditions will remain a "medium" magnitude stress (Table 52) over the long term. Without additional monitoring, certainty of this stress will remain minimal in the long term.

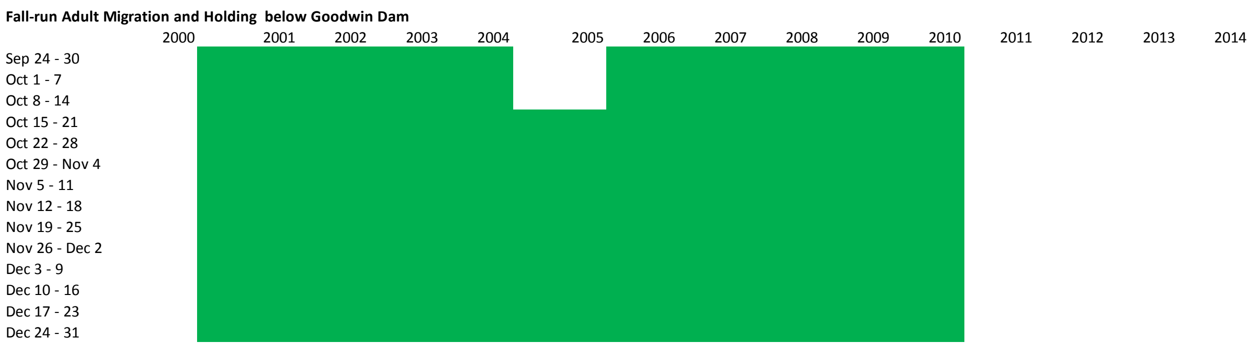
Table 52

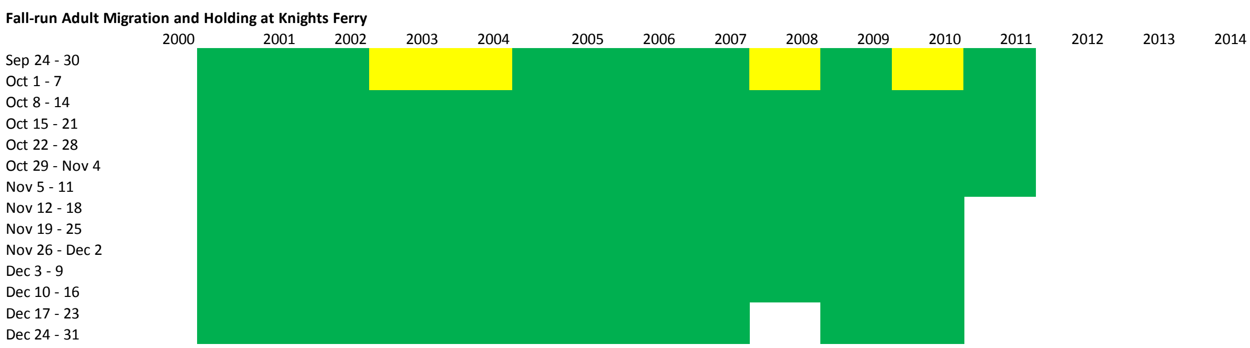
Adult Migration (Fall-run Chinook Salmon) Stressor Scores

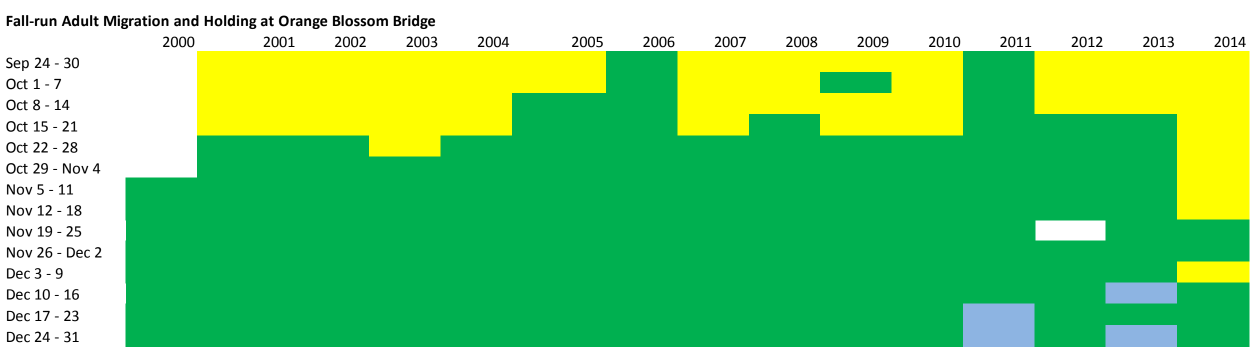
	NT		LT				Stressors: Temperature		DO		Toxins		Fishing and Poaching		Passable Physical Barriers (incl. low water levels and SAV)		Attraction Flows	
Stress	**M**	**C**	**M**	**C**	**Where**	**When**	**NT**	**LT**	**NT**	**LT**	**NT**	**LT**	**NT**	**LT**	**NT**	**LT**	**NT**	**LT**
Failure to Reach Holding or Spawning Habitat in the Natal Stream (Stanislaus) due to Direct Action of Stressors (e.g., mortality, straying, and extreme delays)	3	1	3	1	Ripon and downstream to Stockton DWSC	Late Sept through early Oct	M: 2 C: 1	M: 2 C: 1	M: 2 C: 1	M: 2 C: 1	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1			M: 3 C: 1	M: 3 C: 1
Indirect Mortality (e.g., disease outbreaks) and Sub-lethal Negative Effects	3	3	4	3	Primarily Stockton DWSC to Ripon (temperatures remain high up to Orange Blossom Bridge in some years)	Late Sept through mid Oct to mid Nov, depending on location	M: 3 C: 3	M: 4 C: 3	M: 3 C: 2	M: 4 C: 2	M: 3 C: 2	M: 3 C: 2			M: 2 C: 1	M: 2 C: 1	M: 3 C: 2	M: 3 C: 2
Limited Early Access to River (relative to migration window) due to Impassable or Unsuitable Conditions	3	2	3	2	Primarily Stockton DWSC to Ripon (temperatures remain high up to Orange Blossom Bridge in some years)	Late Sept through early Oct	M: 3 C: 2	M: 3 C: 2	M: 3 C: 2	M: 3 C:2	M: 2 C: 1	M: 2 C: 1					M: 3 C: 2	M: 3 C: 2

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run adult migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT= near term

Comparing the desired adult migration window for Stanislaus River fall-run Chinook salmon run (late September through December) with the timing of temperature and DO conditions downstream of the weir, there is evidence that adult fall-run Chinook salmon migration to the Stanislaus River could be delayed or blocked completely during key time periods in the migration window, either in the lower San Joaquin River mainstem or the lower Stanislaus River, in most years (Figure 12).







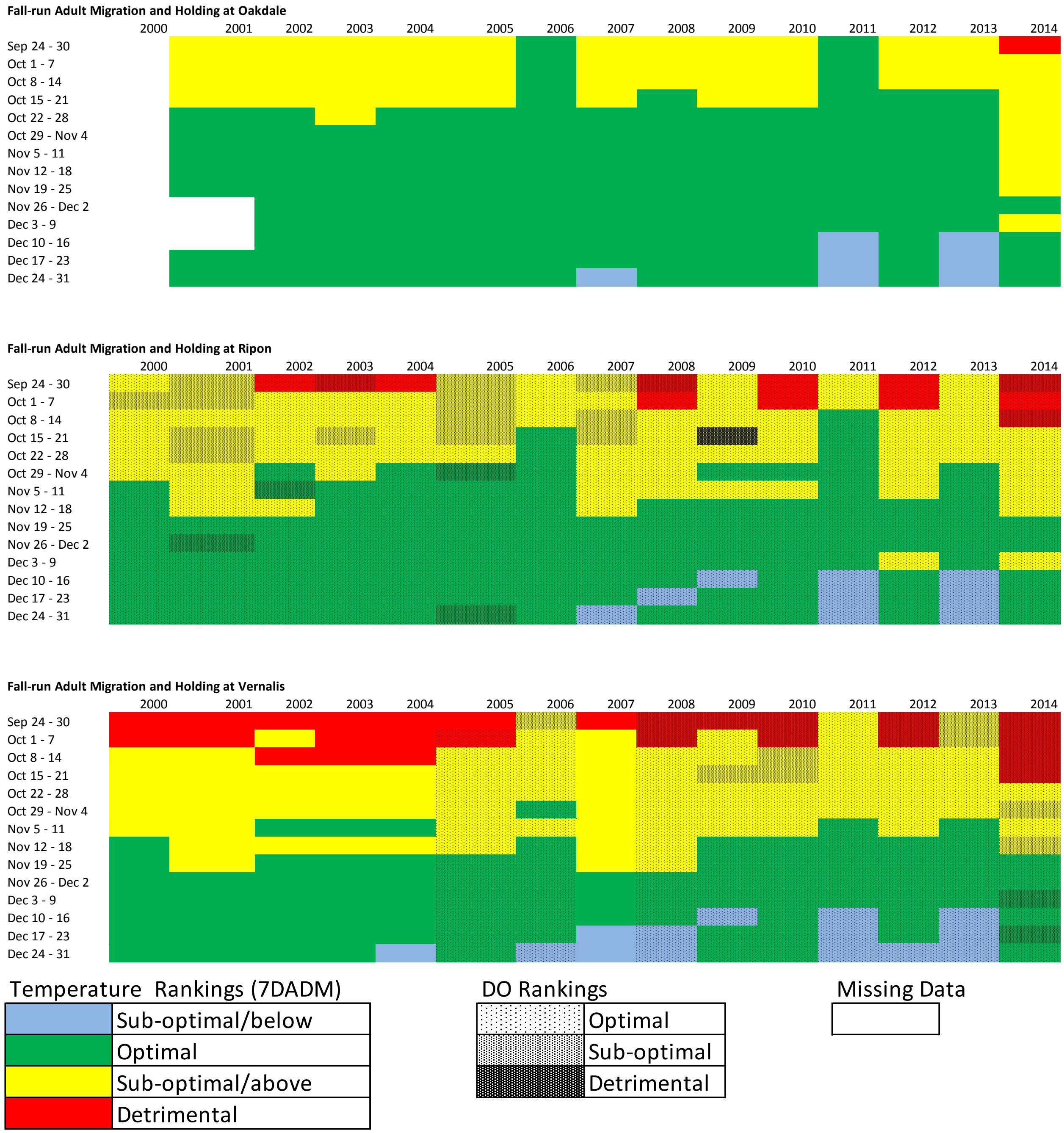


Figure 12

Fall-run Chinook Salmon Adult Migration and Holding

Notes:
Temperature and DO rankings based on observed data during periods of adult migration and holding. Time periods with rankings of sub-optimal or detrimental provide evidence for the potential for barriers to migration and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from the California Data Exchange Center for each location.

High temperatures and low DO likely block salmon migration at levels that are recorded in most years in the lower San Joaquin and lower Stanislaus rivers (see Environmental Objectives for Adult Migration, Section 7.2.1) during the first few weeks of the fall-run Chinook salmon migration (late September and early October). Furthermore, fall-run Chinook salmon migration into the Stanislaus River corresponds with the onset of scheduled pulse flows (Figure 11), and these pulses typically occur in the second or third week of October, several weeks after the fall-run migration is expected to begin. Prior to the onset of flows that may cue fall-run Chinook migration, any adult fish waiting to begin migration in the Delta or lower San Joaquin River would be exposed to poor water quality conditions that may be associated with mortality or straying. Scored collectively, these factors probably have a sustained minor population-level effect (or "medium" magnitude) on adult salmon attempting to reach the Stanislaus River. The certainty of this stress is minimal because there is "medium" to "high" understanding of the relationship across multiple factors (DO and temperature) on this stress, but the predictability is "low." Some individuals can and do complete their migration despite very poor conditions in the migratory corridor, and the timing of adult migration is related to the timing of return from the ocean, which is uncertain and not well monitored. Negative consequences of low DO and high temperatures may be reinforced by the direct effect of toxins on migration success. Generally, toxin concentrations are not high enough to cause complete migration failure for prolonged periods (Hoogeweg et al. 2011); however, the interaction of multiple toxins with high temperatures and low DO levels leads to minimal certainty of the magnitude score (i.e., the magnitude of the effect of toxins on migration success may be higher than expected).

8.2.2.2 Spring-run Chinook Salmon

Failure of Stanislaus-bound spring-run Chinook salmon to reach the Stanislaus River in the near term was scored as a "medium" magnitude stress with a minimal degree of certainty in the near term (Table 53). As described for fall-run Chinook salmon, certainty regarding this stress is "minimal" because the magnitude is related to the temporal distribution of salmon returns from the ocean (i.e., the stock of adult migrants available to begin river migration at any point in time), a factor that is not well monitored.

Without corrective action, failure of Stanislaus-bound spring-run Chinook salmon to reach the Stanislaus River is expected to be a high magnitude stress over the long term (Table 53). Temperatures are expected to increase in the future and will exacerbate low DO conditions in the lower San Joaquin River and Delta. These conditions will increase the stress caused by lack of attraction pulse flows later in the migration window or pulses of limited size and duration. The projected deterioration of migration conditions, combined with an increase in density (and temporal distribution) of migrating spring-run adults, will increase the certainty of this stress to a low level in the long term. Magnitude will still depend on temporal distribution of returning migrants, but, unless corrected, the period of inhospitable migration conditions is expected to become so large that the certainty of the impact is increased. As with fall-run Chinook salmon, increased monitoring of spring-run adult migrants upstream and in the lower part of the watershed would increase the certainty of this stress.

Table 53

Adult Migration (Spring-run Chinook Salmon) Stressor Scores

Stress	NT		LT		Where	When	Stressors											
							Temperature		DO		Toxins		Fishing and Poaching		Passable Physical Barriers (incl. low water levels and SAV)		Attraction Flows	
	M	C	M	C			NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT
Failure to Reach Holding or Spawning Habitat in the Natal Stream (Stanislaus) due to Direct Action of Stressors (e.g., mortality, straying, and extreme delays)	2	1	3	2	Ripon and downstream to Stockton DWSC	Late September through early October	M: 2 C: 1	M: 3 C: 2	M: 2 C: 1	M: 3 C: 2	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1			M: 2 C: 1	M: 3 C: 2
Indirect Mortality (e.g., disease outbreaks) and Sub-lethal Negative Effects	3	2	4	2	Primarily Stockton DWSC to Ripon (temperatures remain high up to Orange Blossom Bridge in some years)	Most of March through June in most years	M: 3 C: 2	M: 4 C: 2	M: 3 C: 2	M: 3 C:2	M: 2 C: 1	M: 2 C: 1			M: 2 C: 1	M: 2 C: 1	M: 3 C: 2	M: 4 C: 2

Notes:

– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run adult migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.

M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.

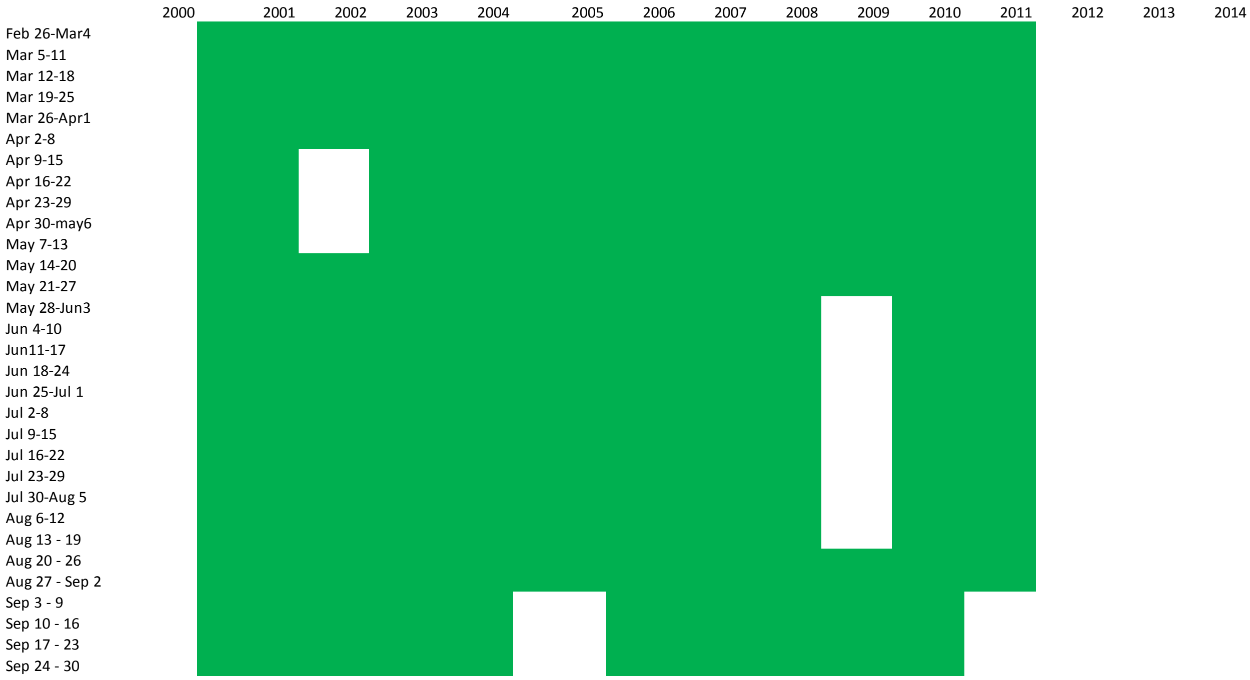
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.

– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.

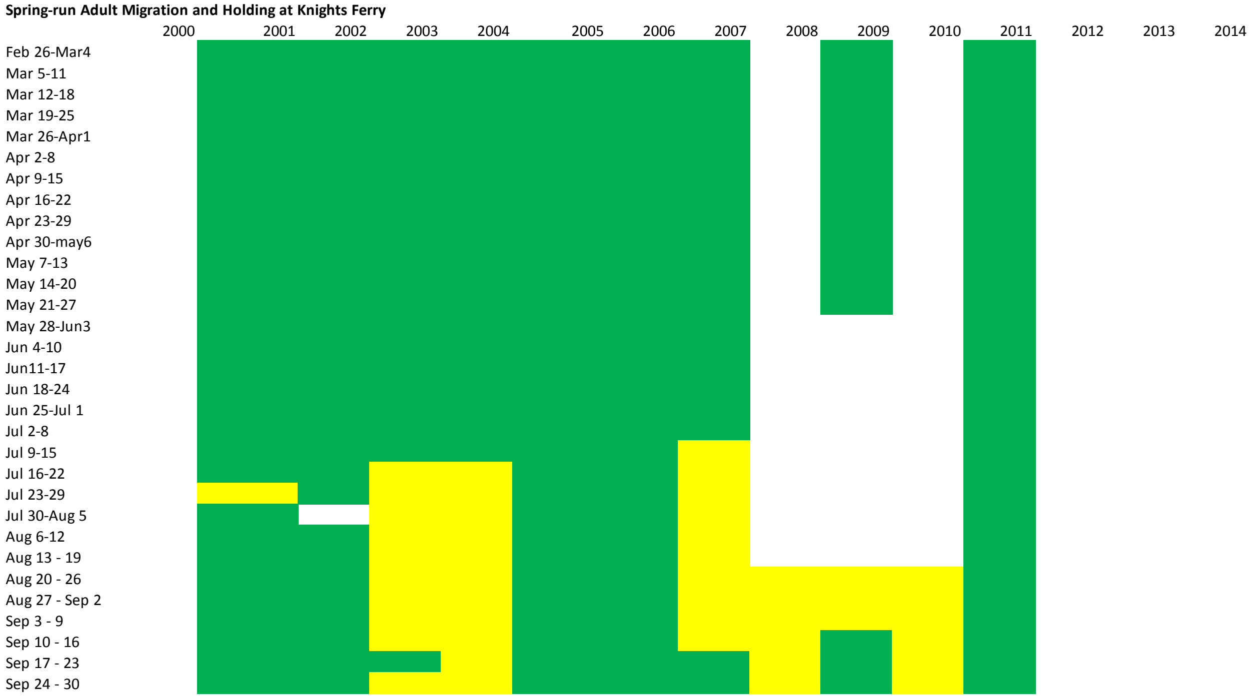
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT = near term

Unlike the fall-run, migration conditions become progressively worse during the spring-run Chinook salmon migration period—spring-run that delay migration are unlikely to find suitable conditions later in the migration season. Adult spring-run Chinook salmon exposed to a combination of high temperatures, low DO, and extremely low river flows are likely to experience significant delays that cause them to stray to other watersheds where better conditions prevail or die as they wait for suitable migration conditions to occur. The combination of factors that produce straying and/or mortality during migration are likely to affect a fraction of adult migrants in a recovering spring-run population in the near term. Based on the timing of temperature and DO conditions during the spring (Figure 13), it is likely that as the spring-run population grows in the near term, many adult spring-run Chinook salmon will experience conditions that can block their migration toward holding grounds in the Stanislaus River during part of their migration season. Temperatures that can block migration occur at Ripon and Vernalis after May in most years and earlier than May under drought conditions. Those DO conditions known to block Chinook salmon migrations (see Environmental Objectives for Adult Migration, Section 7.2.1) also occur frequently in the Stockton DWSC from June through the summer and at Vernalis starting in July. Finally, pulse flows that might attract adult spring-run occur in late April and May as part of water quality standards designed to improve survival of emigrating juvenile Chinook salmon; however, before and after these scheduled pulses occur, required base flows in the lower San Joaquin and Stanislaus rivers may be inadequate to promote adult migration. Straying or mortality resulting from temperature-related or DO-related migration blockages (or the interaction of these factors with contaminant concentrations) may be expected for the latter half of the migration period, but the certainty of this effect is minimal because of uncertainty regarding the timing pattern of spring-run entering the San Joaquin basin.

Spring-run Adult Migration and Holding below Goodwin Dam



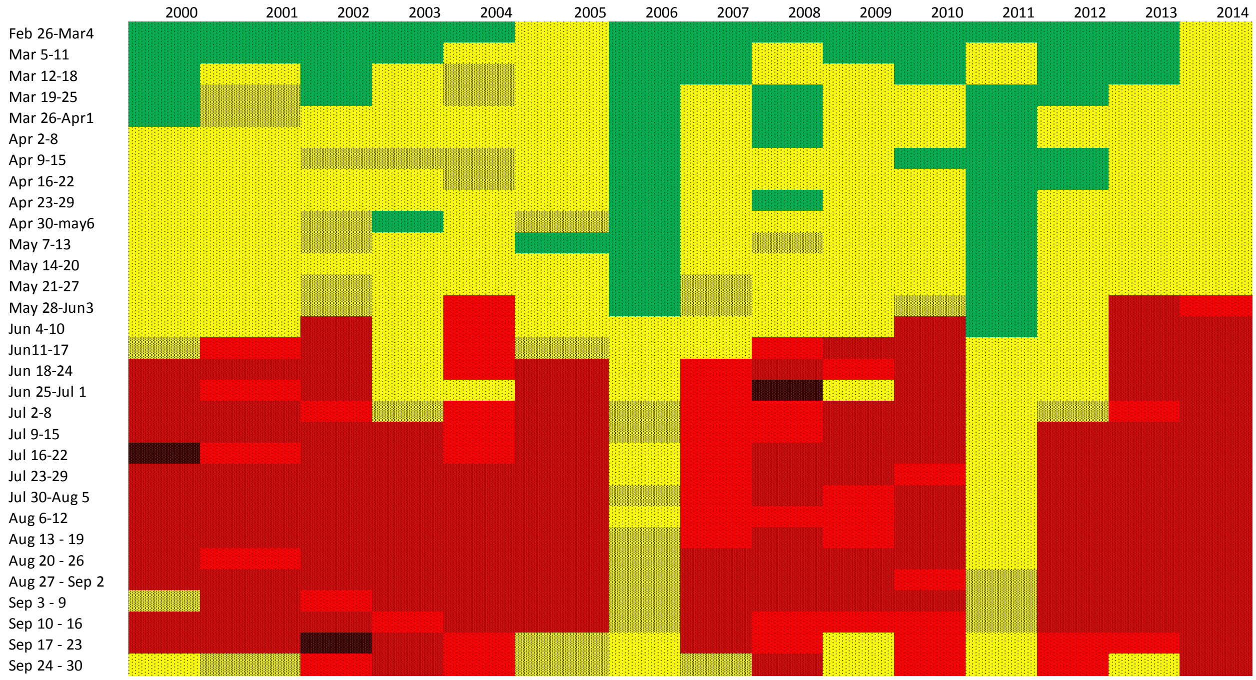
Spring-run Adult Migration and Holding at Knights Ferry



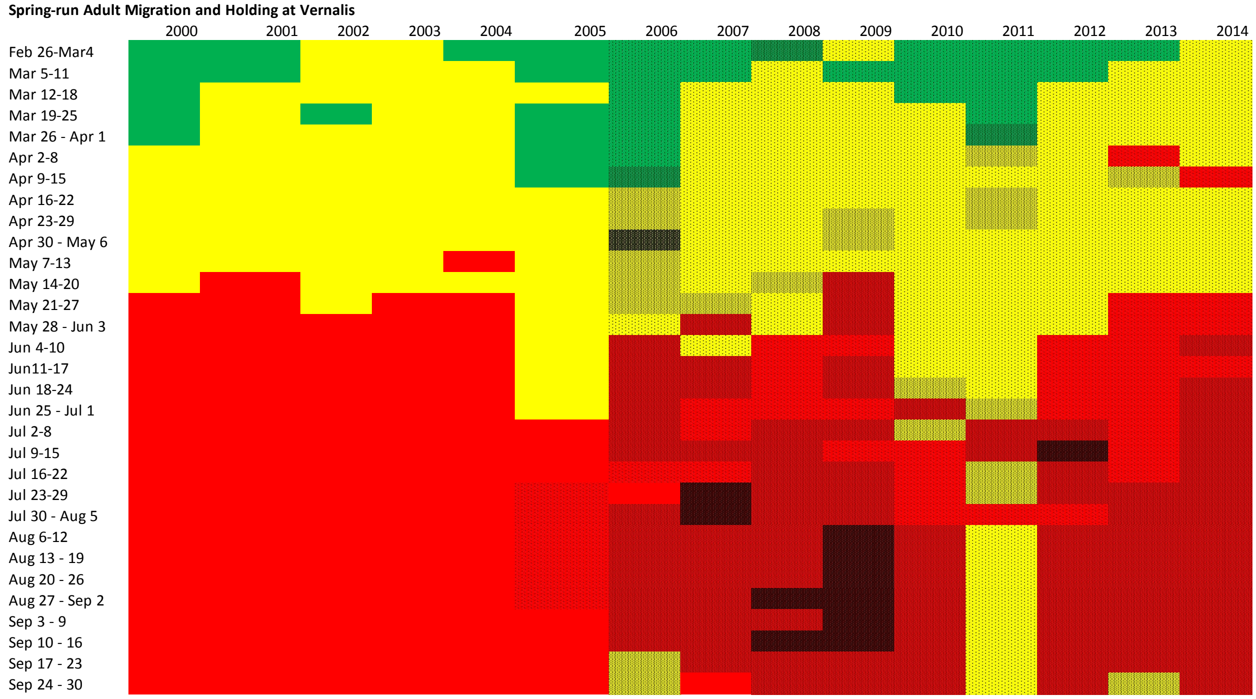
Spring-run Adult Migration and Holding at Orange Blossom Bridge

Spring-run Adult Migration and Holding at Oakdale

Spring-run Adult Migration and Holding at Ripon



Spring-run Adult Migration and Holding at Vernalis



Temperature Rankings (7DADM)	
	Sub-optimal/below
	Optimal
	Sub-optimal/above
	Detrimental

DO Rankings	
	Optimal
	Sub-optimal
	Detrimental

Missing Data

Figure 13

Spring-run Chinook Salmon Adult Migration and Holding

Notes:
Temperature and DO rankings are based on observed data during periods of adult migration and holding. Time periods with rankings of sub-optimal or detrimental provide evidence for the potential for barriers to migration and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from the California Data Exchange Center for each location.

Temperature increases expected in the long term will likely increase the magnitude of direct effects on spring-run migration as a larger fraction of the population experiences inhospitable migration conditions. High temperatures in the long term will also tend to reduce DO levels experienced by adult Chinook salmon migrating into the lower San Joaquin and Stanislaus rivers, especially because current regulations allow for lower DO levels in the Stockton DWSC during the spring than during the fall-run Chinook salmon migration season (CVRWQCB 2015a). Furthermore, pulse flows intended to help transport juvenile Chinook salmon are currently scheduled from mid April to mid May, but the timing of these pulse flows may strand a significant fraction of upmigrating adult spring-run Chinook salmon (i.e., those that return later in the season) in the Delta and lower San Joaquin River. As a result, direct impacts to spring-run Chinook salmon migration success in the long term are expected to increase to a sustained major population-level effect. The certainty of this effect in the long term increases to "low" because the duration of conditions that block upstream migration is expected to cover a larger portion of the migration window. Again, certainty could be improved with additional monitoring of spring-run Chinook salmon adult migrants.

8.2.2.3 Steelhead

Stressful conditions that would cause failure of steelhead migration to spawning grounds on the Stanislaus River are expected to generate low level stress with a minimal degree of certainty in the near term (Table 54). Stressful conditions that could result in migration failure occur early and late in the migration season in most years. Certainty of direct effects on migration success is "minimal" for the reasons described for Chinook salmon; also, migration timing of steelhead may be more plastic than it is for Chinook salmon (i.e., some steelhead that experience poor migration conditions may be able to wait for improved migration conditions to arise).

Without corrective action, factors that would drive blockage of migrating steelhead are likely to remain a “low” magnitude stress (Table 54) in the long term. Without additional monitoring, certainty will remain minimal, meaning the magnitude of the stress could be higher or lower than estimated here.

Table 54

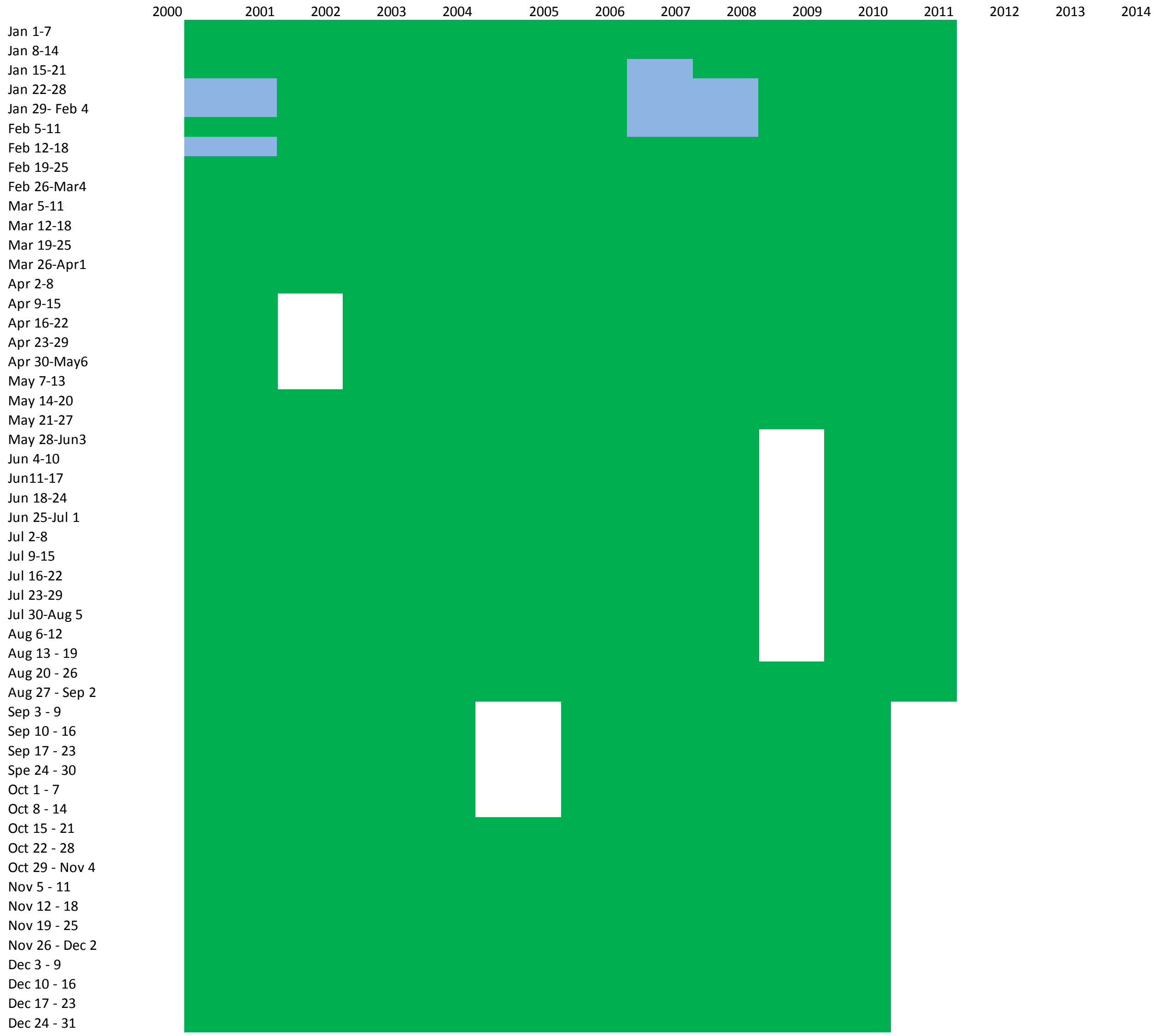
Adult Migration (Steelhead) Stressor Scores

Stress	Near Term		Long Term		Where	When	Stressors											
							Temperature		DO		Toxins		Fishing and Poaching		Passable Physical Barriers (incl. low water levels and SAV)		Attraction Flows	
	M	C	M	C			Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term
Failure to Reach Holding or Spawning Habitat in the Natal Stream (Stanislaus) due to Direct Action of Stressors (e.g., mortality, straying, and extreme delays)	2	1	2	1	Primarily Stockton to Ripon; toxins may be a problem up to Orange Blossom Bridge	September through mid October	M: 2 C: 1	M: 2 C: 1	M: 2 C: 1	M: 2 C: 1	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1			M: 2 C: 1	M: 2 C: 1
Indirect Mortality (e.g., disease outbreaks) and Sub-lethal Negative Effects	3	1	3	1	Primarily Stockton DWSC to Ripon (temperatures remain high up to Orange Blossom Bridge in some years)	September through mid October (temperature and DO) and March through April (temperature and toxins)	M: 3 C: 1	M: 3 C: 1	M: 2 C: 1	M: 2 C: 1	M: 3 C: 1	M: 3 C: 1			M: 1 C: 3	M: 1 C: 3	M: 3 C: 1	M: 3 C: 1

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for steelhead adult migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal

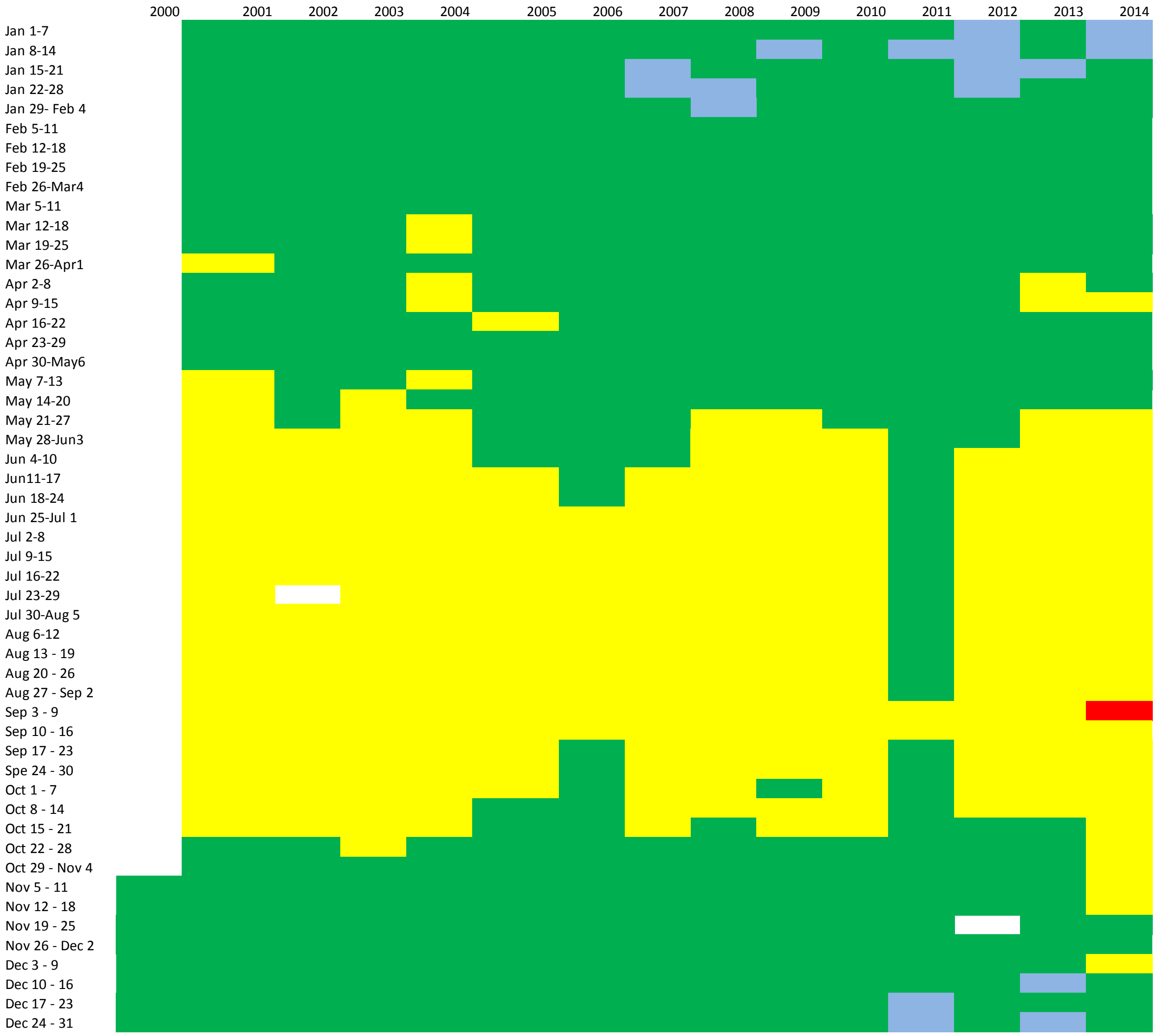
The steelhead adult migration period is longer than that for spring-run or fall-run Chinook salmon (Figure 7). Temperatures that would block migrating adult steelhead occur during the early part of this migration window at Vernalis and occasionally at Ripon (Figure 14). Steelhead may occasionally be blocked by low DO at Vernalis and the Stockton DWSC early in the migration season. Toxins do not reach concentrations that would be expected to completely block steelhead migrations for a protracted period (Hoogeweg et al. 2011; see Appendix B). However, concentrations may be lethal or cause complete migration blockage sporadically from March through May in the lower San Joaquin and infrequently in the lower Stanislaus River (between Ripon and Orange Blossom Bridge) during April and May. The frequency of such events and uncertainty regarding the temporal distribution of adult steelhead migrations and interaction of toxins with high temperature and/or low DO conditions leads to "minimal" certainty regarding the effect of toxins on this stress.

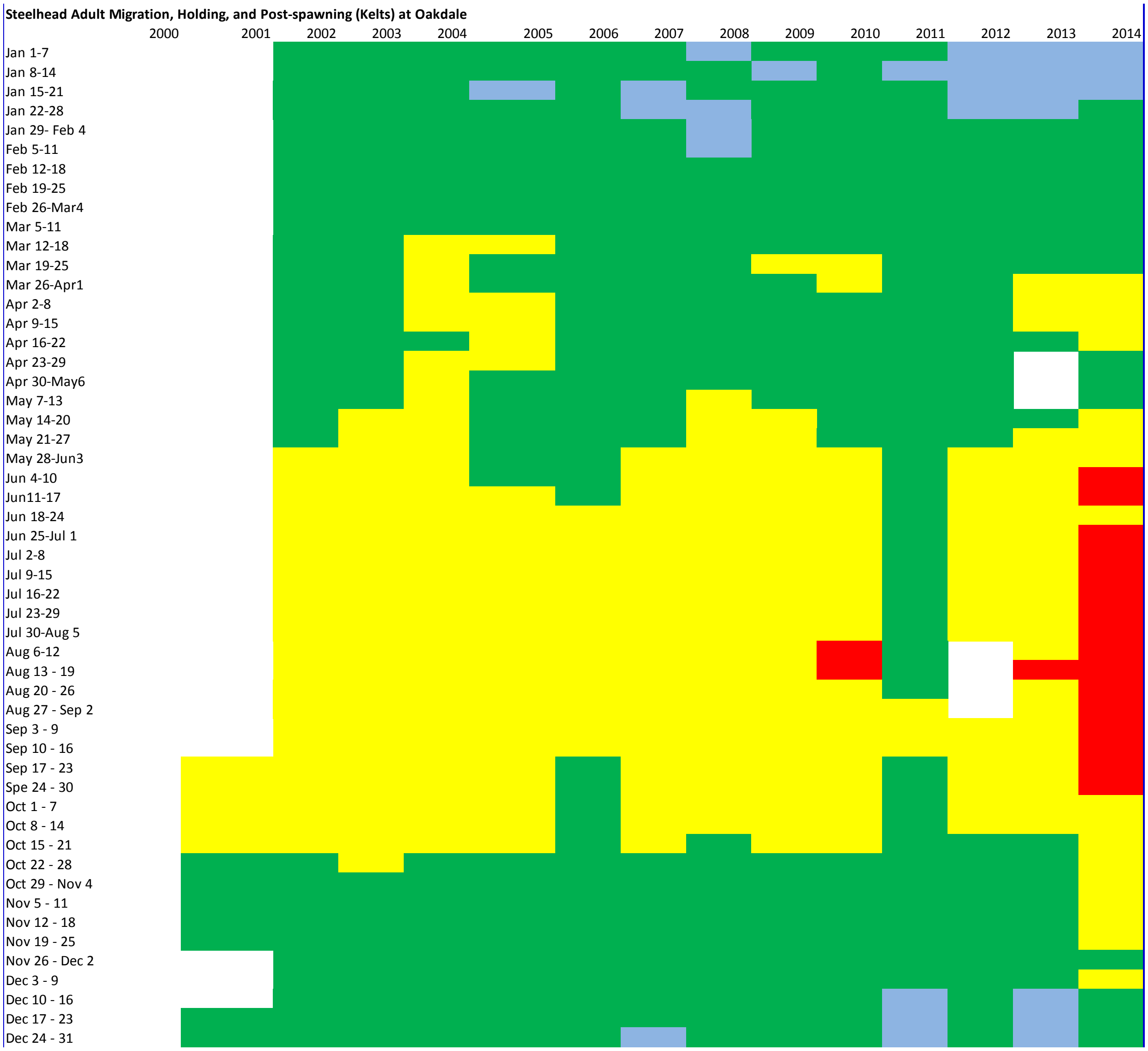
Steelhead Adult Migration, Holding, and Post-spawning (Kelts) at Goodwin Dam

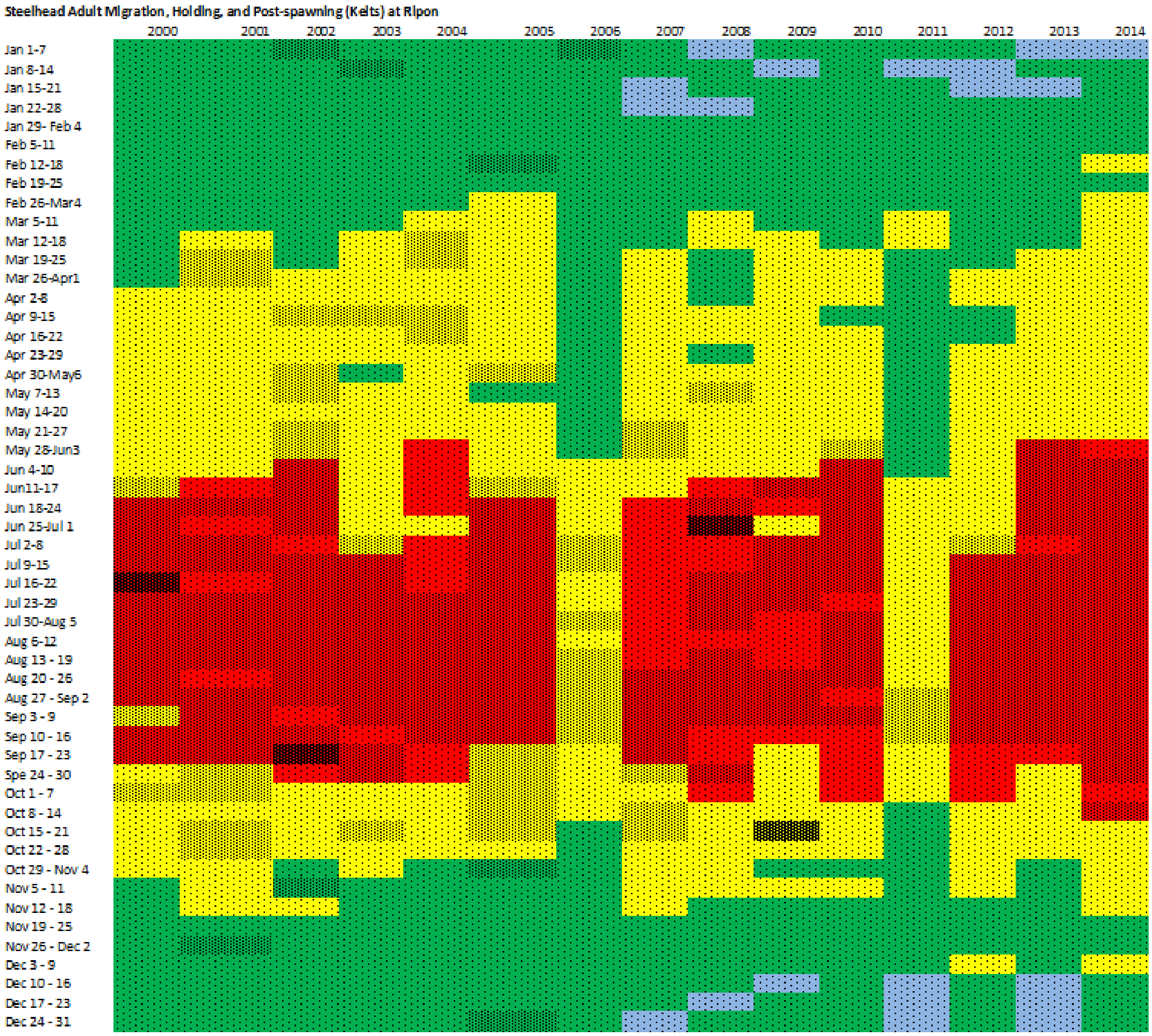


Steelhead Adult Migration, Holding, and Post-spawning (Kelts) at Knights Ferry

Steelhead Adult Migration, Holding, and Post-spawning (Kelts) at Orange Blossom Bridge




Steelhead Adult Migration, Holding, and Post-spawning (Kelts) at Oakdale
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31


Steelhead Adult Migration, Holding, and Post-spawning (Kelts) at Ripon
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31

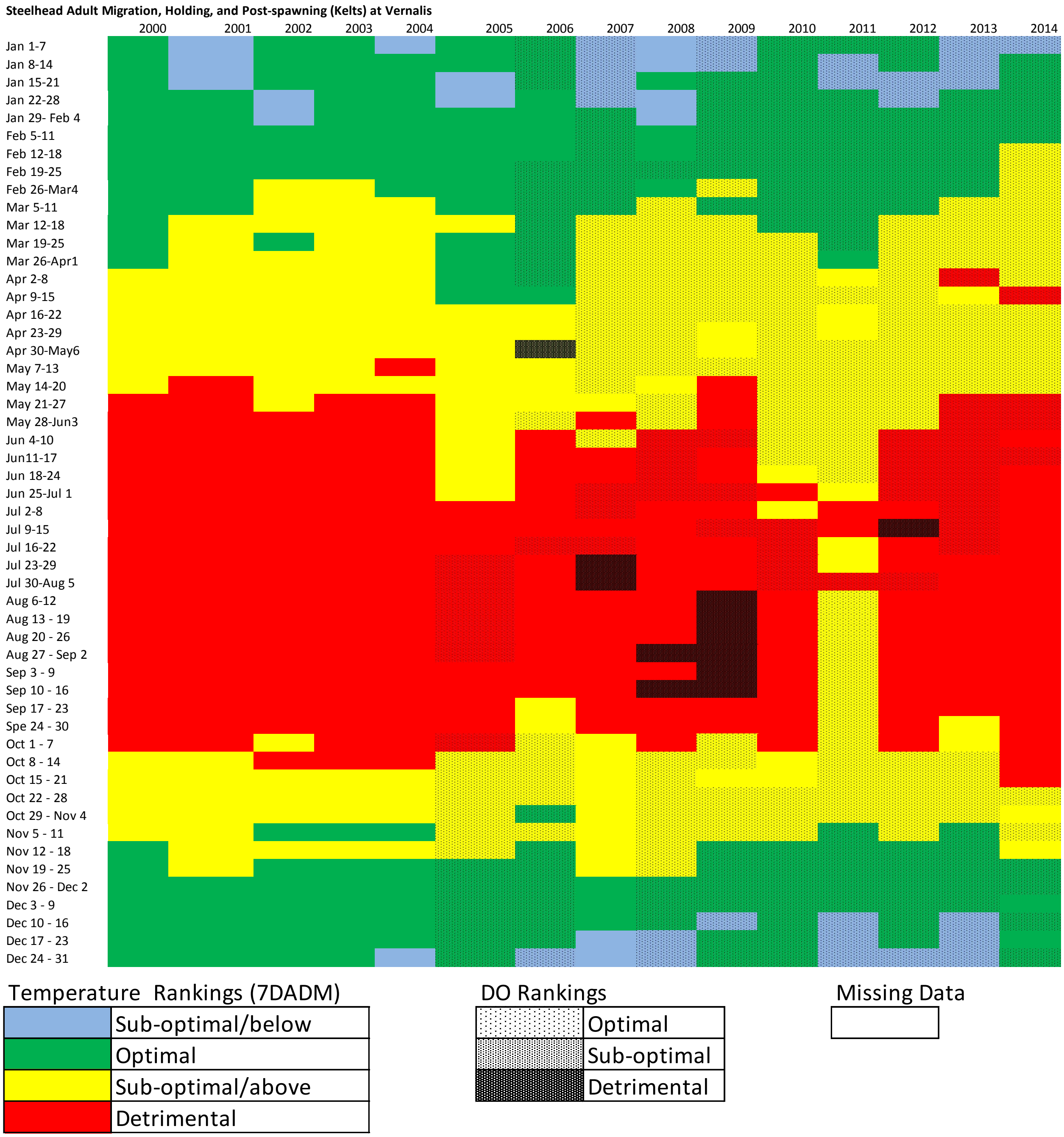


Figure 14

Steelhead Adult Migration, Holding, and Post-spawning (Kelts)

Notes:
Temperature and DO rankings are based on observed data during periods of adult migration and holding. Time periods with rankings of sub-optimal or detrimental provide evidence for the potential for barriers to migration and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from the California Data Exchange Center for each location.

8.2.3 Stress: Indirect Mortality (e.g., Disease Outbreaks) and Sub-lethal Negative Effects (Adult Migration)

Salmon and steelhead may suffer indirect lethal or sub-lethal negative effects following exposure to sub-optimal or detrimental environmental conditions during migration. These effects include death due to disease or lack of energy reserves, either as fish migrate or in subsequent life history stages (indirect mortality), and reduced fertility (negative sub-lethal effects). Disease outbreaks are very rare in the Stanislaus River currently (Wikert 2014, pers. comm.) but may not be detected if they occur below the salmon counting weir on the Stanislaus River. In addition, disease outbreaks and agonistic interactions with other salmon are more likely when density of migrating adults is high; high densities among adult migrants have not occurred frequently in the recent past but would be expected to occur more frequently under restoration in the near term and especially in the long term. Reduction in gamete viability (if any) is unmeasured currently; however, productivity of returning spawners as measured by fry production at Oakdale is very low in many years (Appendix A), suggesting that adult fecundity or egg viability may be compromised during adult migration.

8.2.3.1 Fall-run Chinook Salmon

Reduced spawning success of fall-run Chinook salmon as an indirect lethal or sub-lethal result of poor environmental conditions during adult migration was scored as a “medium” magnitude stress with a “medium” degree of certainty in the near term (Table 52). Magnitude is “medium” because multiple factors contribute to this stress, each stressor is expected to exacerbate the others (i.e., synergies exist among high temperature, low DO, and high contaminant loads), and most of the migration season is characterized by sub-optimal or detrimental conditions for these variables. Certainty of sub-lethal effects is “medium” because the degree and duration of adverse conditions to which fish are exposed are well understood and the effect of that exposure (e.g., quantification of the response to stressful conditions) is moderately well documented (see Environmental Objectives for Adult Migration, Section 7.2.1) and predictable.

Without corrective action, reduced success of Stanislaus-bound fall-run Chinook salmon as an indirect or sub-lethal result of poor environmental conditions during adult migration is expected to become a high magnitude stress over the long term because temperatures and density of migrating salmon are expected to increase, and both would contribute to increased magnitude of stress (Table 52). Certainty of this stress will remain "medium" in the long term; certainty is not expected to decline because temperature increases in the San Joaquin watershed and increasing density of fishes will tend to exacerbate stress that already exists.

Cumulatively, numerous conditions experienced by a large fraction of migrating adult fall-run Chinook salmon are consistent with those known to result in indirect mortality and/or sub-lethal effects, such as reduced fecundity. Thus, a sustained minor population-level impact to productivity is expected with "medium" certainty. Fall-run Chinook salmon migrating towards or through the Stanislaus River currently experience multiple sub-optimal or detrimental conditions during most of their migration period (Table 52). Arrival of adults in the Stanislaus River closely corresponds to the schedule of fall pulse flows (Figure 13), and these flows currently occur in the second or third week of October. Adults that arrive in the Delta or lower San Joaquin River prior to the onset of pulse flows are exposed to inhospitable conditions. Sub-optimal DO conditions persist in the Stockton DWSC through mid October in most years into early October at Vernalis and as far upstream as Ripon (Figure 12). In addition, at least half of the migrating population is currently exposed to sub-optimal temperatures in almost every year at Vernalis and in most years at Ripon (Figure 13; Figure 12). Sub-optimal temperatures persist into mid October in most years as far upstream as Orange Blossom Bridge. Exposure to toxins during the upstream migration may also cause migration delays, energetic expense, and exacerbate susceptibility to pathogens and poor water quality conditions. Passable barriers, including low water levels and dense pockets of submerged aquatic vegetation, may increase the drain on energy reserves required to complete migration—both are responses to highly variable ecosystem processes or other external factors, so the certainty of their impacts is minimal. Increased study of the viability of eggs produced by female Chinook salmon that migrate into the Stanislaus River is called for in the SEP Biological Objectives pertaining to egg viability (Section 6.2.5.4.2).

In the future, water temperatures during the fall migration season are expected to increase in response to regional warming patterns. This will increase the magnitude of the temperature and DO stressors and their synergistic effect on the toxin stressor. If these conditions occur in the long term, and pulse flows are not scheduled in a way that leads to earlier migration through the lower San Joaquin River corridor, then the magnitude of this stress is expected to become high (i.e., a sustained major population-level effect). Certainty will remain "medium"—improved monitoring of the temporal pattern of adult salmon migration and study of indirect mortality and sub-lethal negative effects would increase the certainty surrounding this stress and could change the magnitude score as well.

8.2.3.2 Spring-run Chinook Salmon

Reduced spawning success of spring-run Chinook salmon as an indirect lethal result of poor environmental conditions during adult migration was scored as a "medium" magnitude stress with a "low" degree of certainty in the near term (Table 53). Unlike the fall-run, the sub-lethal negative effects of damage to developing gametes was not included in the stress experienced by up-migrating spring-run Chinook salmon adults because these fish are expected to develop gametes during their holding period, not during adult migration. Reduced energetic reserves needed to produce gametes (during the holding period) is a sub-lethal negative effect on spring-run Chinook salmon. Certainty is low because although there is high understanding of the extent of adverse conditions, predictability of the effect of those conditions is low for the most important indirect lethal outcomes (disease outbreaks) for spring-run resulting from this stress. Disease outbreaks are affected by the density of migrating fish, which may vary within and among years. Similarly, the negative sub-lethal effect of stress on the energy reserves holding salmon need in order to produce gametes is uncertain because it relies, in part, on the duration of the holding period and the energetic status of fish returning from the ocean.

Without corrective action, indirect mortality and/or reduced fecundity of Stanislaus-bound spring-run Chinook as a result of poor environmental conditions during adult migration will become a high magnitude stress over the long term (Table 53). Two of the main environmental conditions that cause the stress (temperature and density of returning migrants) are expected to increase in the future; this increases the potential frequency and extent of disease outbreaks and/or reduced fecundity due to energetic stress on this run. Certainty of this stress will remain low in the long term for the same reasons it is low in the near term.

Adult spring-run salmon migrating during the late winter and spring are exposed to multiple stressors, each of which exacerbates the others (i.e., synergies exist among high temperature, low DO, and high contaminant loads), and most of the migration season is characterized by sub-optimal or detrimental conditions for these variables. Taken together, multiple stressors during the spring-run migration period are likely to have minor population-level effects in the short term and sustained minor and/or periodic major population effects in the long term. Both indirect lethal and sub-lethal effects will be responsive to variability in ecosystem conditions, particularly the density, timing, and condition of spring-run adults returning from the ocean. Sub-optimal DO conditions prevail in the Stockton DWSC through most of the migration window, although optimal DO conditions occur most of the time at Vernalis and upstream. Temperatures are sub-optimal or detrimental through most of the migration window in most years as far upstream as Ripon (Figure 13). Furthermore, spring-run Chinook migrants are exposed to multiple contaminant stressors in the lower San Joaquin River up to Ripon on the Stanislaus River; USGS monitoring of the San Joaquin River at Vernalis detected a minimum of six (and up to 14) pesticides in each sample (Orlando et al. 2014). Monitoring data coincide with model results, indicating high frequency of benchmark exceedances that could lead to indirect mortality during migration or in later life stages.

In the long term, increasing density of adult spring-run migrants combined with expected increases in water temperature (and corresponding declines in DO and the effect of toxins) lead to an increase in the potential magnitude of sub-lethal and indirect lethal effects during adult migration (or during holding as a result of conditions experienced while migrating); the current timing of spring-pulse flows will not alleviate these impacts on adult migrants that arrive early (March) or later in the migration window (late May though June). Long-term certainty of such impacts is "low." In both the near term and the long term, increased monitoring and studies of migrating and holding adult spring-run Chinook salmon would increase certainty regarding this stress.

8.2.3.3 Steelhead

Reduced spawning success of steelhead as an indirect or sub-lethal result of poor environmental conditions during adult migration was scored as a "medium" magnitude stress with minimal certainty in the near term (Table 54). Magnitude is “medium” because, although only a small fraction of the migration season is characterized by sub-optimal or detrimental conditions for temperature and DO, contaminant loads may be harmful early and late in the migration season. Certainty is minimal because the temporal distribution of adult steelhead migrations (and its overlap with impaired migration conditions) is not well documented.

Unless corrective actions are taken, the indirect effects of poor environmental conditions on migrating steelhead adults will remain “medium” in the long term. Certainty will remain minimal (Table 54).

Periodically high temperatures, low DO levels, and episodic high toxic loads downstream of the Stanislaus-San Joaquin confluence during the early fall steelhead migration period (late September) and downstream of Ripon during the spring migration period indicate that a “medium” magnitude negative effect on steelhead productivity may result from poor environmental conditions during upstream migration. The current timing and frequency of managed pulse flows to attract adult steelhead to the Stanislaus River do not cover most of the steelhead migration season; low flows that persist in the absence of short-term, scheduled pulse flows are not adequate to ensure optimal migration of adult steelhead to their holding and spawning habitats. The certainty surrounding this stress is minimal because the SEP Group’s understanding of the precise response of migrating steelhead to poor environmental conditions is limited, the temporal distribution of adult migrants is virtually unknown, and some of the negative outcomes are sensitive to environmental conditions such as the density of migrating adults. Migrating steelhead adults would experience poor DO conditions in many years through the first several weeks of their migration season as far upstream as Ripon. Temperatures are generally sub-optimal through mid November and March through April at Vernalis and through mid October at Ripon. Toxic contaminants are elevated during September and March through May downstream of Ripon and in March through May in the lower San Joaquin downstream of its confluence with the Stanislaus River (Hoogeweg et al. 2011; Appendix C); migrants may also be exposed to a high frequency of pesticide exposures, which may significantly impair successful migration. Steelhead are unlikely to be impaired to a great extent by low water levels or dense patches of invasive vegetation. Increased study of migrating steelhead in the Stanislaus River—including their temporal and spatial distribution in the river, survival prior to spawning, and the viability of their eggs—would increase the certainty surrounding the magnitude of this stress.

8.2.4 Stress: Limited Early Access to River (Relative to Migration Window) due to Impassable or Unsuitable Conditions (Adult Migration)

Biological Objectives include time windows in which target populations are expected to be able to complete each of their freshwater life stages. These time windows represent the potential for salmonids to express the diverse life history strategies that:

- Enhance population stability in the face of adverse conditions (in freshwater or marine environments), and
- Promote population resilience when suitable environmental conditions return.

Failure to provide environmental conditions that allow for expression of the full range of life history diversity in each life stage may also have the effect of limiting the portfolio of life history strategies that emerge in subsequent life history stages. For example, constraints on the adult migration window can exacerbate limited diversity in the timing of spawning and incubation and, in turn, the size and temporal distribution of outmigrating juvenile salmonids. Recent research demonstrates a limited portfolio of life histories among fall-run Chinook salmon emigrating from the Stanislaus River, including relatively low proportions of smolt-sized migrants (Zeug et al. 2014; Sturrock et al. 2015). Limited access of fall-run Chinook salmon to their Stanislaus River spawning grounds affects the expression of different adult life history strategies and the potential timing, diversity, and success of subsequent life stages. This stress is scored only for fall-run Chinook salmon. Delayed migration among spring-run Chinook salmon has little effect on subsequent spawning timing because there is a holding period between migration and spawning and is most likely to result in mortality or straying because migration conditions become worse as the spring-run adult season progresses, and is thus captured under the heading "failure to reach holding or spawning habitat in the natal stream due to direct action of stressors" see Section 8.2.2.2). Delayed migration is not considered as a stress for steelhead.

8.2.4.1 Fall-run Chinook Salmon

In the near term, asymmetrical access to the spawning grounds for adult fall-run Chinook salmon as a result of delayed migration is a "medium" magnitude stress. Certainty surrounding this effect is "low" (Table 52).

Without corrective action, in the long term, late access to the spawning grounds will remain a "medium" magnitude stress, and certainty will remain "low" because better documentation is needed for the relationship between delayed migration and loss of diversity in adult migration phenotypes (i.e., selection) and effects in subsequent life history stages (Table 52).

Delayed migration of fall-run Chinook salmon can be attributed to high temperatures and low DO levels in their migration corridor (Figure 12), particularly in the lower San Joaquin River. In addition, the timing of fall attraction flows leads to a peak migration that occurs in mid to late October (Figure 13). Salmon that arrive prior to the pulse flow are likely to experience deleterious conditions and expend additional energy reaching the spawning grounds; thus, these fish are most likely to experience reduced fecundity or pre-spawning mortality. Truncation of the migration period for fall-run fish is likely to select against early migrating phenotypes; this can reduce population diversity, resilience, and viability even if there is no genetic basis for the phenotypes. In addition, late migration may result in a truncated spawning period and subsequent constriction of diversity in subsequent life history strategies (e.g., timing of emigration and size of juveniles). All of these potential effects suggest the need for additional research on the population-level effects of, and potential to alleviate, persistent delays in migration of adult fall-run Chinook salmon.

8.2.5 Contributing Management Factors

The environmental factors that drive the failure to reach holding or spawning habitats are coupled and work synergistically. For example, temperature affects both DO concentration and fish demand for DO, and it modulates the impact of certain contaminants on migrating adult salmon. Similarly, residence time, nutrient concentration, and temperature all impact the degree of nutrient-related stressors (e.g., macrophyte density or low DO) in the river. Finally, flow rates also play a role in regulating water temperature, residence time, and contaminant/nutrient concentrations in the river.

Reservoir operations, including releases and cold-water pool management, exert significant influence over these stressors. Reservoir cold-water pool levels and release rates determine, in part, temperatures along the river corridor from late spring through early fall. The timing and duration of attraction flows determine the extent to which adult salmonids are exposed to inhospitable water quality conditions in the lower San Joaquin River and Delta. In all but the wettest years (when uncontrolled runoff and flood prevention procedures lead to higher flows), reservoir releases determine the timing, duration, and magnitude of attraction flows for migrating adult salmonids in both fall and spring. Spring pulse flows in the Stanislaus and San Joaquin rivers are required by the WQC Plan (D-1641) in order to move juvenile Chinook salmon downstream—these flows may also provide migration cues to upmigrating adult spring-run Chinook salmon. However, the pulse flows are only scheduled to occur between late April and early May; adult fish migrating later in the migration period will generally experience base flows that are only a tiny fraction of the San Joaquin basin's unimpaired runoff (TBI 2014, unpublished data). It should also be noted that pulse flow and base flow standards are frequently weakened during consecutive dry or critically dry years (e.g., 2015 and 2016) below the reduced levels required in years with dry or critically dry hydrology. Such reductions affect both outmigrant juvenile fall-run and spring-run Chinook salmon and adult spring-run Chinook salmon attempting to migrate into the San Joaquin and Stanislaus rivers. Modification of flows in the lower San Joaquin River and Stanislaus River are necessary to achieve adequate migration opportunities distributed throughout the fall-run migration time window.

Non-flow management practices may exacerbate or alleviate stressors on adult migration. For example, the destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor; this can increase temperatures and primary productivity in the river. Groundwater depletions have likely reduced the hyporheic inputs that probably buffered the Stanislaus River against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the river during critical months. Urban and agricultural developments in the watershed have increased contaminant loads to the river; adjustments to land use practices or the development of contaminant control programs may reduce contaminant loads and the stress they generate for migrating adult salmonids. Finally, the design and operation of the Stockton DWSC coupled with low flow and excessive BOD have exacerbated the low DO conditions and resulting migration stressors in the Delta (Gowdy and Grober 2005).

8.3 Stressors on Adult Holding

Adult holding occurs in the salmonid life cycle after immigration into freshwater, but before spawning. Fall-run Chinook salmon adults spend a relatively short period holding; the duration of their holding period is usually dependent on availability of water temperatures suitable for spawning, passage delays from physical barriers, and the presence of suitable mates. Spring-run Chinook adults hold over the summer months, generally without eating, awaiting water temperatures appropriate for spawning. *O. mykiss* adults may "hold" in the river throughout the year; however, unlike salmon, they are usually foraging and growing or recovering from spawning. Both spring-run Chinook and *O. mykiss* lack access to the high elevation habitats these populations used historically because passage to these habitats is now blocked by dams. Stressors on adult holding may result in direct mortality or injury, disease, and/or increased energy expenditure that can reduce fecundity. The degree of stress to the population associated with complete lack of access to high elevation habitat must be assessed in the context of the amount and quality of holding habitat still accessible.

The SEP Group evaluated two categories of stress in the near term and long term for adult salmonids holding into the Stanislaus River: lack of suitable holding habitat and loss of fecundity.

Stressors on the adult holding life stage (Tables 55 – 57) include the following:

- Water temperature;
- Loss of inputs to coarse sediment that drive macroinvertebrate production;
- Low DO;
- Unsuitable water velocity and depth;
- Lack of cover;
- Insufficient prey density;
- High predator density;
- Presence of contaminants;
- Disease; and

- Poaching.

Measuring any of these effects presents challenges. Direct mortality of holding adults may go unnoticed, especially as holding usually occurs in deeper pools, and detecting reduced gamete viability generally requires directed studies of incubation success (e.g., in a hatchery; see Section 6.2.5.4.2).

Near-term stresses reflect those that would impede attainment of Environmental or Biological Objectives under current conditions. Evaluation of these stresses in the long term incorporated analysis of current conditions and assumed that adult salmon densities would increase substantially and that global and regional warming trends occur as anticipated (Cayan et al. 2008; Dettinger et al. 2004).

8.3.1 Current Holding Timing Patterns

Scoring of stress is based on the potential exposure to stressors across the full range of each population's adult holding timing window (see Figure 7). Current temporal distribution of fall-run Chinook salmon adult holding in the Stanislaus River occurs throughout the adult migration and spawning periods from late September through December. Spring-run Chinook salmon holding is assumed to begin soon after migration begins (March) and end with spawning (late August through October in other Central Valley populations; Williams 2006). *O. mykiss* holding is assumed to occur year-round as both resident and anadromous forms occur within the watershed (Zimmerman et al. 2008). Zimmerman et al. (2008) also found resident *O. mykiss* with steelhead mothers.

8.3.2 Stress: Lack of Suitable Holding Habitat (Adult Holding)

Historically, spring-run Chinook salmon and *O. mykiss* would have utilized sections of the river that are now blocked by dams. The valley floor remains accessible to all runs of Chinook salmon and *O. mykiss*. Reservoir operations and land use changes have modified the instream water temperatures in the remaining accessible habitat.

8.3.2.1 Fall-run Chinook Salmon

In the near term, lack of suitable holding habitat for fall-run Chinook salmon in the Stanislaus River was scored as a "low" magnitude stress (Table 55) with a "medium" degree of certainty.

Without corrective action, lack of suitable holding habitat for fall-run Chinook salmon will increase to a "medium" magnitude stress (Table 55) over the long term, and certainty will remain "medium."

Table 55

Holding Stressors for Fall-run Chinook Salmon

Stress	Near Term		Long Term		Where	When	Stressors																			
							Temperature		DO		Velocity		Depth		Cover		Predator Density		Contaminants		Coarse Sediment Input		Disease		Poaching	
	M	C	M	C			Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term
Lack of suitable holding habitat	2	3	3	3	Whole river	September through October	M: 2 C: 3	M: 3 C: 3	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 1 C: 3	M: 1 C: 3	M: 2 C: 2	M: 3 C: 2	M: 1 C: 2	M: 2 C: 2
Loss of fecundity	2	2	3	2	Whole river	January through June	M: 2 C: 2	M: 3 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2					M: 2 C: 2	M: 2 C: 2						

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run adult holding in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal

The stressor that scored the highest for suitable holding habitat for adult fall-run Chinook salmon is water temperature. Temperatures are sub-optimal for holding at and downstream of Orange Blossom Bridge from the start of the fall-run Chinook salmon migration and holding period through mid October in most years (Figure 12). Temperatures are commonly in the optimal range for holding upstream of Knights Ferry, but sub-optimal temperatures have occurred even at this location (e.g., during September and early October of 2015; Wikert 2014, pers. comm.). Fall-run are expected to experience sub-optimal to detrimental contaminant conditions when holding between Orange Blossom Bridge and Riverbank and minor sub-optimal conditions when holding upstream of Orange Blossom Bridge. However, due to their short duration of holding and small proportion of population exposure, the magnitude of impact due to contaminants is expected to be “low.”

Other stressors ranked “low” or “minimal,” with the exception of disease, which is expected to increase in the long term to “medium” magnitude (Table 55) based on climate change models predicting warmer temperatures and higher concentration of adults after achieving population targets.

8.3.2.2 Spring-run Chinook Salmon

In the near term, lack of suitable holding habitat for spring-run Chinook salmon in the Stanislaus River was scored as a “medium” magnitude stress with a “high” degree of certainty (Table 56).

Without corrective action, lack of suitable holding habitat for spring-run Chinook salmon will increase to a “high” magnitude stress (Table 56) over the long term and certainty will remain “high.”

Table 56

Holding Stressors for Spring-run Chinook Salmon

Stress	NT		LT		Stressors																			
					Temperature		DO		Velocity		Depth		Cover		Predator Density		Contaminants		Coarse Sediment Input		Disease		Poaching	
	M	C	M	C	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT
Lack of suitable holding habitat	3	4	4	4	M: 3 C: 4	M: 4 C: 4	M: 1 C: 2	M: 2 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 3 C: 2	M: 2 C: 2	M: 2 C: 2	M: 1 C: 3	M: 1 C: 3	M: 2 C: 2	M: 3 C: 2	M: 1 C: 2	M: 2 C: 2
Loss of fecundity	3	2	3	2	M: 2 C: 2	M: 3 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2					M: 3 C: 2	M: 3 C: 2						

Notes:
– Location: upstream of Ripon
– When: March through September
– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run adult holding in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT = near term

Temperature is the main driver of this stress for spring-run Chinook salmon; holding habitat with suitable temperatures is currently constrained to the reach just downstream of Goodwin Dam in most years. Temperatures are sub-optimal for holding at and downstream of Orange Blossom Bridge from mid May through the end of the spring-run Chinook salmon holding period (September) in every year (Figure 13). Sub-optimal temperatures also occur frequently from July through September upstream at Knights Ferry, particularly during drought years (e.g., 2013 – 2015; Wikert 2014, pers. comm.). Unless corrective measures are taken, sub-optimal and detrimental temperatures may occur during the holding season throughout currently available habitat under prolonged drought sequences. Even though it is expected to be periodic, such impacts would present a severe constraint on attainment of objectives for the spring-run population in the long term. Spring-run are expected to experience sub-optimal contaminant conditions when holding from Orange Blossom Bridge to Knights Ferry; due to their long duration of exposure, it is expected that contaminants may contribute to spring-run mortality. Upstream of Knights Ferry, contaminants are not expected to be an issue for holding spring-run.

8.3.2.3 O. mykiss

In the near term, lack of suitable holding habitat for *O. mykiss* was scored as a "medium" magnitude stress with a "high" degree of certainty (Table 57).

Without corrective action, lack of suitable *O. mykiss* holding will become a "high" magnitude stress (Table 57) over the long term, and certainty will remain "high."

Table 57

Holding Stressors for *O. mykiss*

Stress	Near Term		Long Term		Where	When	Stressors																			
							Temperature		DO		Velocity		Depth		Cover		Prey Density		Predator Density		Contaminants		Coarse Sediment Input		Disease	
	M	C	M	C			Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Tern	Near Term	Long Term	Near Term	Long Term
Lack of suitable holding habitat	3	4	4	4	Whole River	January through December	M: 3 C: 4	M: 4 C: 4	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 3 C: 2	M: 3 C: 2	M: 3 C: 3	M: 3 C: 3	M: 2 C: 2	M: 2 C: 2

Notes:

– Stress and stressors (i.e., contributing factors to a particular stress) for *O. mykiss* adult holding in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.

– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.

– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.

– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.

Scoring:

4 = High

3 = Medium

2 = Low

1 = Minimal

Temperature and loss of coarse sediment input are the main drivers of this high-magnitude stress for *O. mykiss*. Temperatures were largely sub-optimal in nearly every year from June through September at Orange Blossom Bridge and sub-optimal during some weeks between July and September during most years at Knights Ferry (Figure 14). Without corrective action, lethal water temperatures that accompany extended droughts and low reservoir storage could potentially extirpate the entire population of steelhead and resident rainbow trout. This is of particular concern in the long term.

Since adult *O. mykiss* feed in freshwater (especially recovering kelts), functioning alluvial coarse sediment is necessary to provide macroinvertebrate habitat to sustain the food chain, especially in the 4 miles of the canyon reach just below Goodwin Dam. With little to no off-channel habitat available for fish or for food production, food must come from in-channel sources or move downstream from the reservoir above. *O. mykiss* holding conditions are expected to get worse in the long term based on the assumption of higher water temperatures and increased numbers of *O. mykiss* competing for available spots, but this stress is rated as maximum magnitude, including in the near term. As such, the scoring system used here does not capture the deterioration of conditions in the future, in the absence of restoration actions. Contaminants will likely contribute to some mortality of *O. mykiss* as well as reduce the availability of food.

8.3.3 Stress: Loss of Fecundity (Adult Holding)

Exposure to sub-optimal or detrimental environmental conditions while holding may result in lower egg viability, pre-spawn mortality, or partial-spawn mortality (some, eggs remain in the female after death). Reduction in gamete viability (if any) is unmeasured currently; however, productivity of returning spawners as measured by fry production at Oakdale is very low (Appendix A), suggesting that adult fecundity or egg viability may be compromised during adult migration or holding.

8.3.3.1 Fall-run Chinook Salmon

In the near term, reduced fecundity for fall-run Chinook salmon that experience poor environmental conditions during holding was scored as a "low" magnitude stress with a "medium" degree of certainty (Table 55).

Without corrective action, reduced fecundity will increase to a “medium” magnitude stress over the long term for fall-run, and certainty will remain “medium” (Table 55).

The SEP Group expects that this stress currently has a sustained effect limited to a small fraction of the fall-run Chinook salmon population as these fish exhibit minimal holding behavior. Holding among fall-run is thought to happen mostly while adults are either waiting for temperatures in the spawning reach to cool sufficiently or seeking a suitable spawning partner. The short duration of holding for fall-run will limit the impacts from exposures to contaminants. In the long term, higher temperatures predicted by climate models are likely to increase the magnitude of this stress.

8.3.3.2 Spring-run Chinook Salmon

In the near term, reduced fecundity for spring-run Chinook salmon as a result of conditions during the holding period is expected to be a “low” magnitude stress, but certainty is “low” as well (Table 56).

Without corrective action, reduced fecundity for spring-run Chinook salmon will increase to a “medium” magnitude stress over the long term, and certainty will remain “low” (Table 56).

Spring-run Chinook salmon adults hold in river from March through September, generally in deeper pool areas. Currently, these are distributed throughout the river either in deep mine pits or in Goodwin Canyon. Temperatures are usually optimal in the upstream areas when reservoir storage is sufficient to retain cold water through the summer (e.g., temperatures below Goodwin Dam; Figure 14). However, during prolonged drought, the temperature of water released from Goodwin Dam can exceed sub-optimal levels for extended periods (e.g., more than 16°C [60.8°F] at approximately RM 57.5 on July 8 and 23, 2015; Wikert 2014, pers. comm.; and this would be expected to result in reduced fecundity for holding spring-run Chinook salmon.

8.3.3.3 O. mykiss

O. mykiss are not expected to experience a reduction in fecundity as a result of conditions during the holding period from any of the existing or future stressors analyzed in this report.

8.3.4 Contributing Management Factors

Dams block access to historic high-elevation holding habitats, particularly for spring-run Chinook salmon and *O. mykiss*. The holding behavior for fish in these populations is restricted to warmer, lower elevation tailwaters below Goodwin Dam. Availability of holding habitat is expected to deteriorate in the long term.

Reservoir operation is a major driver of the environmental factors that control the impact of stressors on adult salmonids during their pre-spawn holding period and that may lead to post-migration mortality or sub-optimal gamete production among adult salmonids. For example, flow rates and cold-water pool management regulate water temperature and residence time in the river. In addition, the volume of water released from the reservoir will affect dilution of contaminant discharges to the river. The environmental factors that drive the failure to attain holding habitat Environmental Objectives, post-migration mortality, or negative sub-lethal effects are often coupled and work synergistically (e.g., temperature affects both DO concentration and fish demand for DO). Furthermore, residence time, nutrient concentration, and temperature all impact the degree of nutrient-related stressors (e.g., macrophyte density or low DO) in the river.

Other non-flow management practices may exacerbate or alleviate stressors on adult holding. For example, the destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor; this can increase temperatures and primary productivity in the river. Groundwater depletion has likely terminated the hyporheic inputs that likely buffered the Stanislaus River against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the river during critical months. Creation of gravel bars and alluvial in-channel islands offer the opportunity to create thermal complexity and provide cold-water refuges during peak temperature times (Ock and Kondolf 2012).

Urban and agricultural developments in the watershed have increased contaminant loads to the Stanislaus River. Adjustments to land use practices or the development of contaminant control programs may reduce contaminant loads and the stress they generate for migrating adult salmonids.

8.4 Stressors on Spawning

Spawning is a short life stage, lasting hours for Chinook salmon (Berejikian et al. 2000a) and an average of 3 days for *O. mykiss* (Briggs 1953; Shapovalov and Taft 1954; Hannon et al. 2003). Despite its brevity, spawning is an important transitional link from one generation of salmonids to the next. Physiological conditions in fish trigger the onset of spawning at specific times of the year for different species. Spawning salmonids require adequate space, correctly sized gravel, appropriate river depth and velocities, nearby cover (especially for *O. mykiss*), and clean water (e.g., devoid of disruptive contaminants) to spawn successfully. In addition, avoiding interbreeding is also an important component of spawning success that supports the Biological Objectives.

Stresses are potential negative outcomes that prevent attainment of Environmental and/or Biological Objectives. The following three stresses were evaluated for spawning salmonids in the Stanislaus River:

- Inadequate availability of high quality spawning habitat segregated from other runs,
- Interbreeding/introgression, and
- Compression of the spawning window due to delayed spawning.

Stressors are variables that contribute to stress, alone or in combination. River temperatures, DO, velocity, depth, cover, contaminants, predation, poaching, amount of available spawning habitat segregated from that used by other populations (necessary to prevent interbreeding or red superimposition by one population that reduces productivity of another population), disease, and impacts from hatchery operations were individually considered to assess their relative contribution to population stresses during the spawning life stage.

Near-term stresses reflect those that would impede attainment of Environmental or Biological Objectives currently. Evaluation of these stresses in the long term incorporated analysis of current conditions and assumed that adult salmon densities would increase substantially and that global and regional warming trends occur as anticipated (Dettinger et al. 2004; Cayan et al. 2006).

8.4.1 Current Spawning Timing

Scoring of stress and contributing stressors was based on the potential exposure to conditions across the full range of each population's spawning timing window as compared to the expected timing window and spatial extent of spawning in the Stanislaus River (Figure 7). Spring-run Chinook salmon and Central Valley steelhead spawning are not well monitored at this time, so the current timing of spawning for these two populations is based on the timing for runs observed in other Central Valley watersheds. Spring-run spawning timing was considered to be late August through March (Figure 7). Spawning timing for *O. mykiss* was considered to be between December and April (McEwan 2001; Williams 2006; Figure 7).

8.4.2 Current Spawning Extent

Current spawning area is limited to the area above RM 34 (6 miles downstream of the Oakdale RST), although the majority of redds (mean 90%; Giudice 2014) are observed upstream of the Oakdale RST. Spawning is observed throughout the river upstream of Oakdale to the base of Goodwin Dam.

8.4.3 Stress: Inadequate Availability of High-quality Habitat (Spawning)

Attainment of goals and objectives for Chinook salmon and *O. mykiss* will require sufficient high quality habitat, as described in the SEP Group's Environmental Objectives for spawning (Section 7.2.3). High-quality habitat includes adequate amounts of spawning gravel (correctly sized sediments) that is inundated to adequate river depth, at adequate velocity, and by water of adequate quality. To attain SEP Biological Objectives for productivity of each population, high-quality spawning habitat for each population must also be spatially or temporally segregated from other runs or species. Spatial or temporal segregation is intended to prevent redd superimposition, which destroys some or all of the incubating eggs or alevins, and genetic introgression between runs (i.e., spring-run and fall-run) or between hatchery and naturally produced individuals, which is hypothesized to reduce diversity and/or fitness. However, interactions between runs and between hatchery and naturally produced fish are discussed in Section 8.4.4.

8.4.3.1 Fall-run Chinook Salmon

Inadequate availability of high-quality spawning habitat for fall-run in the near term was rated a “low” magnitude stress with expected minor effect on the population; certainty of this stress was “medium” (Table 58).

Over the long term, this stress will increase to “high” magnitude. The certainty will remain “medium” (Table 58).

Table 58

Spawning Stressors for Fall-run Chinook Salmon in Spawning Reach, October through December

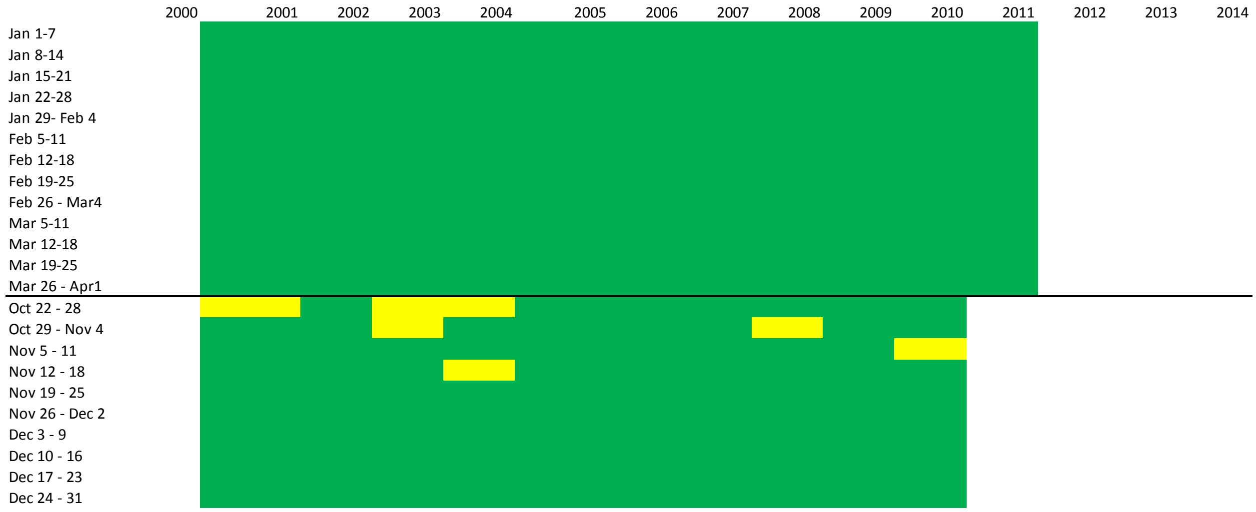
Fall-run Stressor in Spawning Reach, October-December	NT		LT		Stressors: Temperature		DO		Velocity		Depth		Coarse Sediment Input		Cover		Predator density		Contaminants		Habitat Distribution		Disease		Poaching		Hatchery Operations		Run Segregation	
	M	C	M	C	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT
Inadequate availability of high-quality habitat	2	3	4	3	M: 2 C: 3	M: 4 C: 3	M: 1 C: 2	M: 2 C: 1	M: 1 C: 2	M: 1 C: 2	M: 3 C: 3	M: 3 C: 3	M: 2 C: 2	M: 3 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 1	M: 1 C: 1	M: 2 C: 2	M: 3 C: 2	M: 1 C: 4	M: 3 C: 3	M: 1 C: 2	M: 2 C: 2	M: 1 C: 2	M: 2 C: 2				
Interactions with hatchery fish and other runs	4	4	4	3																							M: 4 C: 4	M: 4 C: 3	M: 1 C: 4	M: 4 C: 3
Compression of the spawning window due to delayed spawning	2	2	4	2	M: 3 C: 2	M: 4 C: 2	M: 1 C: 2	M: 2 C: 1																						

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run spawning in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT = near term

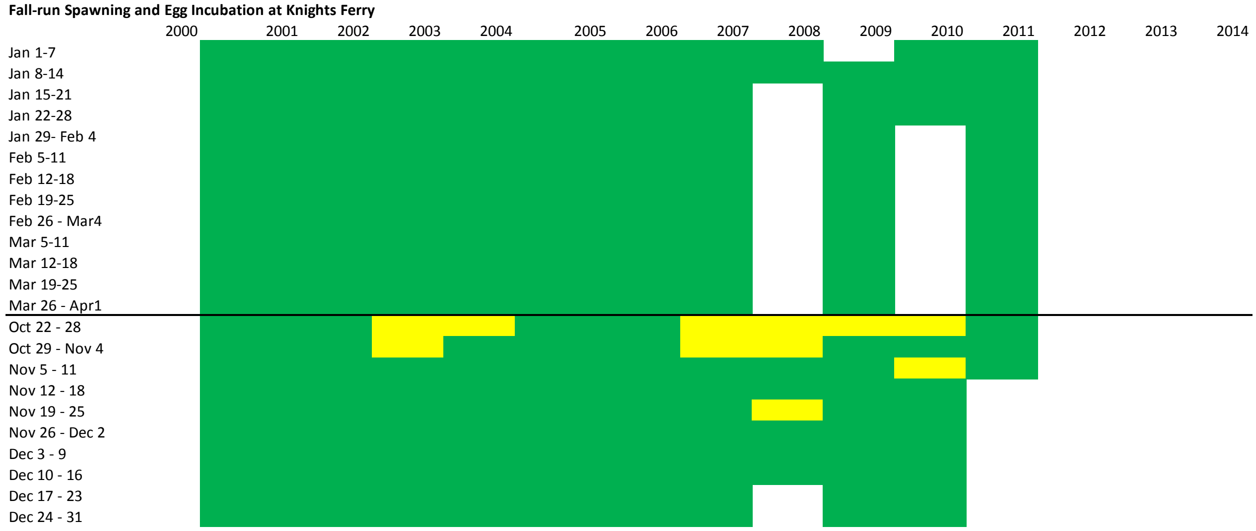
Currently, the amount of spawning habitat in the Stanislaus River is sufficient for returning fall-run spawners (but see Section 8.4.4). Magnitude for this stress was considered "low" in the near term largely due to adequate availability of spawning habitat with appropriate depth, velocity, substrate, and temperature criteria during the core-spawning period. Other habitat components, such as DO, water velocity, water depth, cover, disease, contaminants, predator density, poaching, and habitat distribution (the distribution of spawning habitats throughout the river), were all rated as "minimal" or "low" magnitude stressors. Competition for spawning habitat space and negative effects from redd superimposition are not expected to be stressors because an estimated 25 to 27 acres of spawning habitat in wet and dry years, respectively, are available on the Stanislaus River (CVPIA Science Integration Team 2016). This is more than estimated 14.7 acres needed to support "wild" adult spawners and reach target juvenile numbers (Appendix B, Table B-3).

Certainty for the stress associated with amount of available habitat was considered to be "medium." Understanding is "high" with regard to temperatures during the spawning season and spawning habitat availability on the Stanislaus (Figure 15; CVPIA Science Integration Team 2016). However, information on DO, contaminants, and predation and poaching in the spawning reach of the river was based largely on professional judgement rather than Stanislaus River-specific studies. There is insufficient information regarding large classes of contaminants and potential impacts in the upstream reaches. The only data for DO are from a gage located at Ripon, which is far from the current spawning area. Spawning surveys conducted by CDFW suggest little sign of pre-spawn mortalities and egg retention in females in the spawning reach (Giudice 2014); however, there is little information on viability of spawned eggs. Additionally, although the temperature data for current conditions came from long-term data from California Data Exchange Center (CDEC) gages (at Goodwin Dam, Knights Ferry, and Orange Blossom Bridge), there are no studies indicating whether poor temperature conditions are contributing to spawning delays.

Fall-run Spawning and Egg Incubation below Goodwin Dam



Fall-run Spawning and Egg Incubation at Knights Ferry



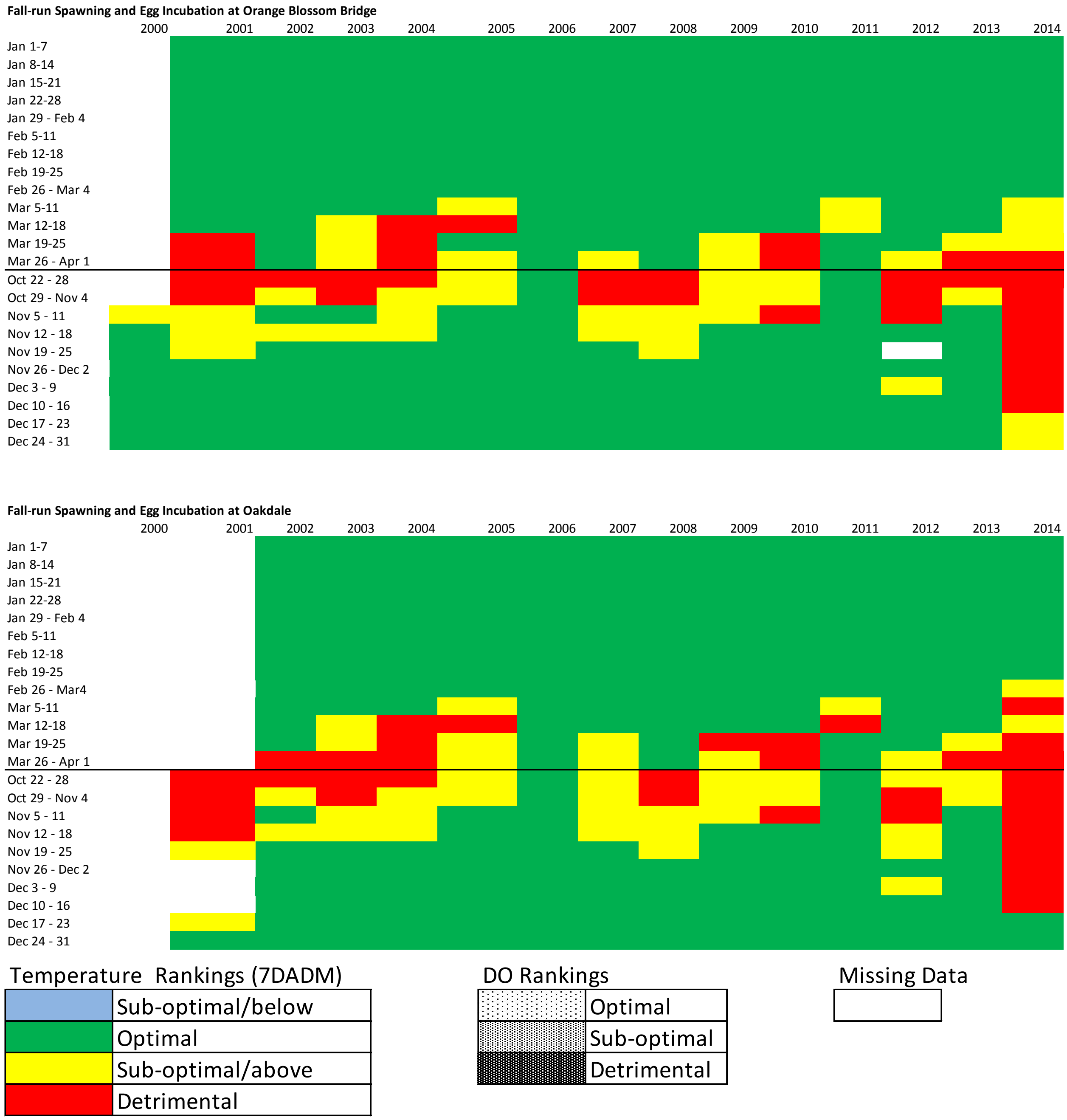


Figure 15

Fall-run Chinook Salmon Spawning and Egg Incubation

Notes:
Temperature and DO rankings based on observed data during periods of spawning. Time periods with rankings of sub-optimal or detrimental provide evidence for the potential for delayed spawning, increased pre-spawn mortality, and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

In the long term, the lack of high quality habitat will increase to a “high” magnitude stress (major population-level effect) due to several factors. Increases in the expected number of returning spawners will require additional habitat area. Climate change scenarios project more rain, less snow, and warmer water temperatures in the future, which will exacerbate current sub-optimal temperature conditions for spawners (Dettinger et al. 2004; Cayan et al. 2008). Negative effects from DO may increase in magnitude in the long term with the expected increase in suboptimal temperatures. Finally, as is typical in rivers blocked by dams, the Stanislaus River lacks the ability to replenish gravel and sustain habitat through natural geomorphic processes. In the long term, there will not be enough habitat for adult spawners unless substantial efforts are made to restore this habitat.

The certainty for this stress in the long term remains “medium.” There is substantial evidence for the following: the need for additional spawning habitat space as spawning populations increase; predicted increases in temperature over time; and the presence of dams leading to eventual decreased availability of spawning gravels and increased bed armoring. It can be reasonably assumed that, without corrective action, warmer temperature conditions predicted by climate models will contribute to spawning delays and/or failure to spawn.

8.4.3.2 Spring-run Chinook Salmon

Inadequate availability of high-quality spawning habitat for spring-run in the near term was rated a “medium” magnitude stress with an expected minor effect on the population; certainty of this stress was “medium” (Table 59).

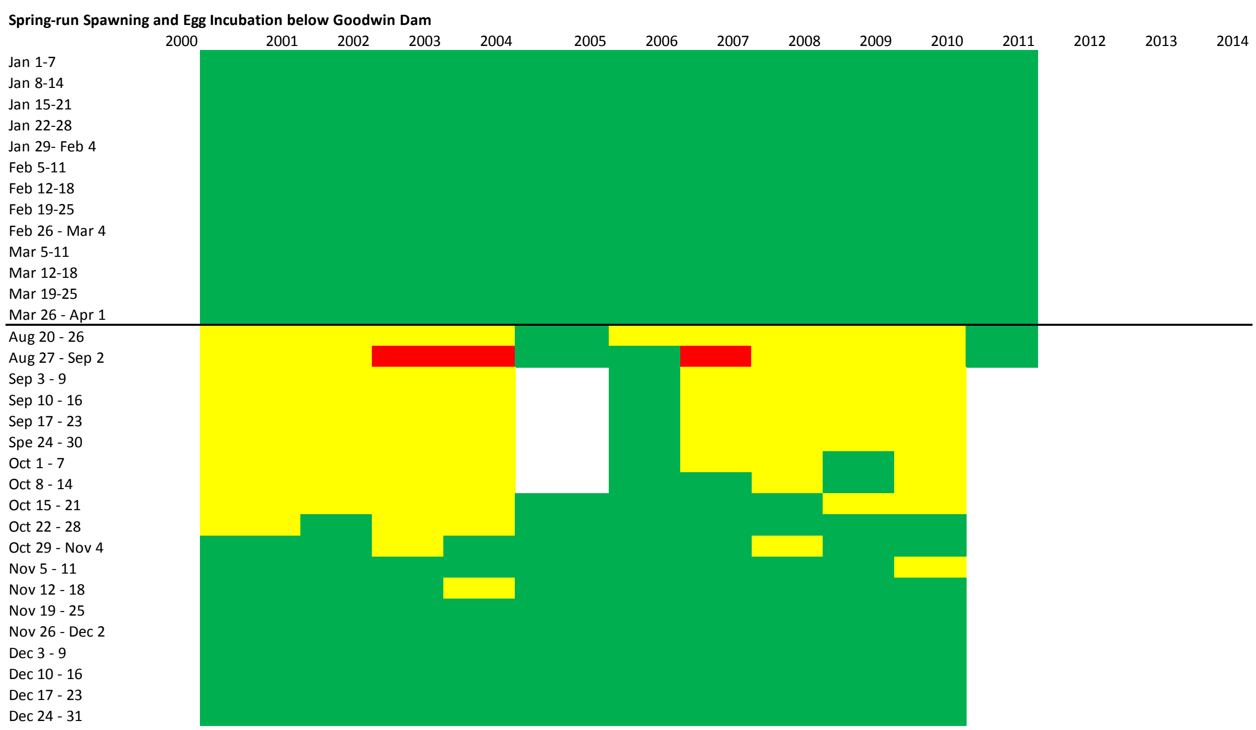
Over the long term, this stress will increase to “high” in magnitude. The certainty will remain “medium” (Table 59).

Table 59
Spawning Stressors for Spring-run Chinook Salmon

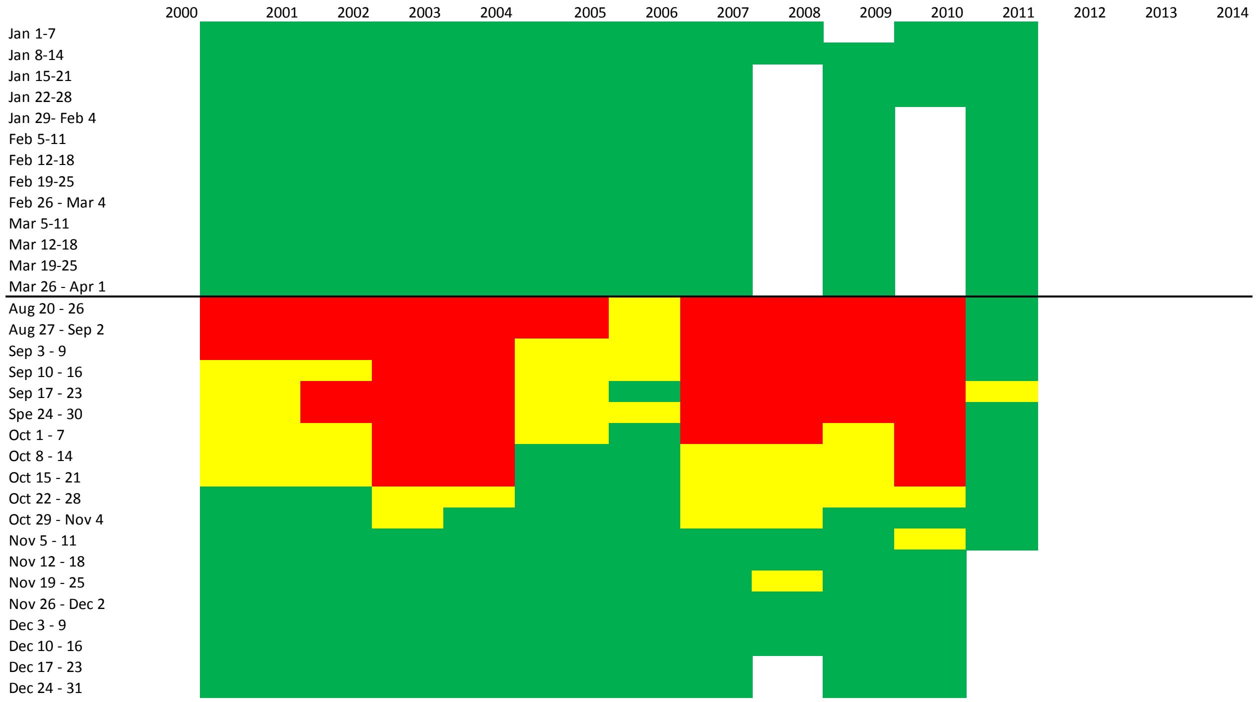
Spring-run Stressor, Spawning Reach, late August-October	NT		LT		Stressors: Temperature		DO		Velocity		Depth		Coarse Sediment Input		Cover		Predator density		Contaminants		Habitat Distribution		Disease		Poaching		Hatchery Operations		Run Segregation	
	M	C	M	C	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT
Inadequate availability of high-quality habitat	3	3	4	3	M: 3 C: 3	M: 4 C: 3	M: 1 C: 2	M: 2 C: 1	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 3	M: 3 C: 3	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 2 C: 2	M: 3 C: 2	M: 3 C: 3	M: 4 C: 3	M: 1 C: 2	M: 2 C: 2	M: 1 C: 2	M: 1 C: 2				
Interactions with hatchery fish and other runs	4	4	4	3																							M: 2 C: 3	M: 4 C: 3	M: 4 C: 4	M: 4 C: 3
Compression of the spawning window due to delayed spawning	3	2	4	2	M: 3 C: 3	M: 4 C: 2	M: 2 C: 1	M: 2 C: 1																						

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run spawning in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Spawning Reach; When: late August through October
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT = near term

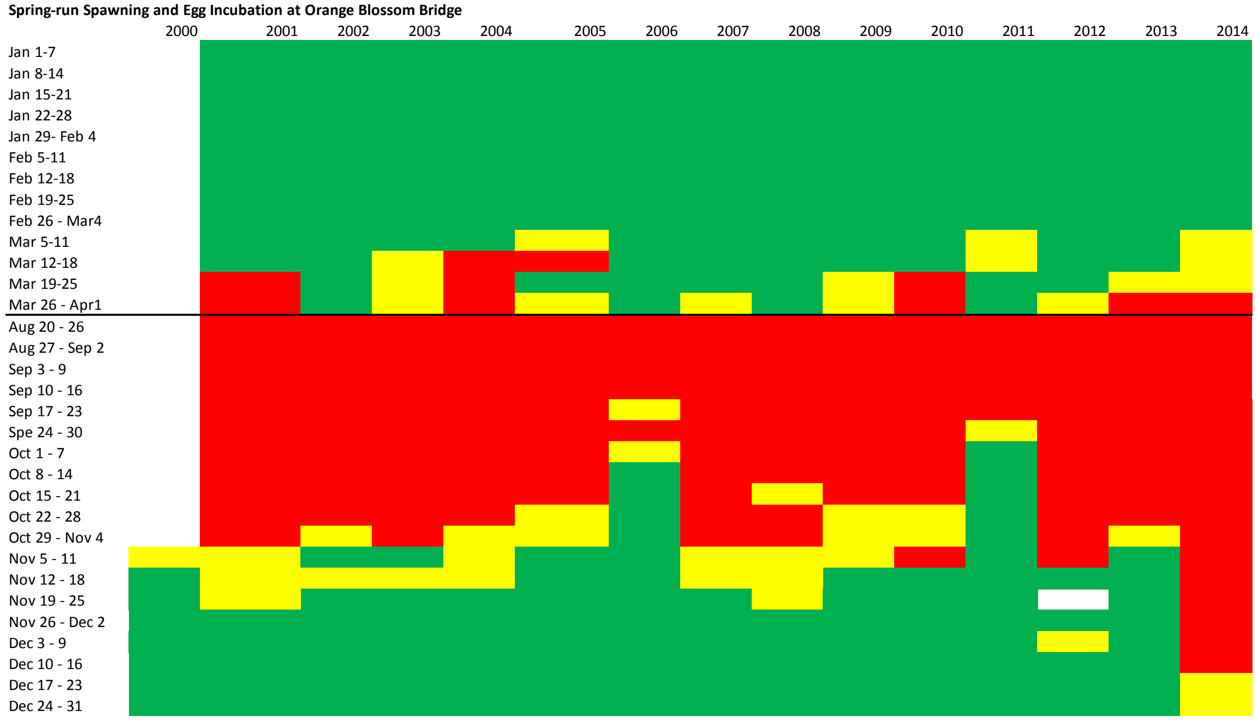
Magnitude for the inadequate availability of high-quality habitat stress was considered "medium" in the near term as a result of habitat component stressors such as temperature and extent of appropriately sized gravel. Temperatures are potentially detrimental or suboptimal throughout the spawning reach from Orange Blossom Bridge to Goodwin Dam during late August to early November (Figure 16). Similar to fall-run, spring-run would require 14.7 acres of high quality spawning habitat to support returning adult spawners and juvenile productivity objectives that are required to achieve restoration goals. Although sufficient spawning habitat exists to support current numbers of spawning spring-run, spawning habitat is not segregated from fall-run. Lack of spatial and temporal segregation between fall-run and spring-run will likely result in red superimposition for spring-run. Together, the many stressors combine to make the inadequate availability of habitat a "medium" magnitude stress.



Spring-run Spawning and Egg Incubation at Knights Ferry



Spring-run Spawning and Egg Incubation at Orange Blossom Bridge



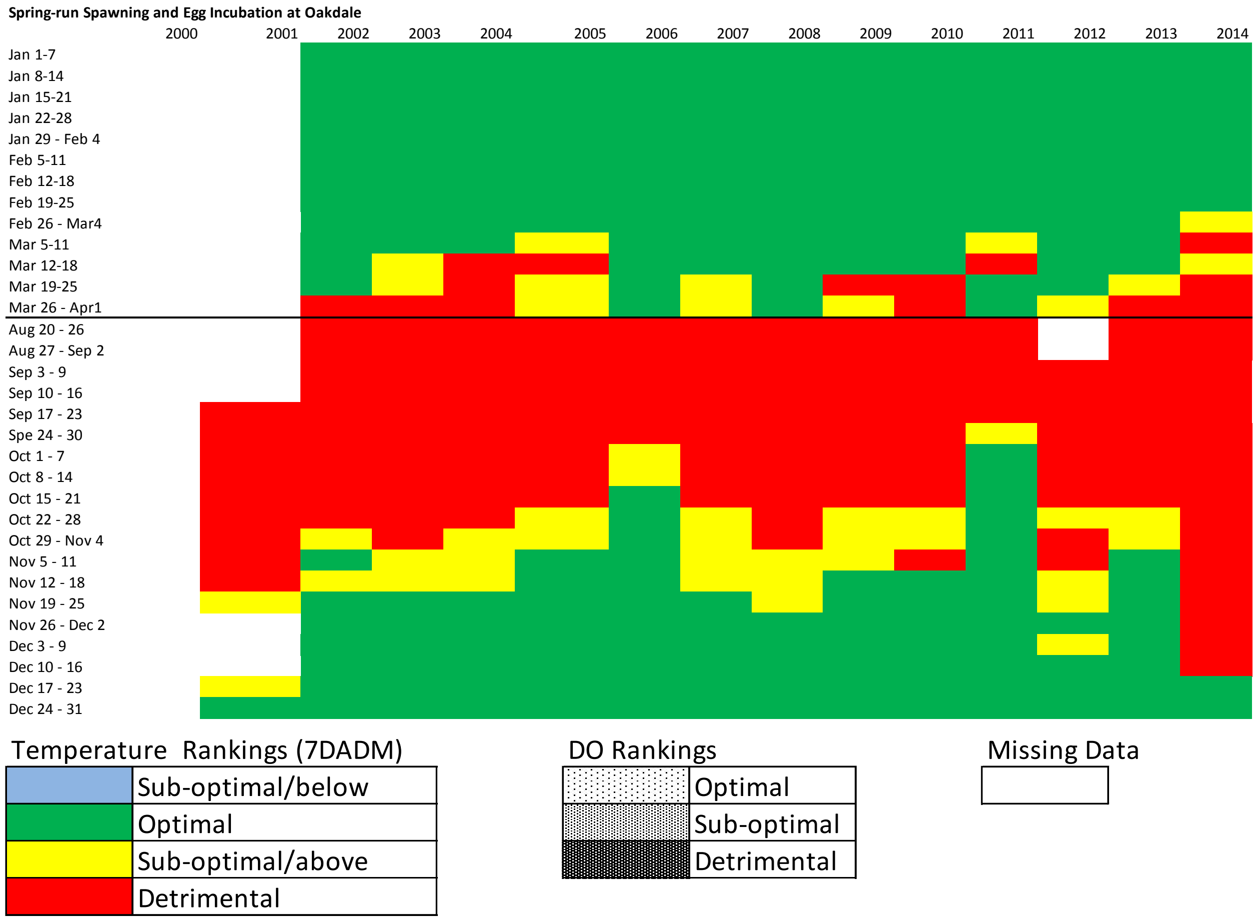


Figure 16

Spring-run Chinook Salmon Spawning and Egg Incubation

Notes:
Temperature and DO rankings based on observed data during periods of spawning. Time periods with rankings of sub-optimal or detrimental provide evidence for the potential for delayed spawning, increased pre-spawn mortality, and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

Certainty for the aggregate stress, amount of available habitat, was considered to be "medium." Similar to fall-run Chinook salmon, understanding is "medium" with regard to temperatures during the spawning season and spawning habitat availability on the Stanislaus River (Figure 16; CVPIA Science Integration Team 2016). However, information on DO, contaminants, and predation and poaching in the Stanislaus River was based largely on professional judgement rather than Stanislaus River-specific studies. Insufficient information exists regarding large classes of contaminants, and potential impacts in the upstream reaches are unknown. The only data for DO are from a gage located at Ripon, far from the current spawning area. Personnel communication from CDFW indicates there is little information regarding spring-run spawners in the system. Additionally, although the temperature data for current conditions came from long-term CDEC gages, there is no information as to whether poor temperature conditions are contributing to spawning delays.

Without corrective measures, the lack of high quality habitat will increase to a "high" magnitude stress (major population-level effect) in the long term due several factors. Similar to fall-run Chinook salmon, climate change scenarios predicting warmer water temperatures in the future will exacerbate current sub-optimal temperature conditions for spawners (Dettinger et al. 2004; Cayan et al. 2008). Negative effects from DO may also increase in magnitude in the long term as temperatures rise. Increased numbers of fall-run Chinook will continue to impact spring-run redds due to redd superimposition. Finally, over the long term, there will not be enough habitat to accommodate increased numbers of adult spawners due to the increased expected number of spawners and the gradual loss of spawning gravel downstream of the dam.

The certainty for this stress in the long term remains "medium." There is substantial evidence for increased temperatures in the future and for the lack of suitable physical habitat spawning as the number of spawners increase and the dam continues to block replenishment of spawning gravels.

8.4.3.3 Central Valley O. mykiss

Inadequate availability of high-quality spawning habitat for *O. mykiss* in the near term was rated a "low" magnitude stress with an expected minor effect on the population; certainty of this stress was "low" (Table 60).

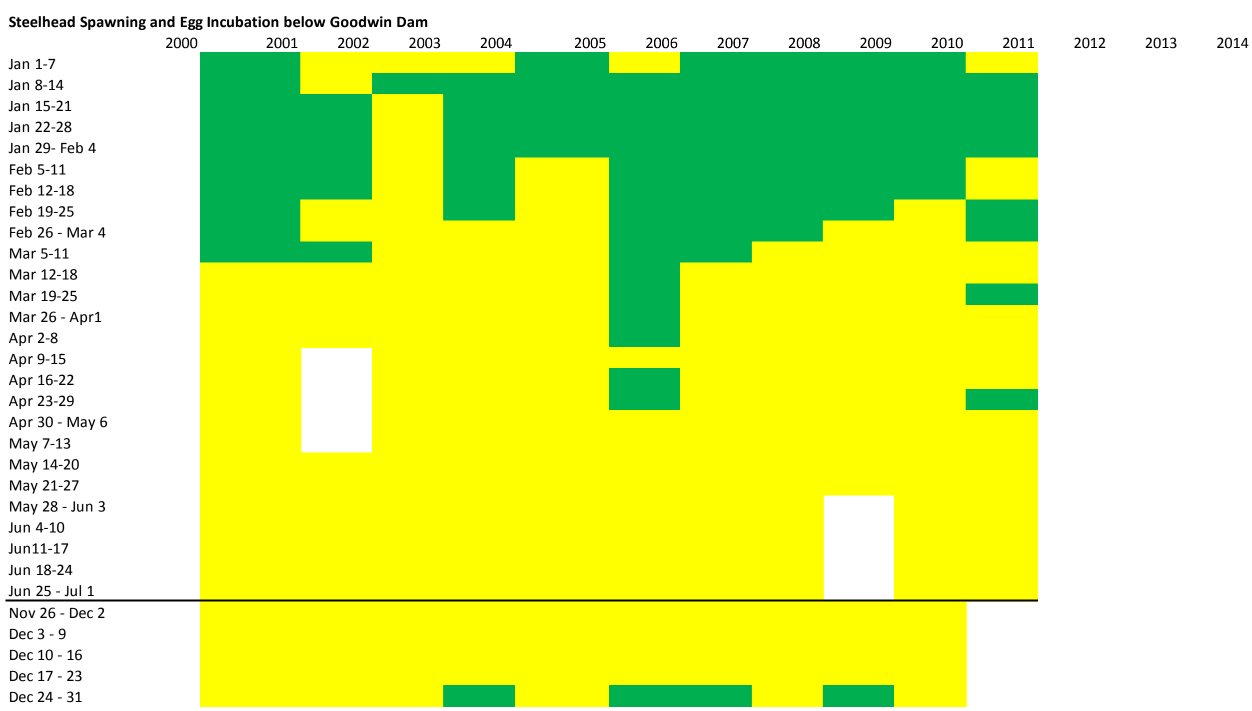
Over the long term, this stress will increase to "medium" in magnitude. The certainty will remain "low" (Table 60).

Table 60
Spawning Stressors for *O. mykiss*

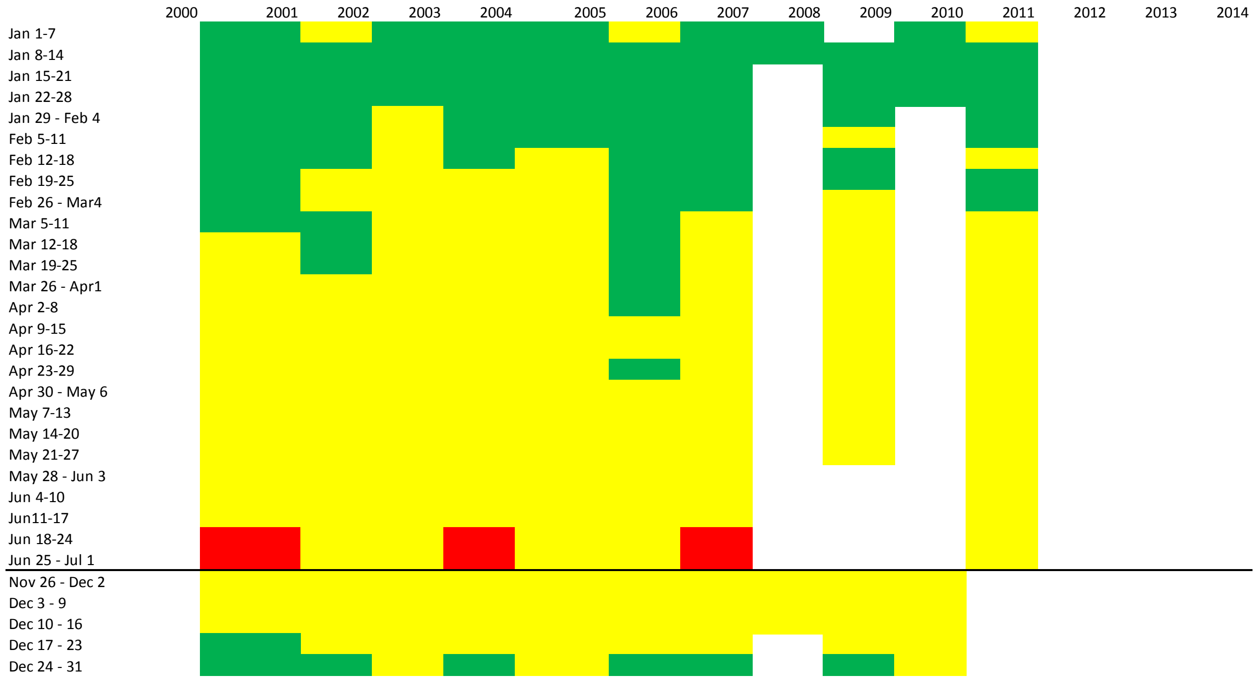
O. mykiss Stressor, Spawning Reach, December – April					Spawning																									
	NT		LT		Temperature		DO		Velocity		Depth		Coarse Sediment Input		Cover		Predator density		Contaminants		Habitat Distribution		Disease		Poaching		Hatchery Operations	
	M	C	M	C	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT
Inadequate availability of high-quality habitat	2	2	3	2	M: 2 C: 2	M: 3 C: 2	M: 1 C: 3	M: 2 C: 3	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 1 C: 2	M: 2 C: 2	M: 2 C: 2	M: 1 C: 2	M: 1 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 3 C: 2	M: 1 C: 1	M: 3 C: 2	M: 1 C: 2	M: 2 C: 2	M: 1 C: 2	M: 1 C: 2		
Interactions with hatchery fish and other runs	3	2	3	2																							M: 4 C: 4	M: 4 C: 3
Compression of the spawning window due to delayed spawning	2	1	3	1	M: 2 C: 1	M: 3 C: 1	M: 2 C: 1	M: 2 C: 1																				

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for *O. mykiss* spawning in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Spawning Reach; When: late August through October
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT = near term

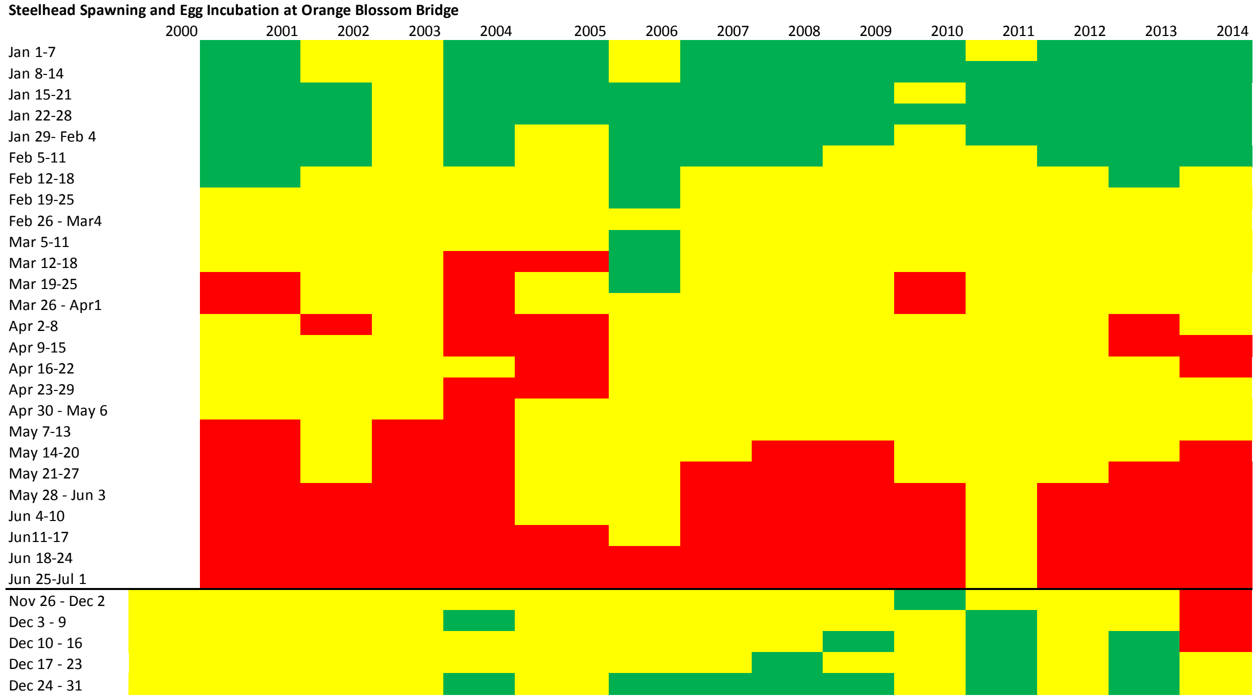
Magnitude for the inadequate availability of high-quality habitat stress was considered "low" in the near term because an evaluation of the habitat component stressors revealed that temperature was the only concern, and it was rated as a "medium" magnitude stressor. Temperatures are potentially suboptimal throughout the spawning reach upstream of Orange Blossom Bridge during at least part of the October to June spawning season (Figure 17). The downstream extent of currently available spawning habitat (near Orange Blossom Bridge) is expected to have higher temperatures than the upper reaches near Goodwin Dam during early and late spawning (fall and late spring). Spawning may frequently be restricted by unsuitable temperatures early (October to November) and later (March to June) in the spawning season. The certainty is "low" for this stressor because of the complex life history of *O. mykiss*, the lack of information on steelhead spawning success in the Stanislaus River, and the lack of spatially explicit temperature data in the spawning reach. Lack of segregation from fall-run is not expected to adversely affect most *O. mykiss*, as the peak spawning season is expected to begin in December when most fall-run have spawned. Additionally, *O. mykiss* preferentially use slightly smaller gravel size, so redd superimposition is expected to be minimal. Contaminants were rated as a "low" magnitude stressor. Together, the many stressors combine to make the availability of habitat a "low" magnitude stress.



Steelhead Spawning and Egg Incubation at Knights Ferry



Steelhead Spawning and Egg Incubation at Orange Blossom Bridge



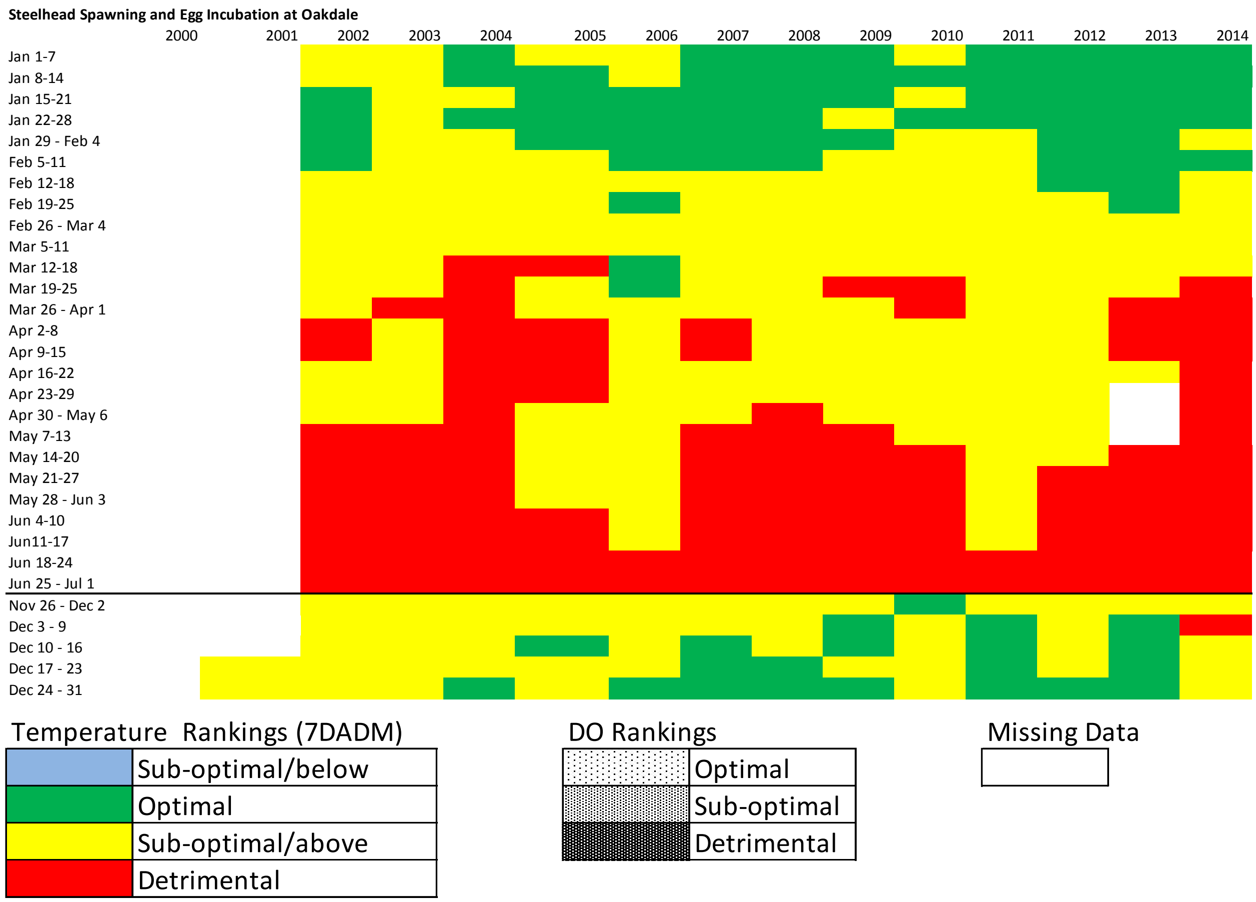


Figure 17

***O. mykiss* Spawning and Egg Incubation**

Notes:
Temperature and DO rankings are based on observed data during periods of spawning. Time periods with rankings of sub-optimal or detrimental provide evidence for the potential for delayed spawning, increased pre-spawn mortality, and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

Certainty for the aggregate stress, the amount of available habitat, was considered to be "low." Similar to Chinook salmon, understanding is "high" with regard to temperatures during the spawning season (Figure 17); it is "medium" for *O. mykiss* requirements and spawning habitat availability on the Stanislaus River because spawning habitat availability has only been estimated for Chinook (CVPIA Science Integration Team 2016). Information on DO, contaminants, and predation and poaching in the Stanislaus River was based largely on professional judgment rather than Stanislaus River-specific studies. Insufficient information exists regarding large classes of contaminants, and potential impacts in the upstream reaches are unknown. The only data for DO are from a gage located at Ripon, which is far from the current spawning area. Personnel communication from CDFW indicates there is little information regarding *O. mykiss* spawners in the system. Additionally, although the temperature data for current conditions came from long-term data from CDEC gages (Figure 17), there is no information as to whether poor temperature conditions are contributing to spawning delays or failure to spawn.

Without corrective action, the lack of high-quality habitat will likely increase to a "medium" magnitude stress (minor population-level effect) in the long term due to several factors. Similar to fall-run Chinook salmon, climate change scenarios predicting warmer water temperatures in the future will likely result in sub-optimal temperature conditions for spawners (Dettinger et al. 2004; Cayan et al. 2008). Negative effects from DO are expected to increase in magnitude in the long term with increases in temperature. Increased numbers of fall-run Chinook salmon may impact *O. mykiss* redds through superimposition. In the long term, there will likely not be enough habitat for spawning adults due to the increased number of spawners and lack of spawning gravel replenishment downstream of the dam.

The certainty for this stress in the long term remains "low." There is substantial evidence for increased temperatures in the future and the lack of spawning gravel replenishment downstream of dams.

8.4.4 Stress: Interactions with Hatchery Fish and Other Runs (Spawning)

Introgression between ESUs or between hatchery-spawned and naturally produced salmon can have negative impacts on life history adaptation and population viability from reduced fitness (Section 3.2). To attain SEP Biological Objectives for genetic integrity of each population, high-quality spawning habitat for each population must be spatially or temporally segregated from other runs or species to prevent introgression and support local adaptation.

8.4.4.1 Fall-run Chinook Salmon

Interbreeding stress was scored as "high" magnitude with "high" certainty in the near term, during October through December, within the spawning reach (Table 58).

In the long term, without aggressive hatchery management and segregation from spring-run fish, this stress will remain “high” in magnitude. The certainty will become “medium” because the outcome is dependent on future management actions (Table 58).

There is no spatial segregation of habitat to prevent naturally produced fall-run Chinook salmon from interbreeding with hatchery strays and spring-run Chinook salmon. Near-term “high” magnitude rankings, indicating major population effect, are based on evidence that hatchery fish negatively impact wild Chinook salmon populations and the large proportion of hatchery fish that reproduce in the Stanislaus River. In addition, reducing introgression between fall-run and spring-run salmon ESUs is a major goal for the maintenance and restoration of fall-run Chinook salmon in the Central Valley (Sections 3.2 and 6.2.2). The certainty is “high” for this stress because of the recent robust data on the prevalence of hatchery-spawned adults returning to spawn in the Stanislaus River (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013). Although no site-specific studies have verified negative population-level effects from hatchery fish on the Stanislaus River, introgression is considered a major stressor system-wide (Section 3.2). Additionally, fall-run and spring-run ESUs are currently restricted to roughly the same spawning areas due to Goodwin Dam.

Without intervention, this stressor will remain “high” magnitude in the long term because hatchery and wild fish and spring-run and fall-run fish will interbreed unless physical or temporal barriers to reproduction are established. Increased numbers of spring-run spawners will increase interbreeding among ESUs and cause additional interbreeding stress (Section 6.2.2). The certainty decreases to “medium” because the outcome is dependent on many variables for which the SEP Group had no a priori expectation such as hatchery practices, land use conditions that may change available habitat, and future management actions.

8.4.4.2 Spring-run Chinook Salmon

Interbreeding stress was scored as “high” magnitude and “high” certainty in the near term, during late August to October, within the spawning reach (Table 59).

In the long term, without access to spawning habitat above Goodwin Dam or segregation from fall-run fish, this stress will remain “high” in magnitude. The certainty will become “low” because the outcome is highly dependent on future management actions (Table 59).

Near-term “high” magnitude rankings, indicating a major population effect, are based on the lack of spatial segregation for spring-run spawning habitat that would prevent interbreeding with fall-run Chinook salmon. The certainty is “high” for this stressor for the following reasons:

- Recent studies verifying negative population-level effects from interbreeding of ESUs system-wide (Section 3.2), and
- Hybridization and introgression among Central Valley runs, resulting from dam construction and hatchery management practices, is well known (e.g., Smith et al. 1995).

Lack of spatial and temporal segregation between spring-run and fall-run Chinook salmon will also lead to high rates of redd superimposition for spring-run, which spawn earlier than fall-run.

In the long term, this stress will remain “high” magnitude because as numbers of fall-run and spring-run adults increase, interbreeding among ESUs is likely to increase. The certainty decreases to “medium” because the outcome is dependent on uncertain variables such as future hatchery practices, land use conditions that may change available habitat, and future management actions on the Stanislaus River that could include passage around Goodwin Dam or segregation weirs.

8.4.4.3 O. mykiss

Interbreeding stress was scored as “medium” magnitude and “low” certainty in the near term, during October through June, within the spawning reach (Table 60).

In the long term, this stress will remain “medium” in magnitude. The certainty will remain “low” because little is known about *O. mykiss* reproduction on the Stanislaus River (Table 60).

In many Central Valley rivers, the steelhead form of *O. mykiss* is dominated by hatchery fish (Garza and Pearse 2008), and the negative effects on fitness of interbreeding between wild and hatchery fish are well studied and can be genetically based (Hansen 2002; Araki et al. 2007). In 3 of the last 5 years of weir operation on the Stanislaus River, more than 50% of the steelhead counted were classified as hatchery origin, indicating potential for substantial introgression with hatchery-origin stock (Johnson, pers. comm.). However, gene flow from hatchery fish in steelhead populations can be buffered by wild resident rainbow trout populations with better fitness (Christie et al. 2011). The certainty is “low” for this stress in the near term because of the complex life history strategies of *O. mykiss* and the lack of information on population-level effects of this stress on Stanislaus River *O. mykiss*.

In the long term, this stress will remain a “medium” magnitude stress because, even with increased numbers of wild-spawned *O. mykiss*, current hatchery management practices are likely to contribute to introgression. The certainty remains “low” for the same reasons as described for the near term.

8.4.5 Stress: Compression of the Spawning Window due to Delayed Spawning

Ensuring opportunities for full expression of potential life history traits by salmonids is an important consideration in the SEP’s diversity objectives (Section 3.2). Compression of the life history cycle resulting from delayed spawning was evaluated for Chinook salmon and *O. mykiss* as a potential stress related to the diversity objectives.

8.4.5.1 Fall-run Chinook Salmon

Compression of the spawning window due to delayed spawning was scored as a “low” magnitude and “low” certainty stress in the near term, primarily due to sub-optimal temperatures (Table 58).

In the long term, this stress will increase to “high” in magnitude due to climate change model projections of increasing water temperature. The certainty will remain “low” for reasons similar to the near term (Table 58).

Near-term "low" magnitude rankings are based on detrimental and suboptimal conditions that occur regularly at the beginning of the fall-run spawning season throughout the current spawning reach. The downstream extent of currently available spawning habitat (near Orange Blossom Bridge) is restricted by unsuitable temperatures early in the spawning season (late October to early November; Figure 15). Unsuitable temperatures may contribute to delayed spawning or failure to spawn (Section 8.5). Although the effects of temperatures on Chinook salmon are well studied and temperature data are available from robust long-term datasets within the current spawning reach (i.e., CDEC gages at Goodwin Dam, Knights Ferry, and Orange Blossom Bridge), the certainty is "low" for this stressor because the nature of the outcome is not predictable. The effect of delayed spawning on the time available for subsequent development of a portfolio of life history types among juvenile outmigrants is attenuated by conditions in the egg incubation and juvenile rearing life stages. Thus, even though the spawning season for fall-run Chinook salmon is potentially constrained, conditions during incubation and juvenile rearing stages still influence the timing and size (life history) distribution of the subsequent cohort of outmigrating juveniles.

In the long term, this stressor will increase to "high" magnitude because projected climate change scenarios show more rain, less snow, and warmer water temperatures in the future, which will exacerbate current temperature conditions. The certainty remains "low" for similar reasons as described for the near term. However, there is an established, well-understood trend suggesting that near-term temperature conditions are likely to continue or increase over the next 20 years (Dettinger et al. 2004; Cayan et al. 2008).

8.4.5.2 Spring-run Chinook Salmon

Compression of the freshwater life cycle due to delayed spawning was scored as a "medium" magnitude, "low" certainty stress in the near term during late August through October within the spawning reach (Table 59)

In the long term, this stress will become "high" in magnitude. The certainty will remain "low" for reasons similar to those in the near term (Table 59).

Near-term “medium” magnitude rankings are due to observed temperatures that are often detrimental or suboptimal upstream of Orange Blossom Bridge during late August to early November (Figure 16). The downstream extent of currently available spawning habitat (near Orange Blossom Bridge) is restricted by unsuitable temperatures early and late in the spawning season (late August to early November and late March). Goodwin Dam blocks higher elevation spawning habitat historically used by spring-run. Although the effects of temperatures on Chinook salmon are well studied and temperature data is available from robust long-term datasets within the current spawning reach (CDEC gages at Goodwin Dam, Knights Ferry, and Orange Blossom Bridge), the certainty is “low” for this stressor because the nature of the outcome can be attenuated by conditions during the egg incubation and rearing life stages.

In the long term, this stressor will increase to “high” magnitude because projected climate change scenarios show more rain, less snow, and warmer water temperatures in the future that will exacerbate current conditions. The certainty remains “low” for reasons described for the near term. However, there is an established, well understood trend suggesting that the near-term temperature conditions are likely to continue or increase over the next 20 years (Dettinger et al. 2004; Cayan et al. 2008).

8.4.5.3 O. mykiss

Compression of the freshwater life cycle due to delayed spawning was rated a “low” magnitude stress and a “minimal” certainty in the near term during the main spawning window, December through April, within the spawning reach (Table 60).

Over the long term, without corrective action, the magnitude will increase to “medium” magnitude; certainty will remain “minimal.” Not much is known about the potential for delayed spawning on the Stanislaus River; however, evidence from other streams does not suggest that delayed spawning would have significant population-level effects for *O. mykiss* (Table 60).

Near-term “low” magnitude rankings, indicating periodic population effects, are based primarily on temperatures. Temperatures are usually sub-optimal upstream of Orange

Blossom Bridge in early fall and late spring (Figure 17). The downstream extent of currently available spawning habitat (near Orange Blossom Bridge) is frequently restricted by unsuitable temperatures early (October to November) and later (March to June) in the spawning season. Temperatures at Goodwin Dam can be sub-optimal throughout the spawning season, with the exception of January when temperatures are generally optimal. The certainty is "minimal" for this stressor because of the complex life history form and lack of information on *O. mykiss* spawning success in the Stanislaus River. In the long term, this stress will become "medium" magnitude because increased temperatures may restrict spawning in some or most months. The certainty remains "minimal" for similar reasons to those described for the near term.

8.4.6 Contributing Management Factors

Resolution of negative interactions among salmonid populations during the spawning period may include some mix of changes to hatchery operations, river management practices, and potential implementation of actions to create physical reproductive barriers among target populations. These issues will require a basin-wide (or perhaps, Central Valley-wide) response.

Dams block access to historic high elevation spawning habitats, particularly for spring-run Chinook salmon and *O. mykiss*. Thus, spawning for all salmonids is currently restricted to warmer, lower elevation tailwaters below Goodwin Dam. This not only reduces the total area of available spawning habitat but forces the different salmonid populations (spring-run, fall-run, and *O. mykiss*) to utilize the same area, which may increase impacts due to redd superimposition. In addition, dams limit recruitment of spawning gravel from upstream and high-volume flows that produce geomorphic work; without continuing gravel amendments and actions to modify/or maintain riverbed and riverbank habitat elements, the dams cause a gradual decline of available spawning habitat

Reservoir operations are also a major driver of the environmental factors that control stressors on spawning adult salmonids. For example, flow rates and cold-water pool management regulate water temperature, water depth, water velocity, and DO levels—critical elements of spawning habitat. In addition, high temperatures that inhibit the onset of spawning by spring-run Chinook salmon tend to increase the temporal overlap between spring-run and fall-run spawning periods. The environmental factors that drive availability of spawning habitat are often coupled and work synergistically (e.g., temperature affects both DO concentration and fish demand for DO).

Other non-flow management practices may exacerbate or alleviate stressors on adult spawning. Gravel augmentation and bank modifications may increase available spawning habitat, at least in the short term. Also, land use modifications and sediment control activities can affect the ability of available spawning gravel to support spawning and incubation. Destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor; this can increase temperatures. Groundwater depletion has likely affected hyporheic inputs that probably buffered the Stanislaus River against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the river during critical months.

8.5 Stressors on Egg Incubation

The egg incubation stage—which includes the time period between when a female salmonid deposits her eggs in a redd and when fry emerge from the gravel/sediment into the water column—represents the first stage of the salmonid life cycle. In general, salmonid populations are most vulnerable during the egg incubation life stage because all of the individuals in a year-class are in a relatively small area, and they cannot move in order to avoid a stressor (e.g., warm water temperatures). Stressors during egg incubation of salmonids may result in direct mortality, impacted rates of development, and disease or physical alterations that may be critical to the development of subsequent life stages. The SEP Group evaluated one type of stress during the egg incubation phase: inadequate incubation conditions (i.e., that result in egg or larval mortality).

Physical stressors that can negatively impact populations during egg incubation were evaluated in the near term and long term for the following: water temperature, DO, contaminants, fine sediment, flow fluctuations, and trampling or disturbance. Trampling or disturbance by anglers or other river users was not expected to be a significant stressor and thus was not further considered. Flow fluctuation is a multifaceted stressor because unusually high flows could cause redd scour, whereas decreased flows during the spawning or incubation period could cause redd dewatering. Pesticides and metalloids (i.e., mercury and selenium) were analyzed as contaminants that could potentially impact target populations at this life stage. Evaluation of near-term stressors analyzed those that would impede attainment of Environmental or Biological Objectives under current conditions; evaluation of these stressors in the long term assumed that global and regional warming trends occur as anticipated and that more fish of each target population would be spawning in the Stanislaus River.

8.5.1 Current Egg Incubation Timing Patterns

Egg incubation in the Stanislaus River generally occurs from late October through March for fall-run Chinook salmon and from December through June for *O. mykiss*. For spring-run Chinook salmon in the Sacramento River basin, egg incubation generally occurs from September through March; SEP objectives for spring-run Chinook salmon in the Stanislaus River include successful spawning throughout this time period. Monitoring that directly examines success of incubating eggs does not currently occur on the Stanislaus River. Some monitoring related to the emergence of salmonids on the Stanislaus River occurs via snorkel surveys, spawning surveys, beach seining, and the operation of RSTs near Caswell and Oakdale. However, direct measurement of egg mortality is challenging because it is difficult to observe the number of eggs deposited by individual females or the number of fry that emerge from a redd without affecting incubation conditions.

8.5.2 Stress: Inadequate Incubation Conditions

Salmonid egg mortality rates can have a strong influence on population growth rates; in general, salmon display high rates of investment in their eggs, a strategy associated with relatively high incubation success (Winemiller and Rose 1992). Thus, even small changes in survival of incubating eggs can represent significant changes in return on parental investment, producing substantial population-level effects. Gravel augmentation projects have been implemented on the Stanislaus River in order to improve the availability of high-quality spawning and incubation habitat.

Various factors, acting alone and in combination, may make incubation conditions unsuitable and lead to elevated rates of egg and/or alevin mortality. The SEP Group assessed water temperature, DO, pesticides, mercury and selenium levels, fine sediments, and redd dewatering and scour as stressors that may lead to inadequate incubation conditions for target salmonid populations incubating in the Stanislaus River.

8.5.2.1 Fall-run Chinook Salmon

Inadequate incubation conditions were judged to cause a "medium" level of stress (sustained minor population-level effect) with a "high" degree of certainty in the near term (Table 61).

Unless measures are taken to improve egg incubation conditions, the stress of inadequate conditions was estimated to become a "high" stress on the population in the long term; certainty will remain "high" (Table 61).

Table 61

Egg Incubation Stressors for Fall-run Chinook Salmon

Stress	NT		LT		Stressors: Temperature		DO		Pesticides		Contaminants: Mercury, Selenium		Fine Sediments		Flow Fluctuation: Redd Dewatering		Flow Fluctuation: Redd Scour	
	M	C	M	C	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT
Inadequate Incubation Conditions	3	4	4	4	M: 2 C: 4	M: 3 C: 4	M: 1 C: 4	M: 1 C: 4	M: 2 C: 2	M: 2 C: 2	M: 1 C: 4	M: 1 C: 4	M: 2 C: 2	M: 2 C: 1	M: 1 C: 3	M: 1 C: 3	M: 2 C: 2	M: 2 C: 1

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run egg incubation in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Oakdale to Riverbank; When: early in incubation season (October)
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT = near term

The near-term stress score synthesizes the effect of numerous egg incubation stressors, some of which act synergistically to increase the level of impact. Water temperatures represent a low magnitude stressor in the near term. The effect on egg survival of exposure to different temperatures has been extensively described in the scientific literature (Appendix C), reflecting a high scientific understanding of this effect. Comparison of Stanislaus River water temperatures to the SEP Group's Environmental Objectives indicates that conditions for fall-run Chinook salmon egg incubation generally are optimal for most of the incubation period in most years at and upstream of Knights Ferry. However, conditions for fall-run Chinook salmon egg incubation deteriorate downstream at Orange Blossom Bridge and Oakdale, where sub-optimal and detrimental temperatures occur in the early weeks of the incubation period in most years (Figure 15). Given that the relationship between salmon egg survival and temperature is highly understood and predictable and that temperature monitoring near current spawning grounds on the Stanislaus River is robust and ongoing, a "high" certainty score is justified. Modeling predictions indicate that temperatures are expected to increase in the southern Sierra in the long term (i.e., climate change; Cayan et al. 2008; Dettinger et al. 2004). Thus, the effect of temperature on egg incubation in the Stanislaus River is expected to increase to a "medium" magnitude stressor in the long term, and the certainty of that characterization is expected to remain "high."

The overall stress on fall-run Chinook egg incubation in the Stanislaus River is elevated by the action of stressors in addition to high water temperature. The likelihood that the additional stressors would exacerbate temperature stress caused the SEP Group to raise the overall magnitude score to reflect "medium" stress on fall-run egg incubation in the near term and "high" stress in the long term.

The effect of pesticide-derived contaminants was scored as a "low" magnitude stressor with a "low" degree of certainty in the near term. Overall, eggs and alevins developing in the Stanislaus River will have low exposures to pesticides, except for portions of the populations that are developing late in the season or in the downstream end of the spawning distribution. Incubating eggs will be relatively unaffected by pesticides because the vitelline membrane, enveloping layer, and chorion provide defense from metals, pathogens, and xenobiotic chemicals (Finn 2007). However, exposure to toxic compounds is of some concern for fall-run alevins developing between Riverbank and Oakdale between December to March, when winter storms can produce runoff that may have high (potentially detrimental) concentrations of toxins. The SEP Group's analysis of pesticide impacts relied on pesticide modeling developed using pesticide use data; however, for any one pesticide exceedance, the frequency of exceedance is estimated and does not consider additional impacts from multiple pesticides occurring simultaneously (i.e., cumulative pesticide effects were not analyzed; Appendix C).

The conditions were estimated from qualitative assessments of model outputs. However, quantitative values of pesticide concentrations could be calculated from numerical model outputs if necessary in the future. In addition, the degree of adverse impact to egg incubation and alevin development assumes that there is an analogous adverse impact, as during rearing. There is a high probability that contaminants will elicit a physiological or behavior response; however, there is uncertainty whether these will result in development impairments (e.g., deformities or reduced growth) or mortality. Limitations of monitoring pesticide concentrations in the Stanislaus River as well as limited information on the effect of pesticides on incubating salmonid eggs result in a low degree of certainty regarding the impacts of this stressor. The group found no reason that magnitude or certainty of pesticide impacts would change in the long term.

As with pesticide concentrations, the effect of fine sediment on egg incubation was scored to be a "low" magnitude and "low" certainty stressor on fall-run egg incubation when considered in isolation; however, the action of this stressor contributed to the overall stress score. The Knights Ferry Gravel Replenishment Project Phase II report states the following:

> "The egg survival studies also suggest that egg survival in the downstream reaches may have been reduced by the combined effects of near lethal water temperatures that fluctuated greatly in early November, excessive fines that reduce dissolved oxygen concentrations, and intragravel turbidity that presumably coated the eggs with clay-sized particles that reduced the egg's abilities to absorb oxygen. (Carl Mesick Consultants and KDH Environmental Services 2009, introduction at v)

The Carl Mesick Consultants and KDH Environmental Services (2009) study's implication is that negative impacts of excessive fines are limited to a small fraction of the population, which, in this case, would be the eggs in the most downstream reaches. However, the certainty for the magnitude of this stressor is "low" because it is primarily based on non-peer-reviewed research within the Stanislaus River. In the future, the effect of fine sediment on salmonid egg incubation in the Stanislaus River is expected to remain a "low" magnitude stressor, but the certainty of that characterization decreases to "minimal."

The effect of high flows that may scour redds was scored as a "low" magnitude stressor with a "low" degree of certainty in the near term. A Stanislaus Riverbed mobility analysis described in Kondolf et al. (2001) found that flows around 5,000 to 8,000 cfs are necessary to mobilize the D_{50} of the channel bed material. Therefore, for the purposes of the SEP stressor analysis, 5,000 cfs was assumed to represent a minimum flow for which redd scour may begin to be a problem. The SEP Group evaluated the frequency of flows below Goodwin Dam that were greater than 5,000 cfs during the period January 2000 to September 2014. Flows below Goodwin Dam exceeded the 5,000 cfs threshold for just two events during this period. One of those events occurred during the fall-run Chinook salmon egg incubation period (January 2006, maximum flow 6,300 cfs, duration 11 days). The other event occurred during the spring-run Chinook salmon incubation time period (April 2006, maximum flow 5,510 cfs, duration 14 days). Overall, only 1 of 14 year-classes of fall-run Chinook salmon and spring-run Chinook salmon were potentially impacted by redd scour due to high flows. Given the low frequency of flows that could scour salmon redds, this stressor is believed to have only a small effect on salmon populations. The overall certainty of this stressor in the near term is "low" due to a lack of information on the relationship in the Stanislaus River among flow, scour depth, egg burial depths, and egg survival. Presumably, egg survival at flows that just begin riverbed mobilization will be high relative to egg survival at much higher flows, but the specific relationship is not well understood.

In the long term, the effect of high flows that may scour redds is expected to remain a "low" magnitude stressor. Due to climate change, more variable precipitation is expected in the long term, with more frequent very wet periods and drought periods. Given the large storage capacity in the Stanislaus River, relative to the size of the watershed, it may be the case that the more frequent very wet periods will not result in an increase in the frequency of flows that can scour redds below New Melones and Goodwin dams. However, there is enough uncertainty involved to render the outcome certainty "minimal."

The SEP Group's analyses determined that several factors initially considered to be potential stressors on egg incubation success were likely to have "minimal" impact on successful egg incubation of fall-run Chinook salmon on the Stanislaus River. These included DO concentrations, mercury and selenium concentrations, and redd dewatering.

8.5.2.2 Spring-run Chinook Salmon

Inadequate conditions for incubation of spring-run Chinook salmon were judged to be a "high" magnitude stressor with a "high" degree of certainty in the near term (Table 62).

Unless measures are taken to improve egg incubation conditions, the stress of inadequate conditions will remain a sustained major impact on the spring-run Chinook salmon population in the long term; certainty will remain "high" (Table 62).

Table 62

Egg Incubation Stressors for Spring-run Chinook Salmon

Stress	NT M	NT C	LT M	LT C	Temperature NT	Temperature LT	DO NT	DO LT	Pesticides NT	Pesticides LT	Contaminants: Mercury, Selenium NT	Contaminants: Mercury, Selenium LT	Fine Sediments NT	Fine Sediments LT	Flow Fluctuation: Redd Dewatering NT	Flow Fluctuation: Redd Dewatering LT	Flow Fluctuation: Redd Scour NT	Flow Fluctuation: Redd Scour LT
Inadequate Incubation Conditions	3	4	4	4	M: 3 C: 4	M: 4 C: 4	M: 1 C: 4	M: 1 C: 4	M: 2 C: 2	M: 2 C: 2	M: 1 C: 4	M: 1 C: 4	M: 2 C: 2	M: 2 C: 1	M: 1 C: 3	M: 1 C: 3	M: 2 C: 2	M: 2 C: 1

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run egg incubation in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: downstream of Knights Ferry; When: early in spawning season (September – October)
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT = near term

The near-term stress score synthesizes the effect of numerous egg incubation stressors, some of which act synergistically to increase the level of impact. The effect of adverse water temperature conditions on the egg incubation stage of spring-run Chinook salmon was scored as a “medium” magnitude stressor with a “high” degree of certainty in the near term. Stanislaus River water temperatures are high relative to the SEP Group’s Environmental Objectives (Figure 16). A sustained minor population effect is expected because of repeated impacts to eggs deposited at and downstream of Knights Ferry. The effect on egg survival of exposing salmonid eggs to different temperatures has been extensively described in the scientific literature, and the water temperature objectives reflect a high scientific understanding. Given that the relationship between salmon egg survival and temperature is highly understood and predictable, a “high” certainty score is justified. Modeling predictions associated with climate change indicate elevated temperatures in the long term; thus, the effect of temperature on egg incubation in the Stanislaus River is expected to increase to a “high” magnitude stressor, and the certainty of that effect is expected to remain “high” in the future.

The overall stress on spring-run Chinook egg incubation in the Stanislaus River is elevated by the operation of other stressors in addition to that caused by temperatures. Although each of the other stressors had lower certainty scores than the temperature stressor, the likelihood that they would exacerbate temperature stress caused the SEP Group to raise the overall magnitude score to reflect high stress on spring-run egg incubation during the near term.

The effect of pesticide-derived contaminants was scored as a “low” magnitude stressor with a “low” degree of certainty in the near term. Overall, eggs and alevins developing in the Stanislaus River will have low exposures to pesticides, except for portions of the populations that are developing late in the season or in the downstream end of the spawning distribution. Exposure to toxic compounds is of some concern for spring-run alevins developing between Knights Ferry and Riverbank between August and September. Upstream of Knights Ferry and during months other than August and September, there should be minimal impacts to alevins. See description of fall-run pesticide effects in Section 8.5.2.1 for an overview of how pesticide impacts were modeled.

The effect of fine sediment on spring-run egg incubation was scored as a "low" magnitude and "low" certainty stressor when considered in isolation; however, the action of this stressor contributed to the overall stress score. In the future, the effect of fine sediment on spring-run salmon egg incubation in the Stanislaus River is expected to remain a "low" magnitude stressor, but the certainty of that characterization decreases to "minimal." See description of fine sediment effects on fall-run incubation success, in Section 8.5.2.1, for an overview of how fine sediment effects were determined.

The effect of high flows that may scour spring-run Chinook salmon redds was scored as a "low" magnitude stressor with a "low" degree of certainty in the near term. The overall certainty of this stressor in the near term is low because there is a lack of information on the relationship in the Stanislaus River among flow, scour depth, egg burial depths, and egg survival. See description of redd scour effects on fall-run incubation success, in Section 8.5.2.1, for an overview of how scour effects were determined. The magnitude of this effect on spring-run Chinook salmon incubation is expected to remain "low" in the long term, but certainty of the effect declines to "minimal."

The SEP Group's analyses determined that several factors initially thought to be potential stressors on egg incubation success were likely to have "minimal" impact on successful egg incubation of spring-run Chinook salmon on the Stanislaus River. These included DO concentrations, mercury and selenium concentrations, and redd dewatering.

8.5.2.3 O. mykiss

Inadequate incubation conditions for *O. mykiss* were judged to be a "high" magnitude stressor with a "high" degree of certainty in the near term (Table 63).

Unless measures are taken to improve egg incubation conditions, the stress of inadequate conditions will remain a sustained major impact on the *O. mykiss* population in the long term; certainty will remain "high" (Table 63).

Table 63

Egg Incubation Stressors for *O. mykiss*

Stress	NT		LT		Stressors: Temperature		DO		Pesticides		Contaminants: Mercury, Selenium		Fine Sediments		Flow Fluctuation: Redd Dewatering		Flow Fluctuation: Redd Scour	
	M	C	M	C	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT
Inadequate Incubation Conditions	3	4	4	4	M: 3 C: 4	M: 4 C: 4	M: 1 C: 4	M: 1 C: 4	M: 2 C: 2	M: 2 C: 2	M: 1 C: 4	M: 1 C: 4	M: 2 C: 2	M: 2 C: 1	M: 1 C: 3	M: 1 C: 3	M: 2 C: 2	M: 2 C: 1

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for *O. mykiss* egg incubation in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: downstream of Knights Ferry; When: after March
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT = near term

The near-term stress score synthesizes the effect of numerous egg incubation stressors, some of which act synergistically to increase the level of impact. The effect of adverse water temperature conditions on the egg incubation stage of *O. mykiss* was scored as a "medium" magnitude stressor with a "high" degree of certainty in the near term. The comparison of Stanislaus River water temperatures to the Environmental Objectives indicates that conditions for *O. mykiss* egg incubation are primarily sub-optimal (and, in some cases, detrimental) throughout much of the lower Stanislaus River from March through August (Figure 17). Given that temperatures are expected to be sub-optimal or detrimental over a large portion of the *O. mykiss* spawning habitat in the lower river throughout most of the egg incubation period, a sustained minor population effect is expected. The effect on egg survival of exposing *O. mykiss* eggs to different temperatures has been extensively described in the scientific literature (Section 7.2.4.1), and the water temperature objectives reflect a high degree of scientific understanding justifying a high certainty score. Given modeling predictions associated with climate change, the effect of temperature on egg incubation in the Stanislaus River is expected to increase to a "high" magnitude stress. A sustained major population effect is expected as temperature increases are likely to result in detrimental water temperatures for egg incubation throughout most of the life stage and most, if not all, of the lower Stanislaus River spawning habitat. The certainty of that major population effect occurring in the long term is "high."

The overall stress on *O. mykiss* egg incubation in the Stanislaus River is elevated by the operation of other stressors in addition to that caused by temperatures. Although each of the other stressors had lower certainty scores than the temperature stressor, the likelihood that they would exacerbate temperature stress caused the SEP Group to raise the overall magnitude score to reflect "high" stress on *O. mykiss* egg incubation during the near term.

The effect of pesticide-derived contaminants was scored as a "low" magnitude stressor with a "low" degree of certainty in the near term. *O. mykiss* alevins will be exposed to detrimental pesticide concentrations during March to August from Riverbank to Oakdale (Appendix C); this may adversely impact alevins that are still developing. The river between Oakdale and Knight's Ferry experiences sub-optimal conditions from December to April, but they become detrimental from May to August. See description of fall-run pesticide effects, in Section 8.5.2.1, for an overview of how pesticide impacts were modeled.

The effect of fine sediment on *O. mykiss* egg incubation was scored as a "low" magnitude and "low" certainty stressor when considered in isolation; however, the action of this stressor increased the overall stress score. In the future, the effect of fine sediment on spring-run salmon egg incubation in the Stanislaus River is expected to remain a "low" magnitude stressor, but the certainty of its effect decreases to "minimal." See description of fine sediment effects on fall-run incubation success, in Section 8.5.2.1, for an overview of how fine sediment effects were determined.

The effect of high flows that may scour redds during the *O. mykiss* egg incubation stage was scored as a "low" magnitude stressor with a "low" degree of certainty in the near term. Only 1 *O. mykiss* year-class out of 14 was potentially impacted by redd scour due to high flows. The overall certainty of this stressor in the near term is "low" because there is a lack of information on the relationship in the Stanislaus River among flow, scour depth, egg burial depths, and egg survival. See the description of red scour effects on fall-run incubation success, in Section 8.5.2.1, for an overview of how fine sediment effects were determined. The magnitude of this effect on *O. mykiss* incubation is expected to remain "low" in the long term, but certainty of the effect declines to "minimal."

The SEP Group's analyses determined that several factors initially considered to be potential stressors on egg incubation success were likely to have a "minimal" impact on successful egg incubation of Stanislaus River *O. mykiss* . These included DO concentrations, mercury and selenium concentrations, and redd dewatering.

8.5.3 Contributing Management Factors

Dams blocking access to high-elevation incubation habitats is a major factor contributing to stressors on the egg incubation process by limiting access to cold-water habitat. This effect is particularly evident for spring-run Chinook salmon and *O. mykiss*, which historically migrated to habitats beyond existing dams to spawn.

Reservoir operation is a major driver of the environmental factors that control the impact of stressors that may lead to mortality during the egg incubation life stage of salmonids. For example, flow rates and cold-water pool management regulate water temperature. In addition, the volume of water released from the reservoir will regulate sediment loads and the dilution of contaminant discharges to the river. The environmental factors that drive the failure of eggs to develop into emergent fry are coupled and work synergistically (e.g., temperature affects both DO concentration and egg/alevin demand for DO; temperature also modulates the impact of certain contaminants on developing eggs and alevin.). Additionally, flows (and fluctuations in flows) determine the availability of incubation habitat even within the area where temperatures are acceptable (e.g., scour and dewatering).

Other non-flow management practices may exacerbate or alleviate stressors on egg incubation. For example, the destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor; this can increase temperatures and primary productivity in the river. Urban and agricultural developments in the watershed have increased contaminant loads to the river and periodic fine sediment inputs. Adjustments to land use practices or the development of contaminant control programs may reduce contaminant and sediment inputs and the stress they generate on eggs and alevin. Groundwater depletions have likely terminated the hyporheic inputs that probably supplemented Stanislaus River surface flows and buffered the river against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the Stanislaus River during critical months.

8.6 Stressors on Juvenile Rearing and Migration

Juvenile rearing occurs in the salmonid life cycle after emergence from the redd and lasts until the fish leaves freshwater. Juvenile migration occurs over the same period as rearing and consists of the fish moving downstream towards the marine environment. Central Valley salmonids evolved in river systems with vast wetland habitats, including floodplains and tidal marshes that inundated during high flows in spring and summer, providing highly complex shallow-water habitats for juvenile rearing and migration (Williams 2006). These habitats have nearly all been lost in the Stanislaus River and lower San Joaquin River corridor due to changes in the hydrograph, sediment availability, and channel modification resulting from the construction of dams and levees.

The SEP Group evaluated the following six categories of stress in the near term and long term for juvenile salmonids rearing and migrating in the Stanislaus River:

- Compression of rearing and migration time window;
- Lack of suitable rearing habitat;
- Lack of suitable migratory conditions;
- Lack of suitable migratory cues;
- Lack of suitable over-summering habitat; and
- Lack of fitness/ genetic maladaptation.

Stressors to juvenile rearing include sub-optimal or detrimental ranges of water temperature, DO, flow volume, flow velocity, depth, cover, prey density, predator density, contaminants, coarse sediment input, hatchery straying, and disease. Inadequate distribution of suitable rearing habitats (i.e., along the river corridor) may also stress salmonid populations on the Stanislaus River.

Near-term stresses reflect those that would impede attainment of Environmental or Biological Objectives under current conditions. Evaluation of these stresses in the long term incorporated analysis of current conditions and assumed that juvenile salmon densities would increase substantially and that global and regional warming trends occur as anticipated (Cayan et al. 2008; Dettinger et al. 2004).

8.6.1 Current Rearing and Migration Timing Patterns

Scoring of stress is based on the potential exposure to stressors across the full range of each population's rearing and migration timing window (Figure 7). Current temporal distribution of fall-run Chinook juveniles in the Stanislaus River occurs after incubation is completed—from the end of January through June (Figure 7)—until water temperatures warm sufficiently to prevent smoltification, which usually occurs between May and July for Chinook salmon (see Figure 18). Spring-run Chinook salmon begin rearing and migration in winter, though some are known to rear longer and outmigrate the following fall, winter, or spring (Williams 2006). Spring-run are also unable to successfully migrate when water temperatures in the migratory corridor become unsuitable. For *O. mykiss*, rearing occurs year-round and includes a robust population of resident rainbow trout, which are a source population for threatened Central Valley steelhead. *O. mykiss* juveniles generally migrate during the same temporal windows as Chinook salmon. However, the anadromous steelhead life form displays tremendous behavioral plasticity that extends to migration timing (Moyle 2002; Doctor et al. 2014; Kendall et al. 2014). Because of their low population numbers and ESA listing status, little monitoring of steelhead rearing and migration has occurred on the Stanislaus River with the exception of incidental collection in RSTs and some snorkel survey observations.

8.6.2 Stress: Compression of Rearing and Migration Time Window (Juvenile Rearing and Migration)

Rearing and migration opportunities for juvenile salmonids are limited on the Stanislaus River by the deterioration of conditions in spring. This may limit the life history diversity (e.g., the timing of and body size at entry into subsequent environments) present in each annual cohort. In particular, production of larger fish and those that migrate later in the season may be limited by deteriorating conditions as the spring progresses (e.g., Zeug et al. 2014; Sturrock et al. 2015).

8.6.2.1 Fall-run Chinook Salmon

Rearing and migration opportunities for juvenile fall-run Chinook salmon are constrained by deteriorating conditions in spring. The stress on the population was rated "high" magnitude with "high" certainty in the near term (Table 64).

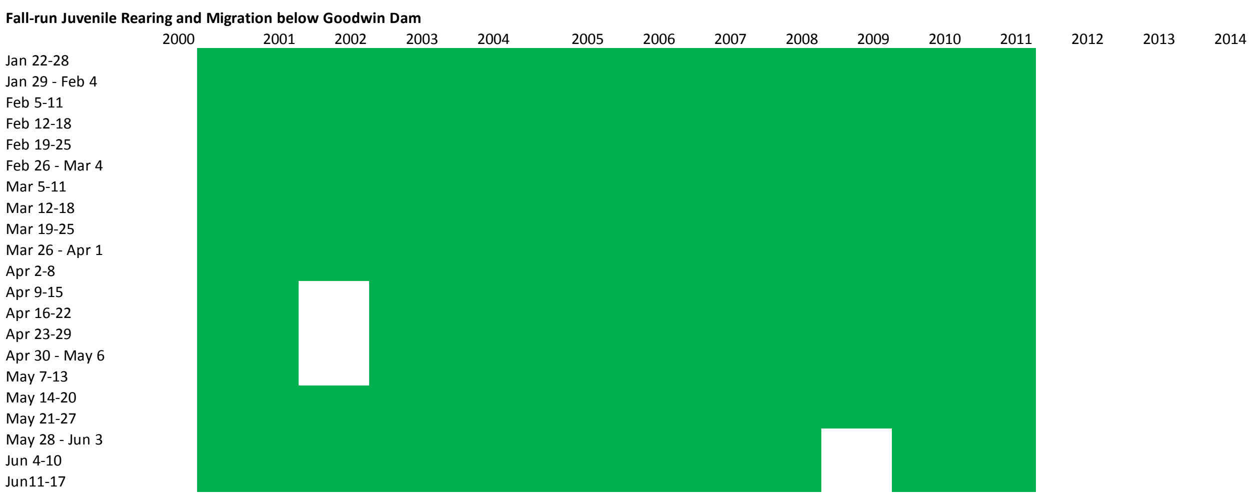
Without corrective action, temporally constrained rearing and migration opportunities will remain a "high" magnitude stress with "high" certainty over the long term (Table 64).

Table 64
Scoring Stressors for Juvenile Rearing and Migration of Fall-run Chinook Salmon

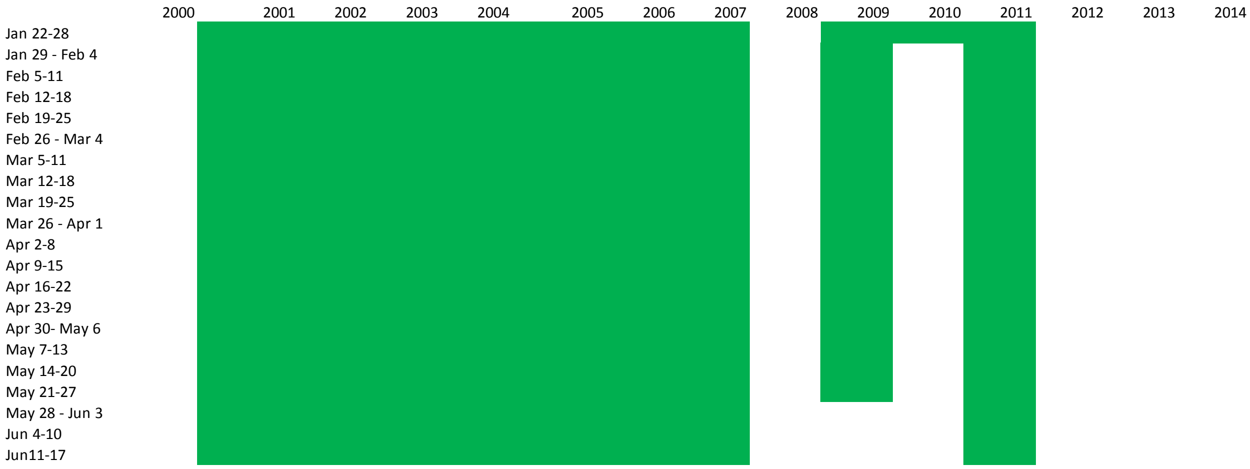
Stress	NT M	NT C	LT M	LT C	When	Temperature NT	Temperature LT	DO NT	DO LT	Flow Volume NT	Flow Volume LT	Velocity NT	Velocity LT	Turbidity NT	Turbidity LT	Depth NT	Depth LT	Cover NT	Cover LT	Prey Density NT	Prey Density LT	Predator Density NT	Predator Density LT	Contaminants NT	Contaminants LT	Coarse Sediment Input NT	Coarse Sediment Input LT	Hatchery Straying NT	Hatchery Straying LT	Disease NT	Disease LT	Habitat Distribution NT	Habitat Distribution LT
Compression of rearing and migration time window	4	4	4	4	Apr-July	M: 4 C: 4	M: 4 C: 4	M: 2 C: 3	M: 3 C: 3																								
Lack of suitable rearing habitat	4	4	4	4	Jan-Jun	M: 3 C: 4	M: 4 C: 4	M: 1 C: 2	M: 1 C: 2	M: 4 C: 3	M: 4 C: 4	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 3 C: 3	M: 3 C: 3	M: 3 C: 3	M: 3 C: 3	M: 2 C: 2	M: 3 C: 2	M: 3 C: 2	M: 3 C: 2	M: 4 C: 3	M: 4 C: 3	M: 4 C: 4	M: 4 C: 4			M: 2 C: 2	M: 3 C: 2	M: 3 C: 2	M: 4 C: 2
Lack of suitable migratory conditions	4	4	4	4	Jan-Jun	M: 3 C: 4	M: 4 C: 4	M: 1 C: 2	M: 1 C: 2	M: 4 C: 3	M: 4 C: 4	M: 3 C: 2	M: 3 C: 2	M: 2 C: 2	M: 2 C: 2	M: 3 C: 3	M: 3 C: 2	M: 3 C: 2	M: 3 C: 2	M: 2 C: 2	M: 3 C: 2	M: 3 C: 1	M: 3 C: 1	M: 2 C: 3	M: 2 C: 3	M: 4 C: 2	M: 4 C: 2						
Lack of suitable migratory cues	4	3	4	3	Jan-Jun	M: 3 C: 2	M: 4 C: 2	M: 1 C: 1	M: 1 C: 1	M: 4 C: 3	M: 4 C: 3	M: 4 C: 3	M: 4 C: 3	M: 3 C: 2	M: 2 C: 2					M: 2 C: 2	M: 3 C: 2												
Lack of suitable over-summering habitat	1	3	2	3	May-Sep	M: 1 C: 3	M: 2 C: 3	M: 1 C: 1	M: 1 C: 1	M: 1 C: 2	M: 2 C: 2	M: 1 C: 2	M: 2 C: 2	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1	M: 2 C: 1	M: 2 C: 1	M: 2 C: 2	M: 3 C: 2	M: 2 C: 2	M: 2 C: 2	M: 1 C: 2	M: 1 C: 2								
Lack of fitness/ genetic maladaptation	4	3	4	3	Jan-Jun																							M: 4 C: 4	M: 4 C: 3				

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run juvenile migration and rearing in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Whole river
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term
NT = near term

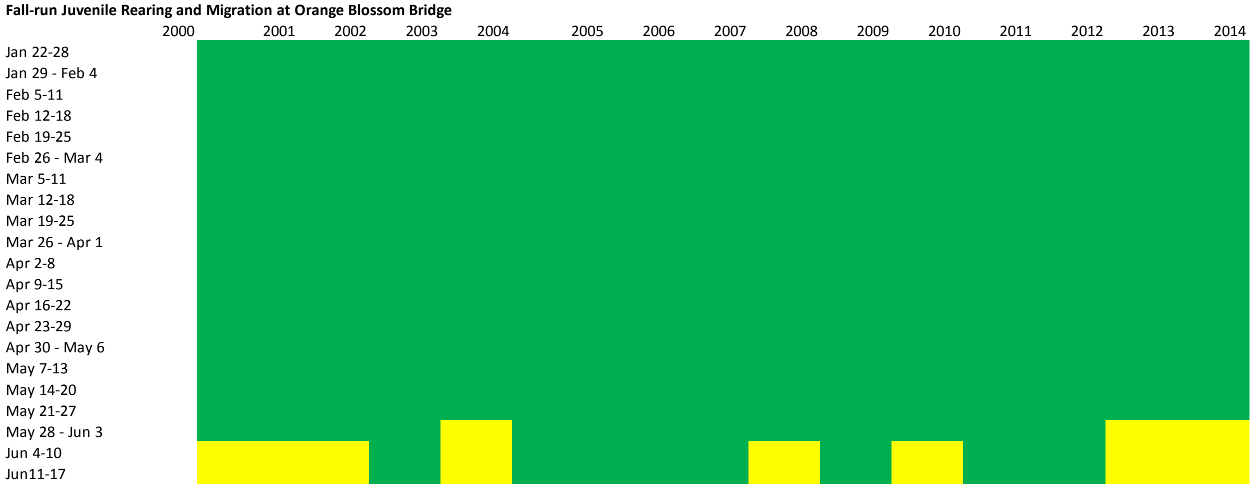
The residence time in freshwater of fall-run Chinook salmon migrating from the Stanislaus River is constrained by water temperature. Warm water temperatures in spring and early summer can prevent smoltification (e.g., Marine and Cech, 2004; Section 7.2.5.1.2), truncating the time in freshwater. Although, larger juveniles are typically better able to avoid predators, recent studies on the Stanislaus River show parr-sized juvenile outmigrants had a higher rate of return as adults than either fry- or smolt-sized outmigrants (Sturrock et al. 2015). It is believed that smolt-sized fish from the Stanislaus die at a higher rate because they are unable to physiologically adapt to salt water (smoltify) due to high water temperatures (Appendix C, Table C-2). Sub-optimal temperatures for smoltification (17°C to 20°C 7DADM [62.6°F to 68°F]) are common during June at Orange Blossom Bridge and points downstream, and they begin to occur in March at Ripon and downstream (Figure 18). Detrimental temperatures are common starting in June at Ripon and by mid to late May at Vernalis. Adding to the stress caused by high temperatures, migrating fall-run Chinook salmon are also negatively affected by sub-optimal DO levels at Ripon and Vernalis that become more frequent later in the spring (Figure 18).



Fall-run Juvenile Rearing and Migration at Knights Ferry



Fall-run Juvenile Rearing and Migration at Orange Blossom Bridge



Fall-run Juvenile Rearing and Migration at Oakdale

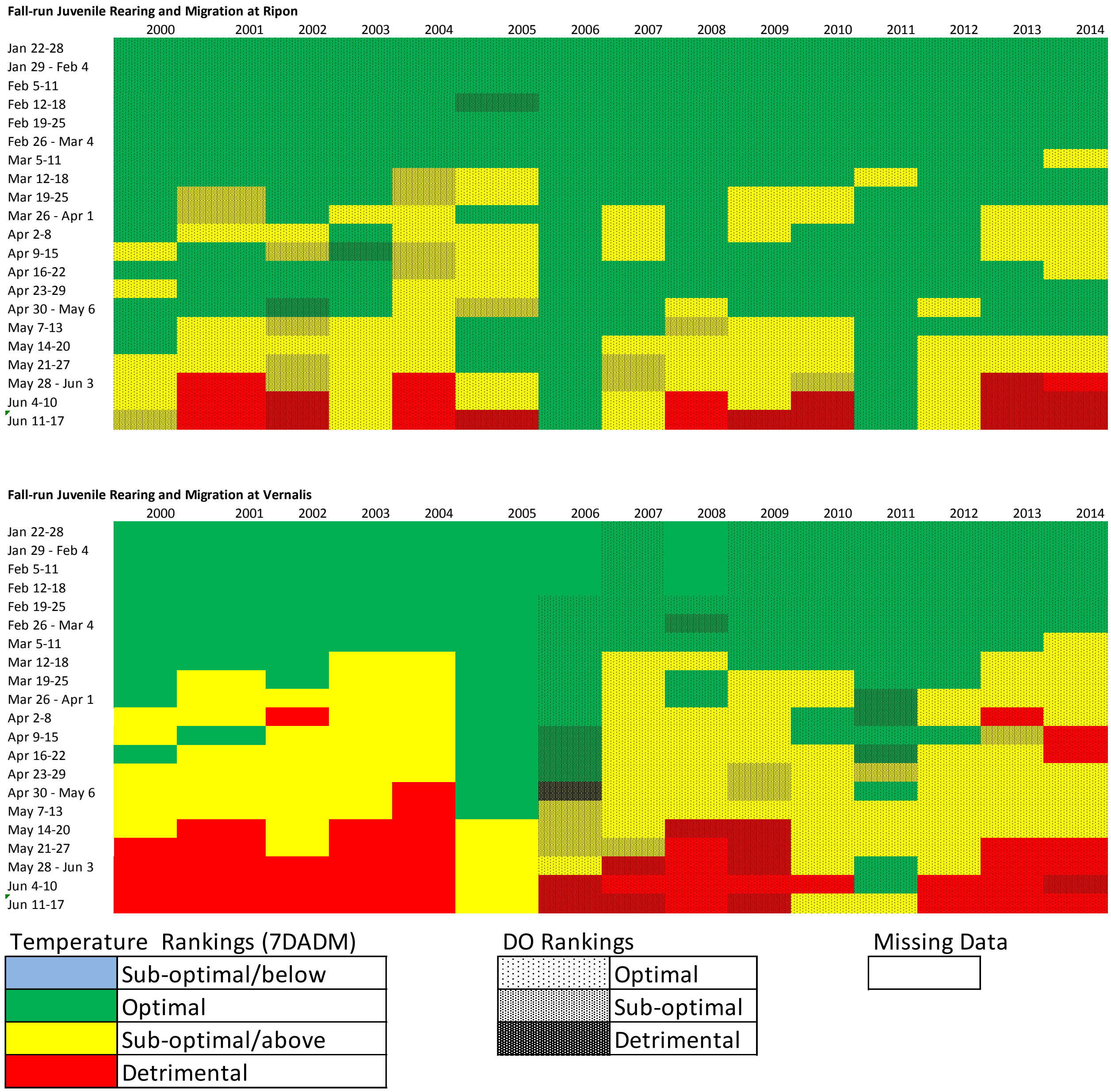


Figure 18

Juvenile Rearing and Migration for Fall-run Chinook Salmon

Notes:
Temperature and DO rankings based on observed data during periods of juvenile rearing and migration. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

In the near term, this truncation of the juvenile migration window represents a sustained, major population-level effect on life history diversity of outmigrants from the Stanislaus River. In the long term, warming associated with climate change is likely to maintain this stress as a result of increases in water temperature (Cayan et al. 2008; Dettinger et al. 2004) and corresponding potential decreases in DO.

8.6.2.2 Spring-run Chinook Salmon

Rearing and migration opportunities for juvenile spring-run Chinook salmon are constrained by deteriorating conditions in the spring. The stress on the population was rated "medium" magnitude with "high" certainty in the near term (Table 65).

Without corrective action, temporally constrained rearing and migration opportunities will remain a "medium" magnitude stress with "high" certainty over the long term (Table 65).

Table 65

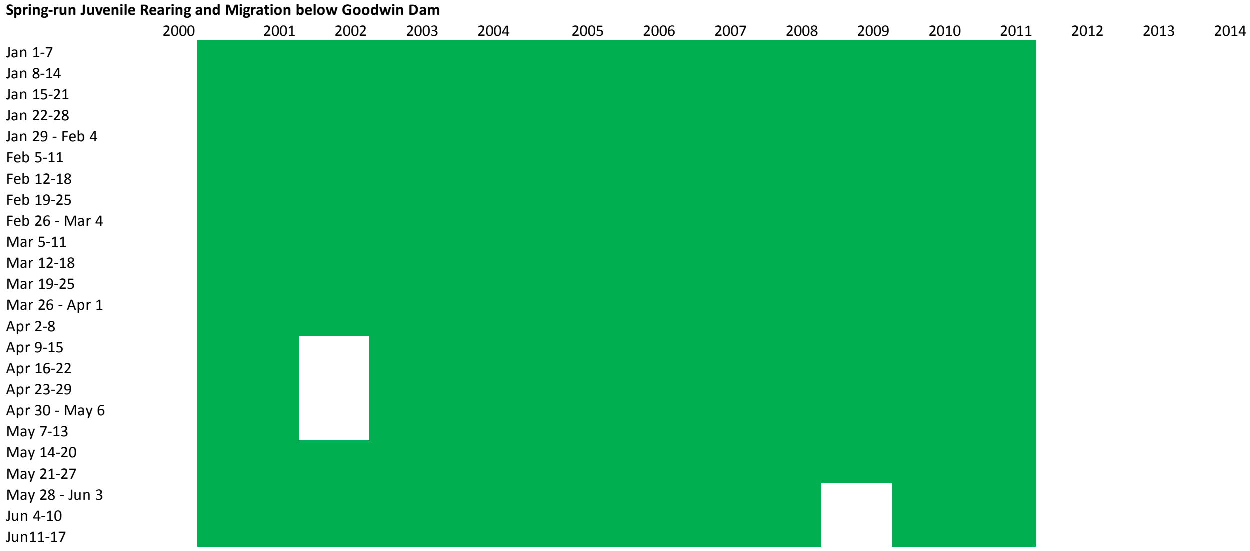
Scoring Stressors for Juvenile Rearing and Migration of Spring-run Chinook Salmon

						Stressors																											
	NT		LT		When	Temperature		DO		Flow Volume		Velocity		Turbidity		Depth		Cover		Prey Density		Predator Density		Contaminants		Coarse Sediment Input		Hatchery Straying		Disease		Habitat Distribution	
Stress	M	C	M	C		NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT
Compression of rearing and migration time window	3	4	3	4	Apr-July	M: 3 C: 4	M: 3 C: 4	M: 1 C: 2	M: 1 C: 2																								
Lack of suitable rearing habitat	4	4	4	4	Jan-Jun	M: 3 C: 3	M: 4 C: 3	M: 1 C: 2	M: 1 C: 2	M: 4 C: 3	M: 4 C: 4	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 3 C: 3	M: 3 C: 3	M: 3 C: 3	M: 3 C: 3	M: 2 C: 1	M: 2 C: 1	M: 3 C: 2	M: 3 C: 2	M: 4 C: 3	M: 4 C: 3	M: 4 C: 4	M: 4 C: 4			M: 2 C: 2	M: 3 C: 2	M: 3 C: 2	M: 4 C: 2
Lack of suitable migratory conditions	4	4	4	4	Jan-Jun	M: 3 C: 4	M: 4 C: 4	M: 1 C: 2	M: 1 C: 2	M: 4 C: 3	M: 4 C: 4	M: 3 C: 2	M: 3 C: 2	M: 2 C: 2	M: 2 C: 2	M: 3 C: 3	M: 3 C: 3	M: 3 C: 2	M: 3 C: 2	M: 2 C: 1	M: 2 C: 1	M: 3 C: 1	M: 3 C: 1	M: 2 C: 3	M: 2 C: 3	M: 4 C: 2	M: 4 C: 2						
Lack of suitable migratory cues	4	3	4	3	Jan-Jun	M: 4 C: 3	M: 4 C: 2	M: 1 C: 1	M: 1 C: 1	M: 4 C: 3	M: 4 C: 3	M: 4 C: 3	M: 4 C: 3	M: 3 C: 2	M: 2 C: 2																		
Lack of suitable over-summering habitat	1	3	3	3	May-Sep	M: 1 C: 3	M: 2 C: 3	M: 1 C: 1	M: 1 C: 1	M: 1 C: 2	M: 2 C: 2	M: 1 C: 2	M: 2 C: 2	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1	M: 1 C: 1	M: 2 C: 1	M: 2 C: 1			M: 2 C: 2	M: 2 C: 2	M: 3 C: 3	M: 3 C: 3					M: 1 C: 1	M: 1 C: 1		
Lack of fitness/ genetic maladapt-ation	1	1	3	3	Jan-Jun	M: 1 C: 3	M: 3 C: 3	M: 1 C: 3	M: 1 C: 3																			M: 1 C: 1	M: 3 C: 3				

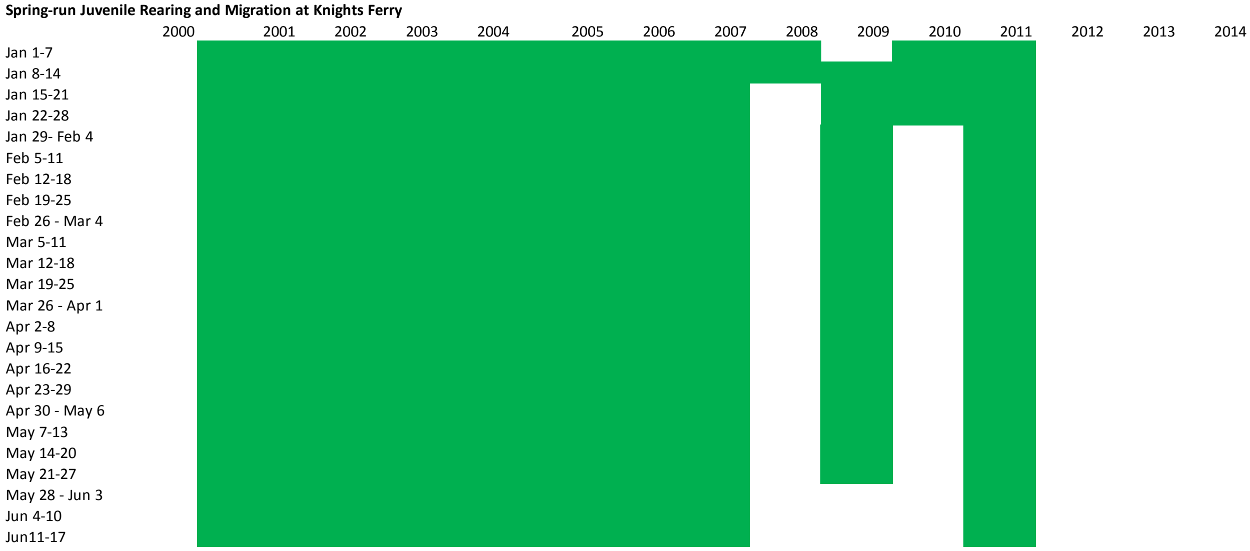
Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run juvenile rearing and migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Whole river
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4 = High
3 = Medium
2 = Low
1 = Minimal
LT = long term; NT = near term

Similar to fall-run Chinook salmon, successful spring-run juvenile migration will be constrained by warm temperatures that impair or prevent smoltification in the near term (Figure 19). The magnitude of this stressor is expected to be less than that for fall-run, since spring-run smolts tend to migrate slightly earlier than fall-run (Moyle 2002; Williams 2006). The certainty of this stress is "high" based on the SEP Group's understanding of the impacts of high temperature and low DO on migrating juvenile Chinook salmon, robust temperature and DO data, and recent publications regarding impairment to late-outmigrating Chinook salmon on the Stanislaus River (Zeug et al. 2014; Sturrock et al. 2015).

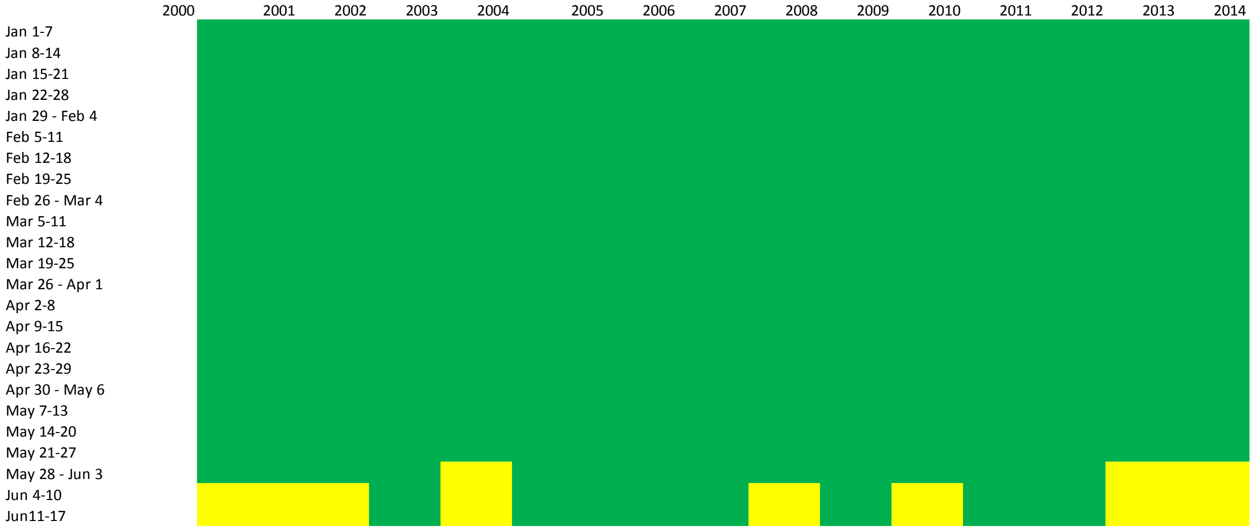
Spring-run Juvenile Rearing and Migration below Goodwin Dam



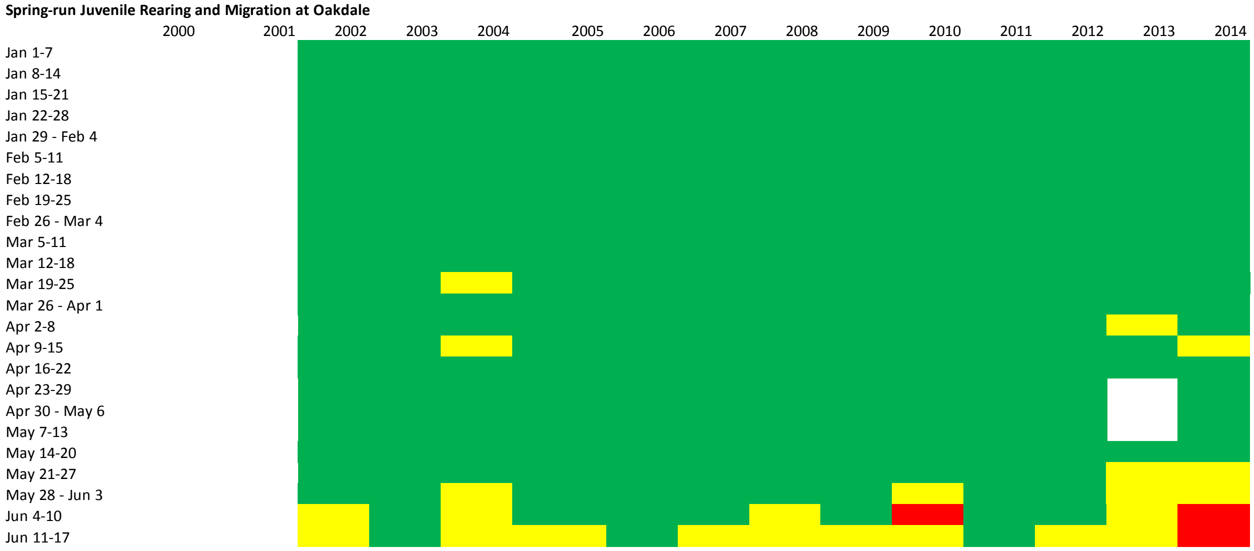
Spring-run Juvenile Rearing and Migration at Knights Ferry



Spring-run Juvenile Rearing and Migration at Orange Blossom Bridge



Spring-run Juvenile Rearing and Migration at Oakdale



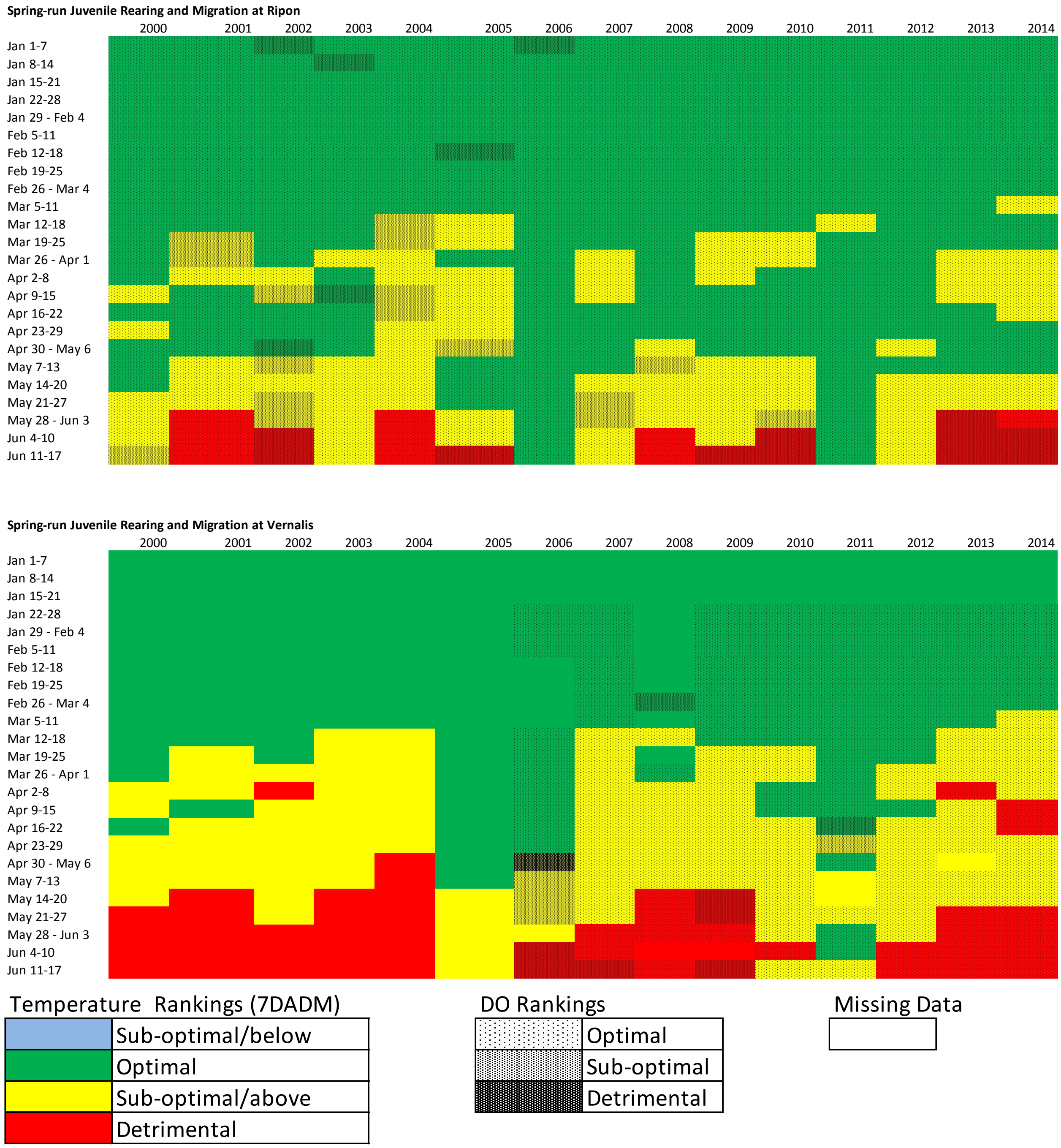


Figure 19

Juvenile Rearing and Migration for Spring-run Chinook Salmon

Notes:
Temperature and DO rankings based on observed data during periods of juvenile rearing and migration. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

8.6.2.3 O. mykiss

Temperatures that impair smoltification in a way that compresses the time window available for migration were rated “low” magnitude with “low” certainty for *O. mykiss* in the near term (Table 66).

Without corrective actions, temporally constrained smoltification opportunities will remain a “medium” magnitude stress for *O. mykiss* in the long term; in addition, without better understanding of the timing and duration of exposure to low temperatures that are required to support smoltification, certainty will remain “Low” (Table 66).

Table 66

Scoring Stressors for Juvenile Rearing and Migration of *O. mykiss*

	NT		LT			Stressors																									
						Temperature		DO		Flow Volume		Velocity		Turbidity		Depth		Cover		Prey Density		Predator Density		Contaminants		Coarse Sediment Input		Hatchery Straying		Disease	
Stress	M	C	M	C	When	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT	NT	LT
Compression of rearing and migration time window	2	2	2	2	Apr-July	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2	M: 2 C: 2																						
Lack of suitable rearing habitat	4	4	4	4	Jan-Dec	M: 1 C: 4	M: 2 C: 4	M: 1 C: 2	M: 1 C: 2	M: 4 C: 3	M: 4 C: 4	M: 4 C: 3	M: 4 C: 4	M: 2 C: 2	M: 2 C: 2	M: 3 C: 3	M: 3 C: 3	M: 3 C: 3	M: 3 C: 3	M: 2 C: 1	M: 2 C: 1	M: 3 C: 2	M: 3 C: 2	M: 4 C: 3	M: 4 C: 3	M: 4 C: 4	M: 4 C: 4			M: 2 C: 2	M: 3 C: 2
Lack of suitable migratory conditions	4	4	4	4	Jan-Dec	M: 2 C: 4	M: 2 C: 4	M: 1 C: 2	M: 1 C: 2	M: 4 C: 3	M: 4 C: 4	M: 4 C: 3	M: 4 C: 4	M: 2 C: 2	M: 2 C: 2	M: 3 C: 3	M: 3 C: 3	M: 3 C: 2	M: 3 C: 2	M: 2 C: 1	M: 2 C: 1	M: 3 C: 1	M: 3 C: 1	M: 2 C: 3	M: 2 C: 3	M: 4 C: 2	M: 4 C: 2				
Lack of suitable migratory cues	4	3	4	3	Jan-Jun	M: 4 C: 2	M: 4 C: 2	M: 1 C: 1	M: 1 C: 1	M: 4 C: 3	M: 4 C: 3	M: 4 C: 3	M: 4 C: 3	M: 3 C: 2	M: 2 C: 2					M: 3 C: 1	M: 3 C: 1										
Lack of suitable over-summering habitat	1	4	1	4	May-Sep	M: 1 C: 4	M: 1 C: 4	M: 1 C: 1	M: 1 C: 1	M: 1 C: 2	M: 2 C: 2	M: 1 C: 2	M: 2 C: 2	M: 1 C: 1	M: 1 C: 1	M: 3 C: 2	M: 3 C: 2	M: 2 C: 1	M: 2 C: 1	M: 3 C: 1	M: 3 C: 1	M: 2 C: 2	M: 2 C: 2	M: 3 C: 3	M: 3 C: 3	M: 3 C: 1	M: 3 C: 1				
Lack of fitness/ genetic maladaptation	3	1	3	1	Jan-Dec																							M: 3 C: 1	M: 3 C: 1		

Notes:

– Stress and stressors (i.e., contributing factors to a particular stress) for *O. mykiss* juvenile rearing and migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.

– Location: Whole river

– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.

– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.

Scoring:

4 = High

3 = Medium

2 = Low

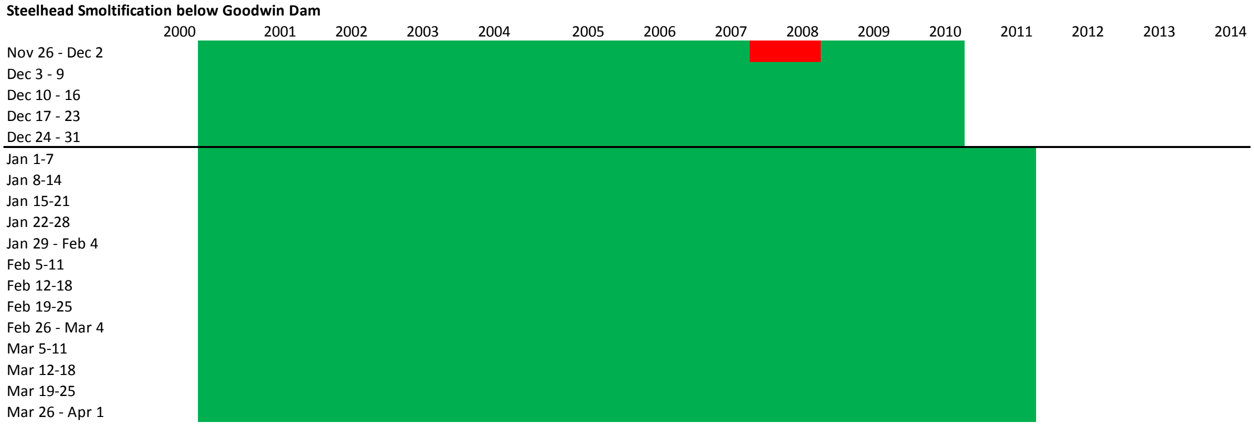
1 = Minimal

LT = long term

NT = near term

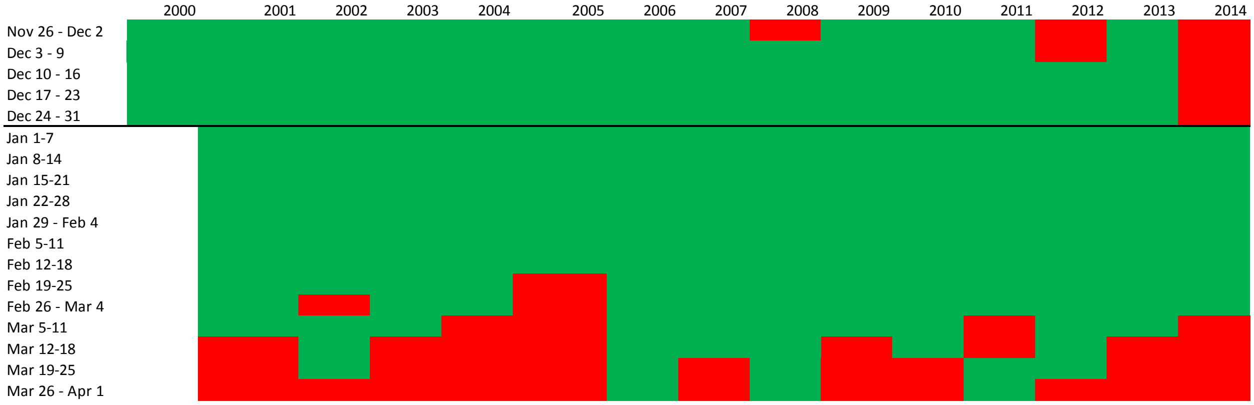
Steelhead smoltification requires exposure to temperatures colder than those required by Chinook salmon (Appendix C, Table C-6); *O. mykiss* will not metamorphose into anadromous smolts unless they are exposed to temperatures less than 11°C (51.8°F) during the winter prior to outmigration (Myrick and Cech 2005). *O. mykiss* juveniles can tolerate substantially higher temperatures later in their migration phase (Appendix C, Table C-5). Temperatures that impair steelhead smoltification occur through most of March at Orange Blossom Bridge and are common after mid February at Ripon; *O. mykiss* in those areas of the river at those times are unlikely to smoltify, but fish may experience suitable temperatures to initiate smoltification upstream of Orange Blossom Bridge and at locations downstream earlier in winter (Figure 20). The literature is not clear regarding the precise duration and timing of exposure required to support subsequent smoltification among *O. mykiss*—thus, the certainty related to compression of the rearing and migration window is low. Research is needed to identify the necessary timing, duration, and location of exposure to temperatures that allow for smoltification among *O. mykiss*.

Steelhead Smoltification below Goodwin Dam



Steelhead Smoltification at Knights Ferry

Steelhead Smoltification at Orange Blossom Bridge



Steelhead Smoltification at Oakdale

Steelhead Smoltification at Ripon

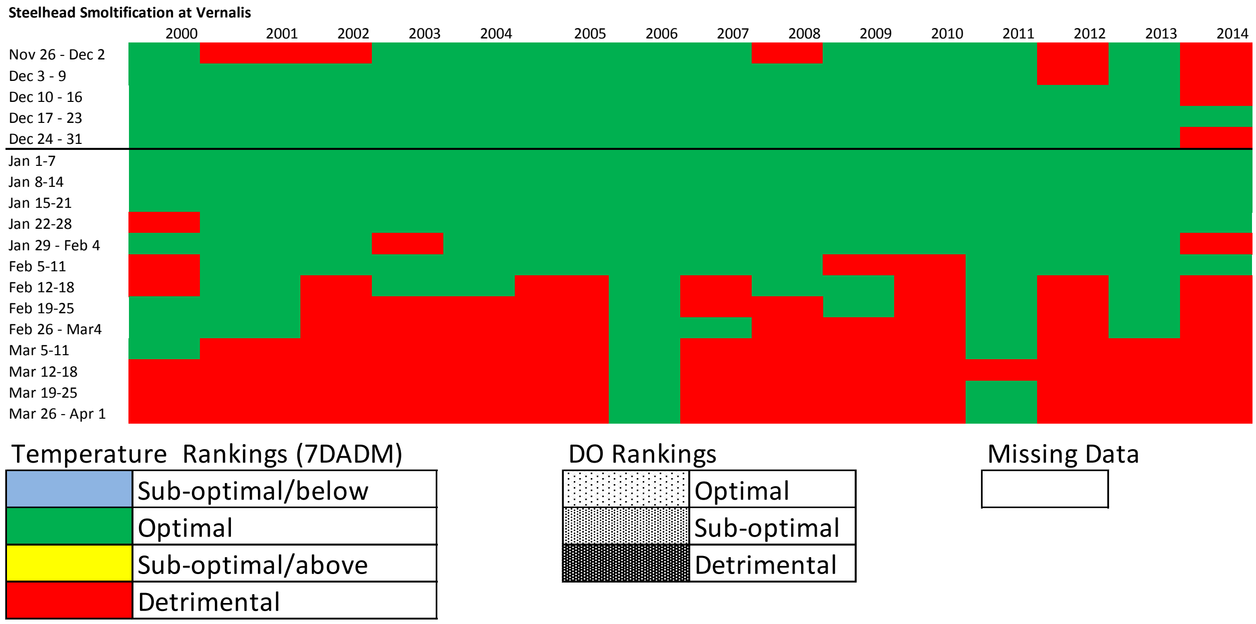


Figure 20

Steelhead Smoltification

Notes:
Temperature and DO rankings based on observed data during peak periods of steelhead smoltification. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

8.6.3 Stress: Lack of Suitable Rearing Habitat (Juvenile Rearing and Migration)

Inadequate rearing habitat can limit the productivity of salmonid populations. Historically, the Central Valley had extensive, seasonally inundated, shallow-water habitat that allowed for salmonid rearing (TBI 1998; Moyle 2002; Williams 2006). This habitat is associated with increased growth and survival of juvenile salmonids (e.g., Sommer et al. 2001b, 2004, 2005; Jeffres et al. 2008) as is shallow side channel habitat (Appendix A of NMFS 2014). Most of these historic shallow-water rearing habitats have been eliminated throughout the Central Valley. In the Stanislaus River, in particular, recent modeling suggests currently available wetted floodplain is a small fraction of the estimated acreage of functional inundated habitat the SEP Group estimates is necessary to support current or future populations (Section 7.2.5.5.6) and a small fraction of the area originally available in the watershed.

8.6.3.1 Fall-run Chinook Salmon

Current estimates show that the Stanislaus River has a deficit of suitable rearing habitat even at current population levels. Therefore, lack of adequate space with suitable conditions for rearing along the Stanislaus River corridor is a "high" magnitude and "high" certainty stress in the near term (Table 64).

Without corrective action, factors that led to the current lack of rearing habitat will increase in intensity; in addition, the population of juveniles requiring rearing space is expected to increase. As a result, stress imposed by lack of suitable rearing space will remain "high" magnitude, with "high" certainty in the long term (Table 64).

Fall-run Chinook salmon lack access to suitable rearing habitat on the Stanislaus River. The SEP Group estimates that current fall-run Chinook salmon populations on the Stanislaus River require 69 acres of functional inundated habitat (Section 7.2.5.5). Applying a correction for habitat suitability developed for the San Joaquin River Restoration Program (SJRRP 2012), this translates into a need for 230 to 986 total wetted acres. Modeling by FlowWest indicates that currently available wetted floodplain is approximately 133 acres.[10] In other words, even if the percentage of suitable habitat per acre of wetted floodplain on the Stanislaus River were equivalent to the high end of the suitability range observed on the San Joaquin River (30%), the current acreage would still represent only approximately 58% of what is necessary to support current salmon populations. This strongly suggests that fall-run Chinook salmon juveniles lack adequate off-channel rearing habitat and survival rates in the Stanislaus River and downstream are negatively impacted by this lack of habitat.

Salmon populations are expected to grow in the near term and long term, and these larger populations will require more rearing habitat. SEP Group objectives call for 707 acres of functional inundated rearing habitat to support future populations; using the conversions developed by the SJRRP (2012), this suggests the need for between approximately 2,360 acres and 10,100 acres of actual inundated floodplain (Section 7.2.5.5). Currently available habitat

[10] FlowWest SRH2d Model, Available from: http://public.tableau.com/profile/mark.tompkins#!/vizhome/20160203_CVPIA_Floodplain/Floodplain

is less than 6% of the habitat required, even under the best case for the relationship between wetted floodplain area and quality rearing habitat.

The frequency and extent of inundation of off-channel habitats have decreased substantially on the Stanislaus River as a result of several fundamental changes. Construction of dams on the Stanislaus River block the supply of alluvial sediment, resulting in scour of the main channel bed. Reservoir operations greatly reduced channel-forming flows, which led to steep armored banks. The combination of armored banks and an incised channel increased the volume of flow necessary to connect the river to riparian floodplains and side channels (Kondolf 1997; Furniss et al. 2004; Grant 2012). These effects, combined with levee construction and flattening of the hydrograph (i.e., limiting magnitude and variation in river flows), have disconnected the river and rearing salmonids from important floodplain and side channel habitats. Finally, there is inadequate distribution of shallow productive habitats along the river's course; most of the available habitats of this type are located upstream of Orange Blossom Bridge, resulting in very few rest areas, predator avoidance pathways, or rearing opportunities in the lower half of the Stanislaus River and in the lower San Joaquin River downstream of its confluence with the Stanislaus River.

In-stream rearing habitat has also been degraded by channel modifications (e.g., former gravel pits), flow modifications, and lack of cover (i.e., structure and turbidity). Disconnection of the channel from the floodplain also increases the percentage of fine sediments (i.e., sand and silt) in gravel beds. This degrades in-channel rearing opportunities, as preferred food items (drifting macroinvertebrates) are replaced by less favorable, sand-dwelling species. Loss of high-quality in-channel and off-channel habitats has left juveniles vulnerable to predators in most years.

How the SEP Group Addressed Predation Stress on Juvenile Salmonids

In recent forums where management of Central Valley fishes are considered and in the media, much attention has focused on the need to reduce "predation" on native fishes, including salmonids. These discussions have focused on what are perceived to be high rates of predation on native fishes, especially by a suite of non-native predatory fishes (e.g., striped bass and species in the family centrarchidae; Lindley and Mohr 2003; Cavallo et al. 2012; for a review, see Grossman et al. 2013).

Predation is a natural process. In natural populations, more juveniles are produced than can survive, and predation eliminates many less fit individuals (Darwin 1861). In the absence of large egg or fish kills caused by disease and/or lethal water quality conditions, predation is almost always the proximate mechanism for juvenile salmon mortality (and, by extension, for natural selection). The observation that predation rates are "too high" in a river is really the same as saying that survival is "too low" to achieve some Biological Objective. Therefore, the SEP Group's productivity objectives (i.e., improvements in survival rates) are intimately tied to creating conditions that will reduce predation; specifically, the Environmental Objectives describe habitat conditions that favor juvenile salmon survival over predator success.

Predation is the interaction of the following:

- "Predation susceptibility," which is a function of factors including:
  - Juvenile salmon size,
  - Juvenile salmon condition,
  - Juvenile salmon abundance,
  - Life history diversity across the population,
  - Habitat conditions that expose juveniles to predators, and
  - Habitat conditions that support evolutionarily-developed predator avoidance mechanisms of juvenile salmon
- "Predation pressure", which is a function of factors including:
  - Predator density
  - Predator activity/metabolic rates
  - Habitat conditions that drive activity/metabolic rates (e.g., temperature)

In general (and not coincidentally), environmental conditions that favor juvenile salmon survival tend to reduce rates of predation; this occurs because optimal habitat conditions reduce both predation susceptibility and pressure. The SEP Group's Environmental Objectives define optimal, sub-optimal, and detrimental habitat conditions for each target population in ways that account for the effect of habitat conditions on predator susceptibility and on the predators themselves. For example, optimal temperatures for Chinook salmon are those that also tend to suppress predator metabolism, particularly for non-native, warm-water predators (e.g., fish in the family centrarchidae). Thus, attaining optimal levels of environmental conditions will create habitats that reduce predation susceptibility and predation pressure.

The SEP Group included "predator density" in its stressor rankings for juvenile rearing because there is no Environmental Objective for "predator density." Theoretically, such an objective could be set using bioenergetic models and assumptions regarding habitat conditions (e.g., temperature, turbidity) in each reach, but stressor reduction would still require progress towards meeting the other habitat objectives. It should be noted that progress towards attaining all the Environmental Objectives relevant to juvenile rearing and migration will naturally reduce predator density over time (i.e., less predation equals reduced biomass of predators). Nevertheless, the SEP Group scored predator density levels as a stressor because there are other, more immediate means of reducing predator density (e.g., removal of unnatural structures where predators tend to aggregate, direct predator removal, expansion of habitat area) that may be proposed as conservation measures to benefit salmon migration and rearing on the Stanislaus River.

Contaminants are also a major stressor on habitat quality for migrating and rearing fall-run Chinook salmon. Pesticides and herbicides can disrupt the salmonid food web through direct mortality of plants and invertebrates, reducing growth of juvenile fish. Pesticides and herbicides may also reduce feeding efficiency and disrupt salmon olfaction and, as a result, the ability of surviving outmigrants to return to natal waters as adults (Appendix C, Section 1.3.3.1). Metabolic costs of detoxifying contaminants can retard growth rates. Cumulative pesticide exposure of salmon in the Stanislaus River (Hoogeweg et al. 2011) is sub-optimal throughout the year between Knights Ferry and Caswell State Park (and likely further downstream); exposure reaches levels that are detrimental (primarily through their effect on juvenile olfaction) by March at Knights Ferry and points downstream (Appendix C, Figure C-1 and Table C-13).

High temperatures currently impact fall-run Chinook salmon rearing. Chinook salmon tolerate and can even benefit from temperatures up to approximately 25°C (77°F) in off-channel habitat with high food production. In the absence of habitats with slow moving water and high prey densities, temperatures close to 25°C (77°F) are detrimental to rearing fish (Section 7.2.5.1). As shown on Figure 18, temperatures become sub-optimal for rearing and migrating fall-run Chinook salmon by June at Orange Blossom Bridge and points downstream; temperatures are sub-optimal in April of most years at Ripon and by late March at Vernalis. Temperatures become detrimental to rearing and migrating salmon by late May at Ripon. Unless shallow, slow-moving, and prey-dense habitats (in which salmon can tolerate higher temperatures) are created, these conditions will be exacerbated by regional warming trends in the long term.

As part of the stressor evaluation and prioritization process, the SEP Group assumed that habitat extent in the future would permit fall-run Chinook salmon populations to increase to levels associated with larger planning goals, such as CVPIA/AFRP production targets. Attainment of those targets is not a Biological Objective for the Stanislaus River because attainment relies on changes to habitat conditions beyond the Stanislaus; however, provision of habitat space necessary to support those production levels is an Environmental Objective for the Stanislaus River (Section 7.2.5.5). Producing the number of juveniles that would be consistent with Central Valley Goals and Objectives for the Stanislaus River would generate increased demand for quality juvenile rearing habitat. Thus, there is high certainty that habitat limitations will persist in the future unless management actions to increase habitat availability are implemented.

8.6.3.2 Spring-run Chinook Salmon

Lack of rearing habitat for juvenile spring-run Chinook salmon is a "high" magnitude, "high" certainty stress to recovering spring-run Chinook salmon populations in the near term (Table 65).

Without corrective action, lack of rearing habitat will remain a "high" magnitude stress with "high" certainty in the long term (Table 65).

All of the same stressors limiting availability of suitable rearing habitat described for fall-run Chinook salmon apply to spring-run. Spring-run juveniles are expected to begin migrating earlier than fall-run, and thus, some fraction of their population may avoid the most severe impacts of stressors like high temperature and pesticide concentrations. However, the current limits on high-quality rearing habitat space and the increased demand for that space in the future will create stress that impedes the recovery of spring-run Chinook salmon on the Stanislaus River.

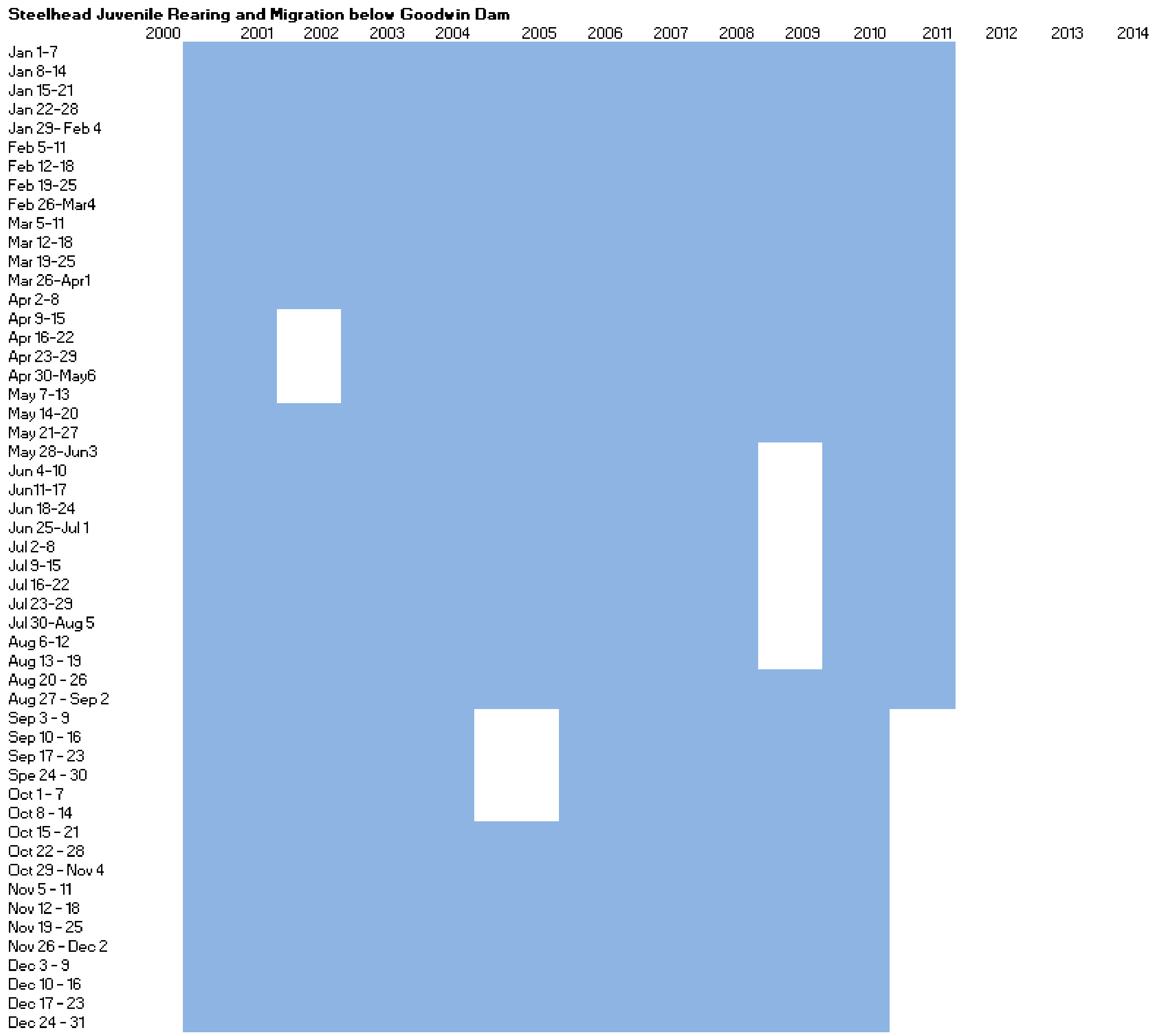
8.6.3.3 O. mykiss

Lack of rearing habitat for juvenile *O. mykiss* is a "high" magnitude, "high" certainty stress to recovering steelhead populations in the near term (Table 66).

Without corrective action, lack of rearing habitat will remain a "high" magnitude stress with "high" certainty in the long term (Table 66).

Production of anadromous phenotypes in the local *O. mykiss* population is likely to be discouraged by a lack of adequate food resources to promote rapid somatic growth. The degree of anadromy in *O. mykiss* populations is dependent on juvenile growth rates; faster individual growth rates are associated with greater anadromy (Satterthwaite et al. 2010; Kendall et al. 2014). Factors that limit inundation of shallow habitats (e.g., floodplains, side channels, riparian margins)—which export productivity to in-channel habitats; formation and maintenance of in-channel bars; and limited in-channel productivity (lack of coarse sediment input, pesticides and other contaminants)—reduce availability of and access to dense food supplies. Similarly, throughout half the year, pesticide concentrations are high enough to impair juvenile olfactory abilities at levels that would be detrimental to population growth rates; they are sub-optimal in the other 6 months of the year (Hoogeweg et al. 2011; see Appendix B, Section 1.3.3.1, Figure B-1, and Table B-13).

In contrast to Chinook salmon, temperatures in the Stanislaus River are optimal for rearing and migrating *O. mykiss*, at least between Orange Blossom Bridge and Oakdale (and probably several RMs on either side of those gage locations) from mid May to early October (Figure 21). Previously, we described the onset of temperatures that may limit smoltification in steelhead (greater than 11°C (51.8°F) from December through March; Section 8.6.2); however, (prior to or after smoltifying) rearing and migrating *O. mykiss* can experience optimal conditions at higher temperatures than Chinook salmon. Temperatures rarely exceed the *O. mykiss* rearing and migration optimal threshold at Oakdale or upstream; indeed, the persistence of temperatures lower than the *O. mykiss* optimum may represent a lack of an important migration cue (Migration cues are discussed in Section 8.6.5.)


Steelhead Juvenile Rearing and Migration below Goodwin Dam
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
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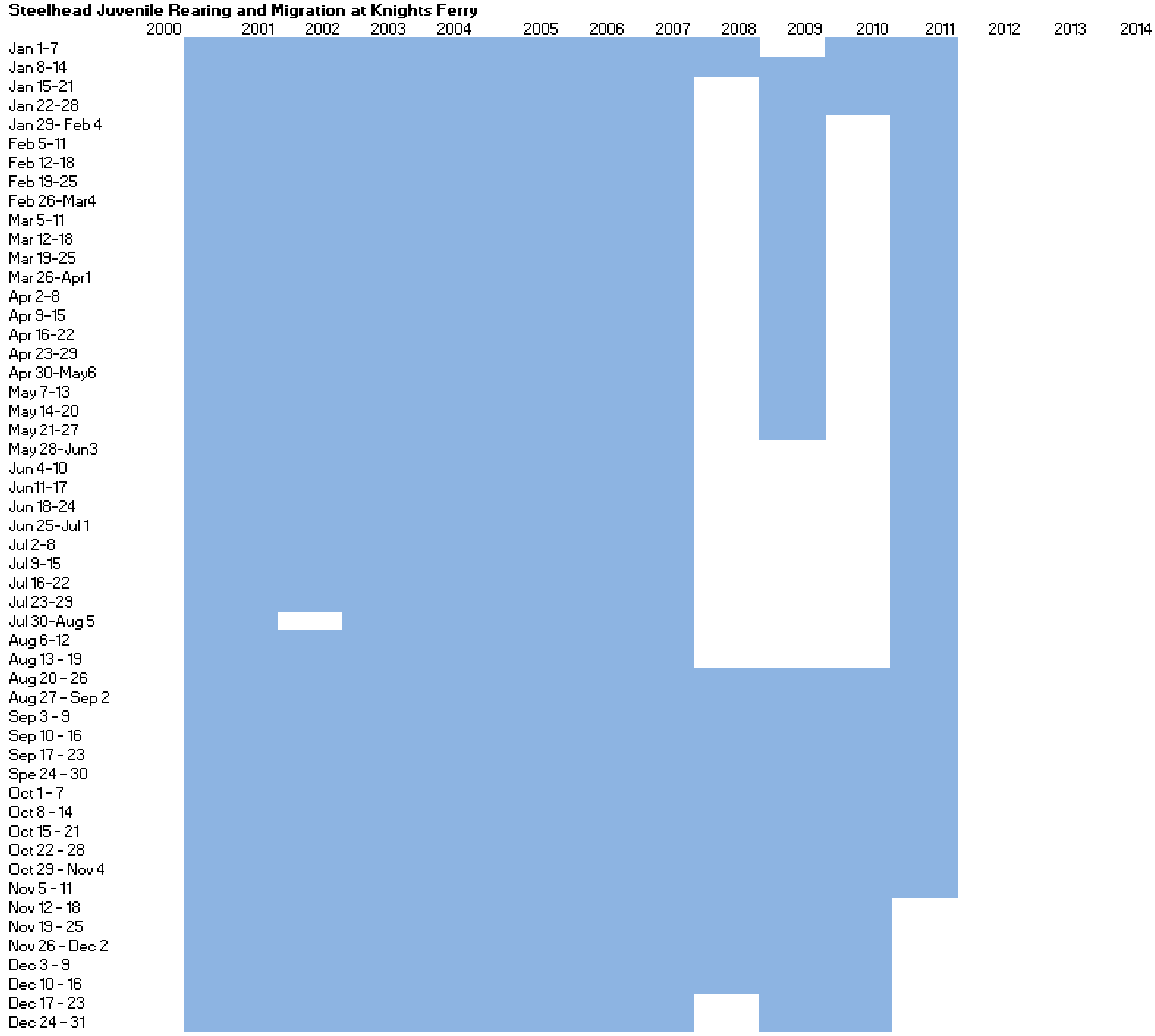
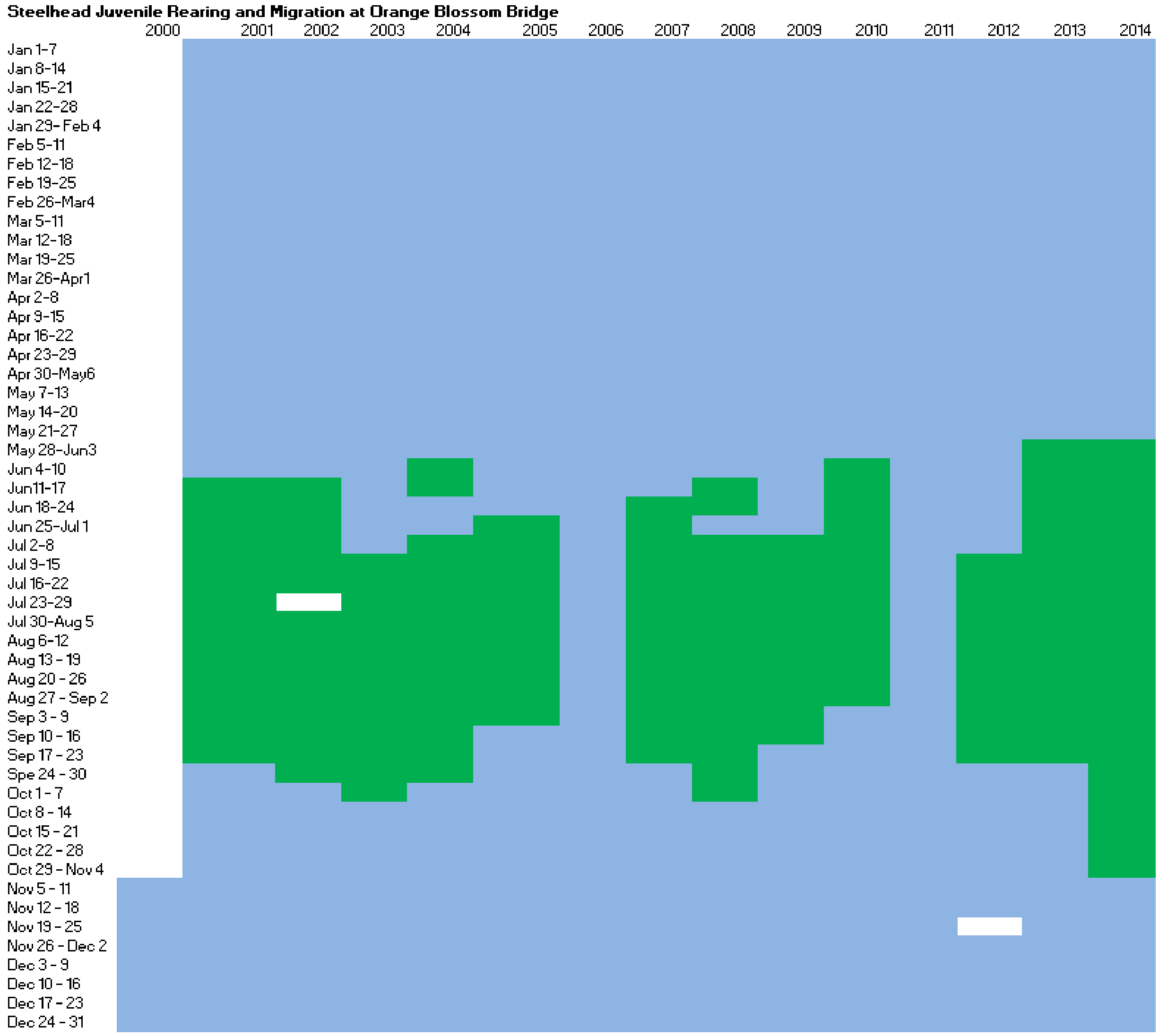
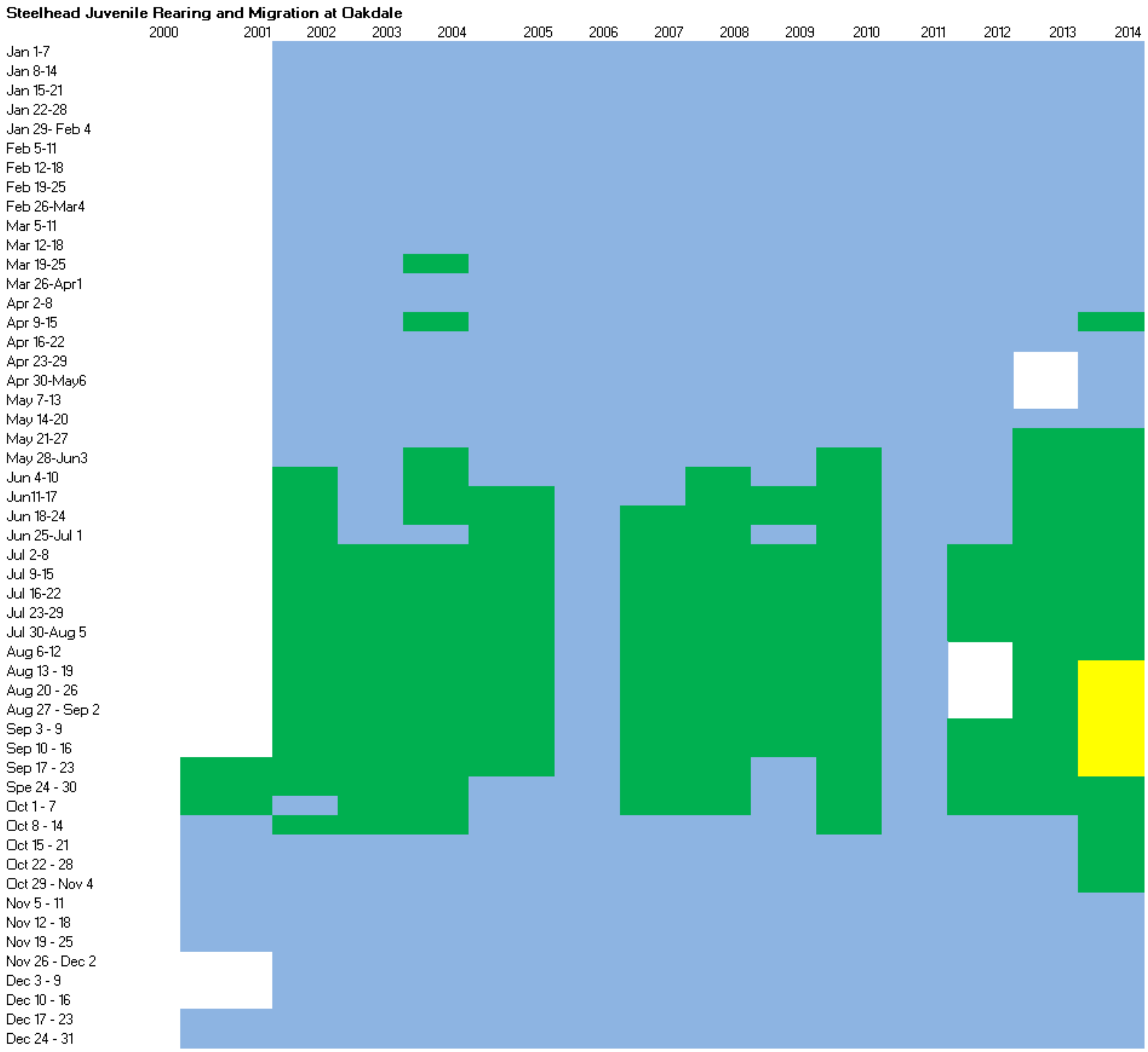
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31

Steelhead Juvenile Rearing and Migration at Knights Ferry




Steelhead Juvenile Rearing and Migration at Orange Blossom Bridge
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31


Steelhead Juvenile Rearing and Migration at Oakdale
2000
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2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
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Oct 1 - 7
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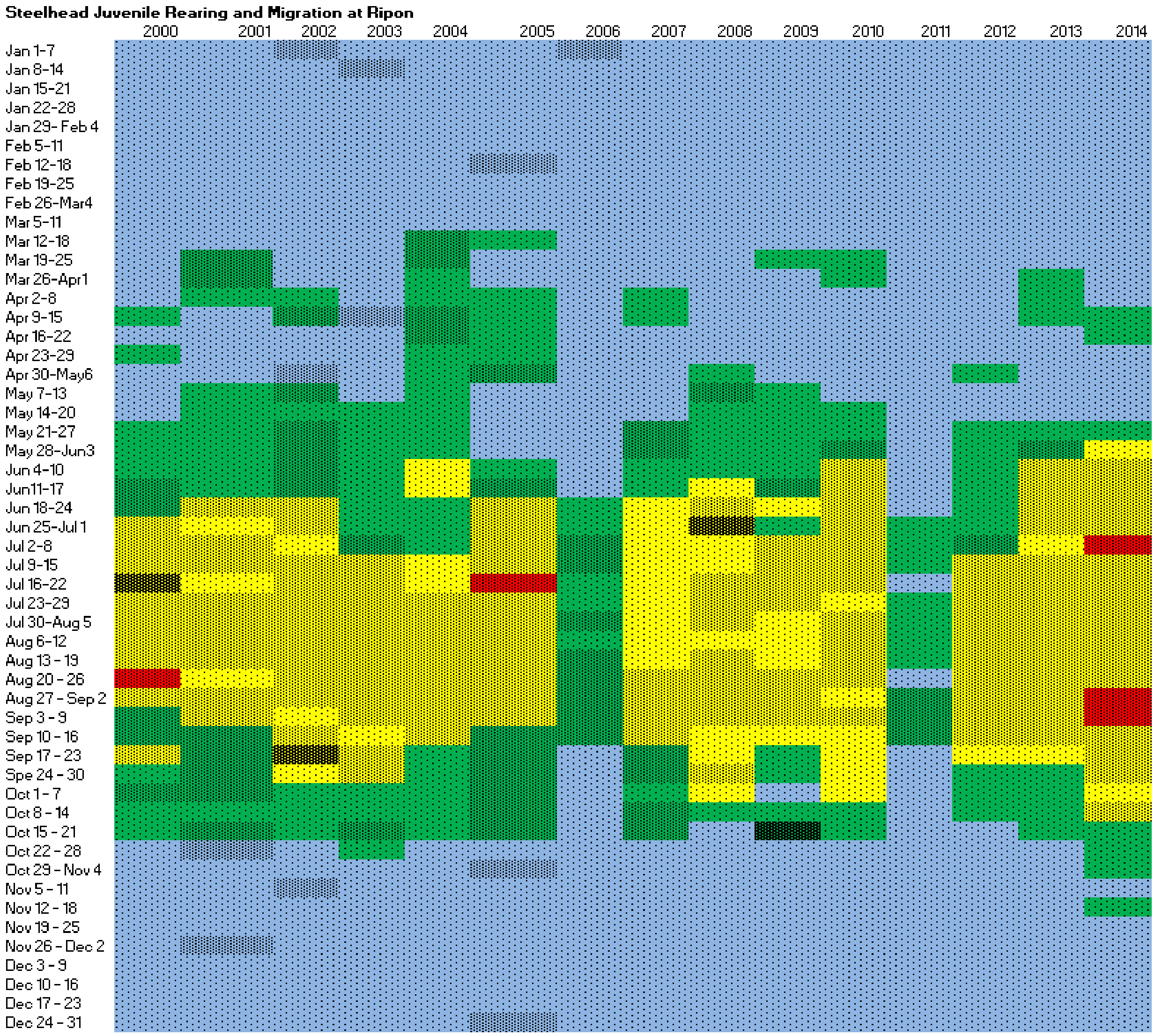
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31


Steelhead Juvenile Rearing and Migration at Ripon
2000
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2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
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Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31

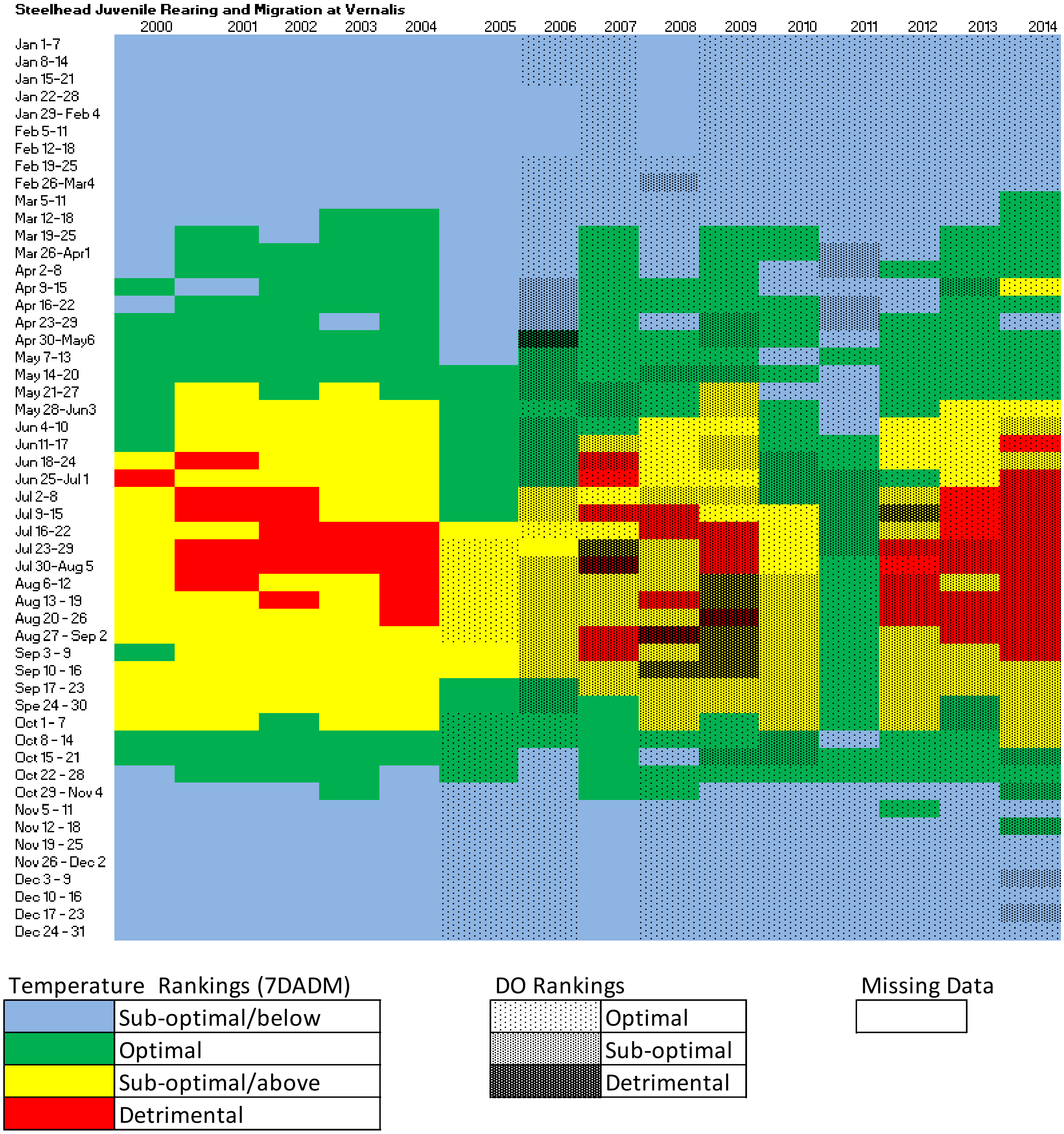


Figure 21

Steelhead Juvenile Rearing and Migration for all Weeks of Year

Notes:
Temperature and DO rankings based on observed data during periods of steelhead juvenile rearing and migration. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

8.6.4 Stress: Lack of Suitable Migratory Conditions (Juvenile Rearing and Migration)

All anadromous fish must have suitable conditions, during the proper season, to allow juveniles to migrate out of the river environment of the Stanislaus and lower San Joaquin rivers into the tidal environment of the Delta on their way to the marine environment of the Pacific Ocean. A variety of water quality and physical habitat conditions must be in suitable ranges to allow for successful migration.

8.6.4.1 Fall-run Chinook Salmon

Fall-run Chinook salmon juveniles encounter inhospitable migratory conditions along the Stanislaus River corridor. This is a "high" magnitude and "high" certainty stress in the near term (Table 64).

Without corrective action, several of the stressors that lead to inhospitable migratory conditions will increase in intensity, meaning that this stress will remain "high" magnitude with "high" certainty in the long term (Table 64).

Changes in the hydrograph attributable to dam construction, water diversion, and disconnection of functional riparian habitats (described in greater detail in Section 8.6.8) have contributed to deterioration in migratory conditions for fall-run Chinook salmon juveniles. Flow volume and channel geometry are insufficient over most of the Stanislaus River's course to provide suitably complex, shallow-water habitats that migrating salmon use for cover, resting, and feeding.[11] Higher flows would also provide increased access to currents that can significantly reduce the energetic expenditure of downstream migration for juvenile salmonids. Additionally, in-channel habitats have been deepened and simplified through dredging, channel scour, and removal of large woody debris (to improve navigation), creating deep, low-velocity pools that are excellent habitat for salmon predators, but that require significant energy expenditure for juvenile salmon attempting to transit.

[11] FlowWest SRH2d Model, Available from: http://public.tableau.com/profile/mark.tompkins#!/vizhome/20160203_CVPIA_Floodplain/Floodplain

Contaminants in agricultural runoff can also harm migrating juveniles. Pesticide runoff impairs salmonid olfaction to an extent that is considered detrimental to the population (Hoogeweg et al. 2011; Appendix C, Section 1.3.3.1, Figure C-1, and Table C-13) and can impair predator-avoidance behavior. Nutrients from runoff and agricultural water returns to the Stanislaus River can stimulate non-native aquatic macrophytes that harbor predators. The magnitude of effect of contaminants on migrating salmon was lower than for rearing salmon as food-web impacts of contaminants were incorporated in the score for rearing salmon, but not migrating salmon. In addition, to the extent that migration and rearing are distinct behaviors, the duration of exposure during migration activities is expected to be less than the exposure duration for rearing fish.

Temperature conditions in late spring to early summer constrict access to in-stream migratory habitat, especially in lower reaches of the Stanislaus and the lower San Joaquin rivers (Figure 18). Temperatures regularly exceed sub-optimal and detrimental levels during the spring.

8.6.4.2 Spring-run Chinook Salmon

Lack of suitable migratory conditions for juvenile spring-run Chinook salmon is a "high" magnitude, "high" certainty stress to recovering spring-run Chinook salmon populations in the near term (Table 65).

Without corrective action, lack of suitable conditions during migration will remain a "high" magnitude stress with "high" certainty in the long term (Table 65).

All of the same stressors on suitable migratory conditions described for fall-run Chinook salmon (Section 8.6.4.1) apply to spring-run Chinook salmon.

8.6.4.3 Steelhead

Lack of suitable migratory conditions for juvenile steelhead is a "high" magnitude, "high" certainty stress to recovering steelhead populations in the near term (Table 66).

Without corrective action, lack of rearing habitat will remain a "high" magnitude stress with "high" certainty in the long term (Table 66).

Most of the stressors on suitable migratory conditions described for fall-run Chinook salmon also apply to steelhead. An exception is that temperatures required for rearing and migrating *O. mykiss* are optimal throughout most of the spring in both the Stanislaus and lower San Joaquin rivers (Figure 21). Temperatures become sub-optimal in the lower Stanislaus River (at and around Ripon) during the summer months when the fraction of steelhead migrating is likely to be very small relative to the total annual outmigrant cohort. Similarly, temperatures at Vernalis become sub-optimal (and detrimental) from late spring through the summer, but this is not expected to affect most of the outmigrant class. In addition, steelhead that experience inhospitable migration conditions may not be lost (as would be the case for migrating Chinook salmon) because *O. mykiss* are facultative anadromous, and it may be possible for them to delay an anadromous migration (or even reverse it) when migration is not possible.

8.6.5 Stress: Lack of Suitable Migratory Cues (Juvenile Rearing and Migration)

Several factors may trigger or facilitate onset of migration among juvenile salmonids. Variability in flow can trigger juveniles to leave off-channel habitat and proceed downstream in the main channel (Zeug et al. 2014). Outmigration of juvenile fall-run Chinook salmon often coincides with large increases in flow associated with rain events and spring and summer snowmelt in the Stanislaus River (Melgo et al. 2015 and earlier Caswell RST Reports[12]). Høgåsen (1998) as cited in Williams (2006) found that rainfall and increased flow and turbidity influenced the onset of migration for juvenile Chinook salmon. In unimpaired systems, runoff from spring rain events adds complexity to the seasonal snowmelt hydrograph. Rain runoff pulses, when added to the base flows provided by snowmelt, offer triggers to stimulate outmigration and assist outmigrants by providing higher velocities to speed migration and higher turbidity to provide visual cover from predators (Gregory 1993;

[12] Available from https://www.fws.gov/cno/fisheries/CAMP/Documents-Reports/

Gregory and Levings 1998). Removal or storage of large volumes of water from the Stanislaus River alters its hydrograph in ways that hamper outmigration, including through loss of inundation of off-channel resting areas in most years and through reduced turbidity.

8.6.5.1 Fall-run Chinook Salmon

Lack of suitable migratory cues for fall-run Chinook salmon juveniles is a “high” magnitude and “medium” certainty stress in the near term (Table 64).

Without corrective action, this stress will remain “high” magnitude, with “medium” certainty in the long term (Table 64).

Changes in the hydrograph attributable to dam construction, water diversion, and management of dam releases have greatly reduced both the volume of water and the variability in flow that help to trigger outmigration in fall-run Chinook salmon (Zeug et al. 2014). Flow pulses are scheduled in the lower San Joaquin River as part of the WQC Plan, but the planned flow pulses are often inadequate to provide sufficient outmigration cues or support for successful migration (SWRCB 2010; CDFG 2010). Furthermore, pulse flows called for the in the WQC Plan have been reduced, under “temporary urgency changes” during recent drought years, meaning little or no migratory cues were provided for entire year-classes of migrating juvenile fall-run Chinook salmon. Finally, pulse flows required under the WQC Plan are scheduled for the same calendar period, ending in mid May every year; such calendar-based flow scheduling may undermine life history diversity (e.g., migration timing) in ways that severely impair run viability (McElhany et al. 2000; Satterthwaite et al. 2014; Zeug et al. 2014; Sturrock et al. 2015). Until recently, fluctuations in flow volume that cue juvenile migration have been largely absent from the hydrograph; yet current efforts to manage reservoir releases to mimic natural variability may be inadequate because release of water from reservoirs may not provide sufficient turbidity, and mismatches with scheduled releases and natural storm events may limit the success of these attempts (Wikert 2014, pers. comm.).

8.6.5.2 Spring-run Chinook Salmon

Lack of suitable migratory cues for juvenile spring-run Chinook salmon is a “high” magnitude and “medium” certainty stress to recovering spring-run Chinook salmon populations in the near term (Table 65).

In the future, lack of suitable cues to stimulate migration will remain a “high” magnitude stress with “medium” certainty in the long term (Table 65).

All of the same stressors on suitable migratory cues described for fall-run Chinook salmon (Section 8.6.5.1) apply to spring-run Chinook salmon.

8.6.5.3 Steelhead

Lack of suitable migratory cues for juvenile steelhead is a “high” magnitude and “low” certainty stress to recovering steelhead populations in the near term (Table 66).

In the long term, lack of rearing habitat will become a “medium” magnitude stress with “low” certainty in the long term (Table 66).

The factors that trigger anadromy in *O. mykiss* populations are somewhat uncertain. As Kendall et al. (2014) wrote:

> Anadromy and residency appear to reflect interactions among genetics, individual condition, and environmental influences. … [p]atterns in anadromy and residency among and within populations suggested a wide range of possible environmental influences at different life stages… [Abstract].

The following environmental influences have been correlated with and shown to potentially driving anadromy (Kendall et al. (2014); see citations in Kendall et al. 2014):

- Water temperature (higher temperatures generally related to greater proportions of anadromous fish);
- Food availability (higher food availability associated with lower proportions of anadromous fish);

- Stream flow and flow variability (anadromy most common in streams with greatest flow and greatest flow variability); and
- Density dependence (higher density related to greater proportion of anadromous fish).

These correlations, though reported from various studies, were characterized as uncertain with regard to mechanism by Kendall et al. (2014) and were acknowledged to be in a context of scant data on the extent of residency and anadromy across populations of *O. mykiss*.

Given this overview, it is most likely that low temperatures (i.e., generally in the optimal range for *O. mykiss* or lower; Figure 21), generally low flows, low variance in flow velocity during much of the year, and relatively low density of *O. mykiss* contribute to low rates of anadromy among the Stanislaus River's *O. mykiss* population. Each of these factors has a low certainty (and the rate of anadromy seems likely to be responsive to numerous ecosystem processes, in addition to unknowns such as the genetic makeup of the population) and should probably be the subject of research on *O. mykiss* populations of each tributary to the San Joaquin River.

8.6.6 Stress: Lack of Suitable Over-summering Habitat (Juvenile Rearing and Migration)

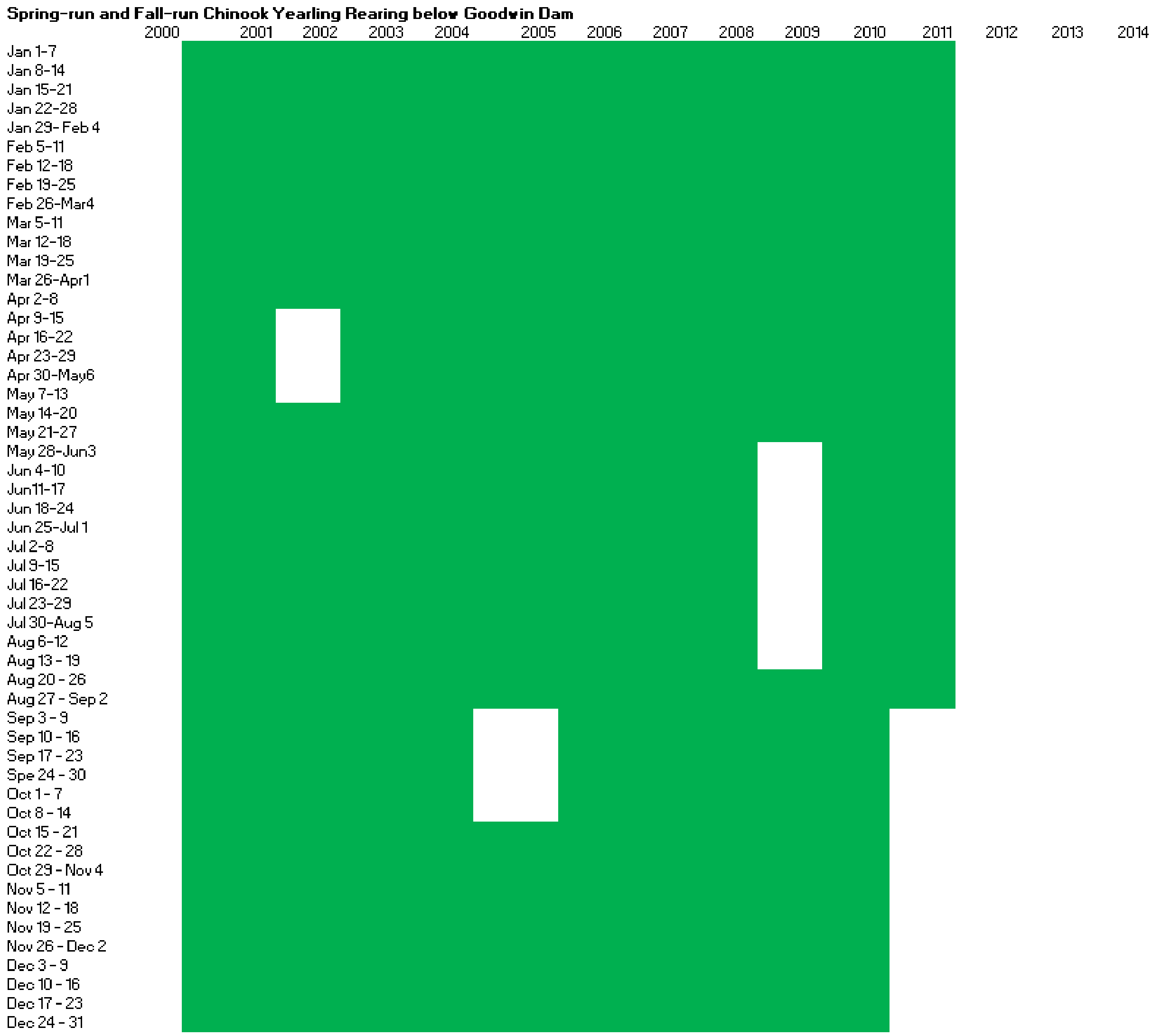
Some fraction of fall-run and spring-run Chinook salmon over-summer in their natal streams as juveniles and are thus affected by conditions in the Stanislaus River through the summer and fall months. Spring-run Chinook salmon show a greater predisposition to this over-summering behavior, and spring-run Chinook populations typically produce a small, but measureable percentage of "yearling" migrants each year (Healey 1991; Moyle 2002). Steelhead (and resident rainbow trout) can spend several years (or even their entire life) in freshwater, so over-summering habitat is vitally important. Water temperature plays the largest role in this stress.

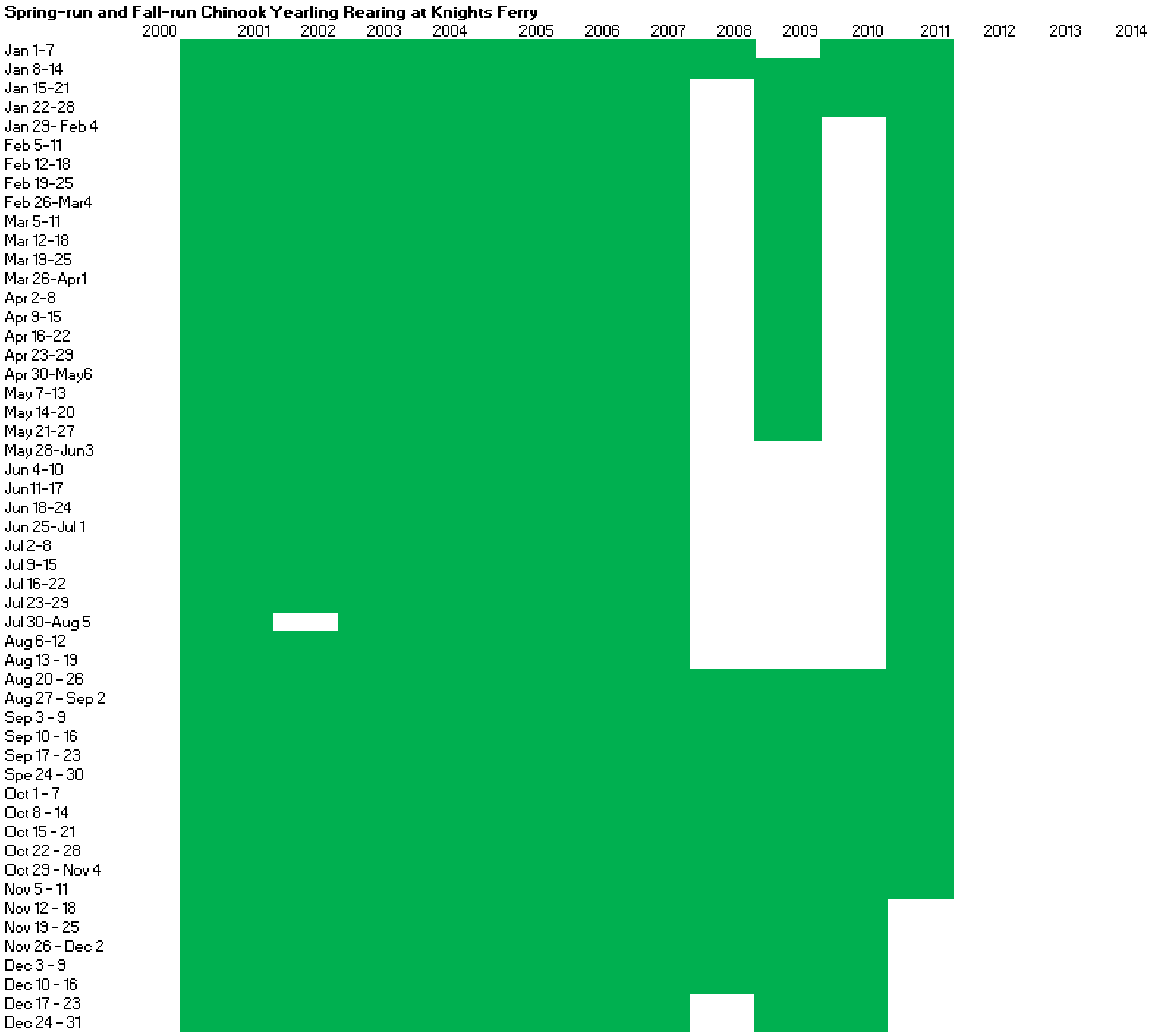
8.6.6.1 Fall-run Chinook Salmon

Lack of habitat in which fall-run Chinook salmon juveniles can rear over the summer is a "minimal" magnitude stress with "medium" certainty in the near term (Table 64).

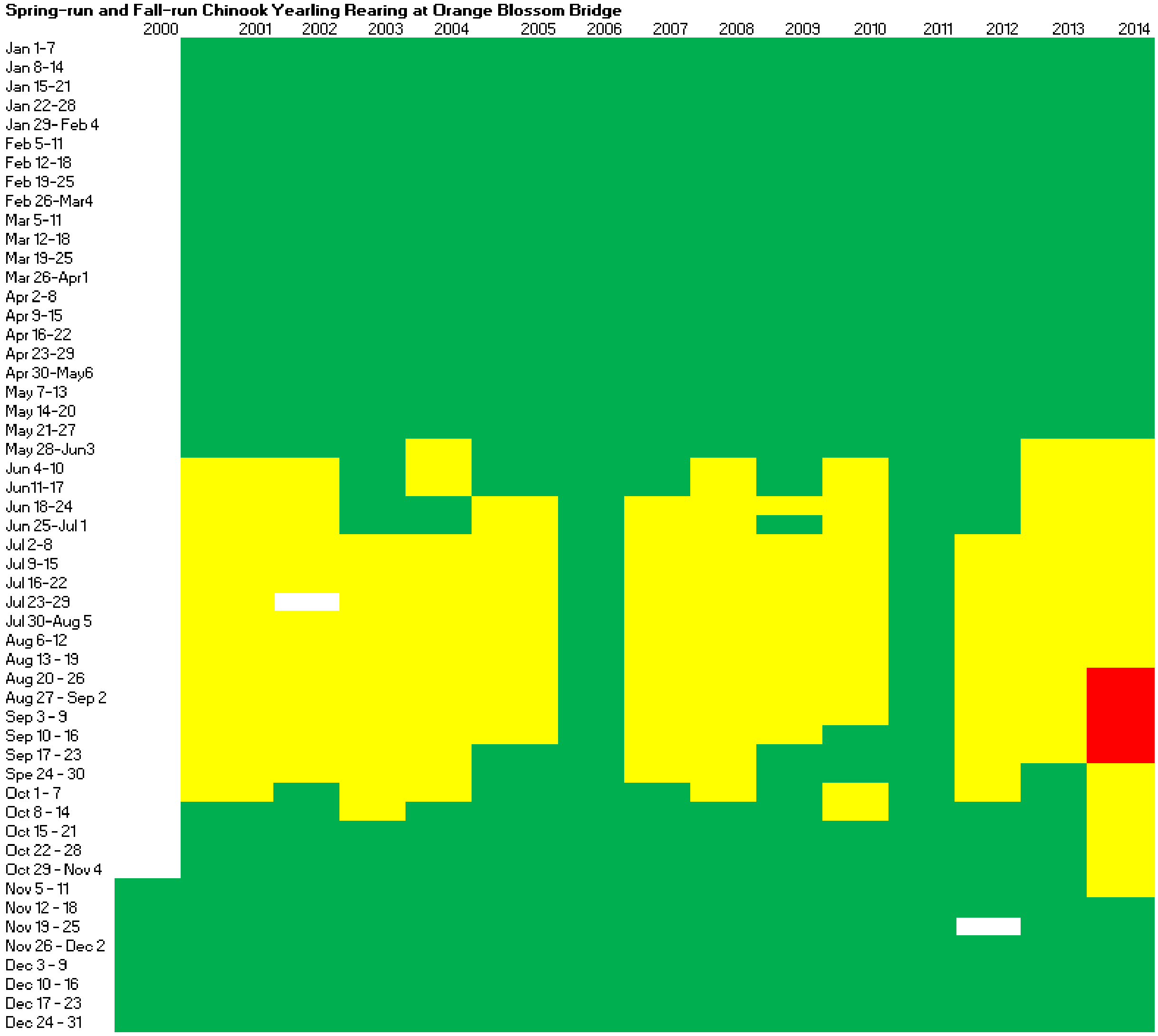
This stress is likely to remain “minimal” magnitude in the long term because only a small fraction of the fall-run population is expected to display this behavior; certainty remains “medium” (Table 64).

The amount of habitat available for over-summering is largely a function of temperature. As water temperatures warm, suitable habitat contracts in an upstream direction (Figure 22). Only a small portion of the fall-run juvenile production is thought to over-summer. Evidence for this behavior comes from RST sampling in which salmon substantially larger than expected outmigrate in early spring. There is uncertainty as to which run (fall, late-fall or spring) these large outmigrants belong. The SEP Group assumed this behavior was infrequent among fall-run, but, because larger fish are better able to avoid the traps, this assumption is uncertain. Limitations of the extent of habitat are likely to increase in the future with larger fish populations and warmer water temperatures projected by climate change models. Contaminants could be a large stressor if the over-summering population was larger or water temperatures allowed over-summering in the lower river where substantial urban, industrial, and agricultural runoff occurs.


Spring-run and Fall-run Chinook Yearling Rearing below Goodwin Dam
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31


Spring-run and Fall-run Chinook Yearling Rearing at Knights Ferry
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31

Spring-run and Fall-run Chinook Yearling Rearing at Orange Blossom Bridge



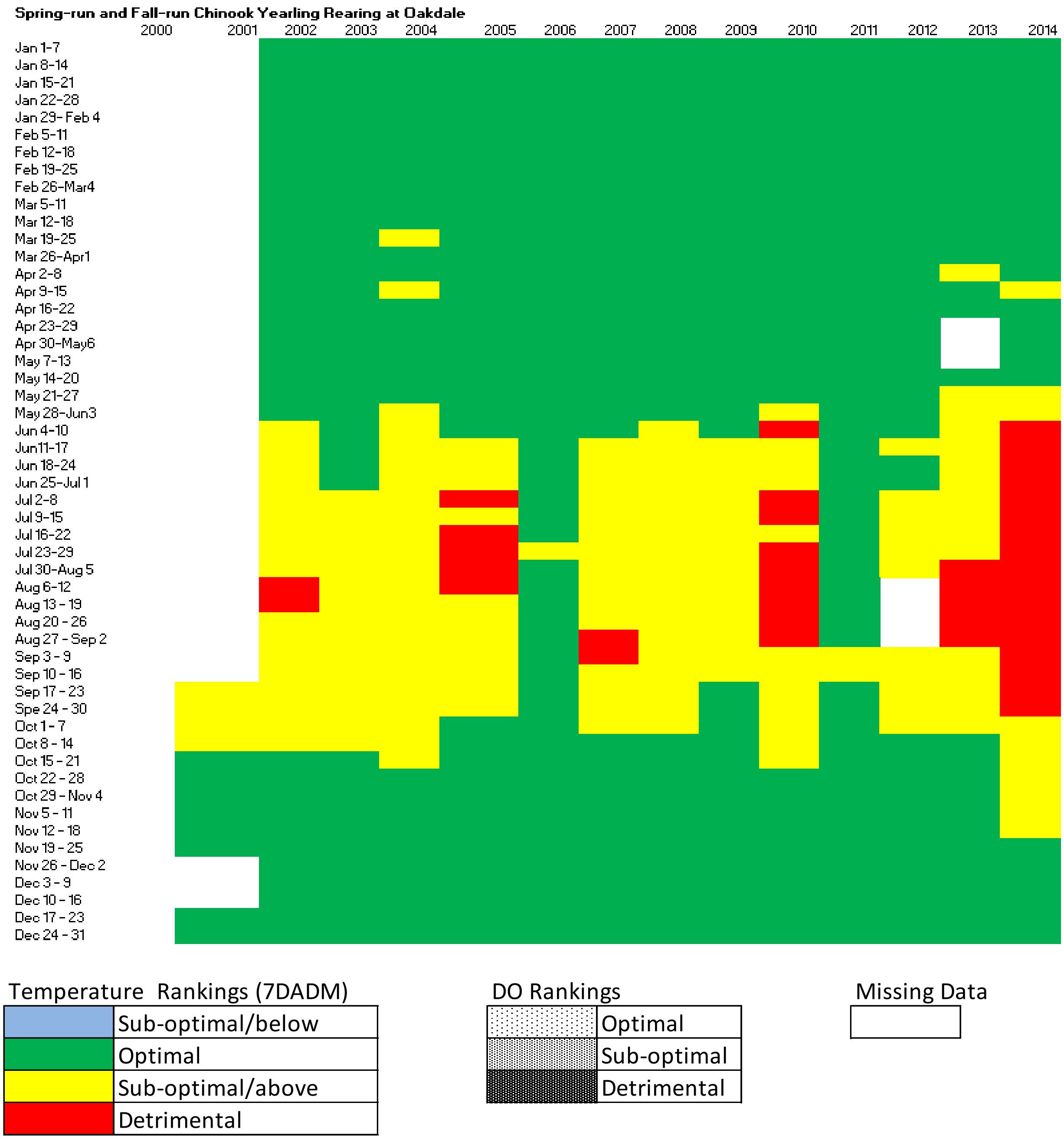


Figure 22

Spring-run and Fall-run Chinook Yearling Rearing

Notes:
Temperature and DO rankings based on observed data during periods of yearling rearing. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

8.6.6.2 Spring-run Chinook Salmon

Lack of habitat in which juvenile spring-run Chinook salmon can rear over summer months is a "minimal" magnitude stress in the near term with "medium" certainty (Table 65).

In the long term, lack of over-summer habitat will increase to a "medium" magnitude stress with "medium" certainty (Table 65). Over-summering of a portion of the spring-run Chinook salmon population is essential to production of a key life history type (yearlings) that are characteristic of successful spring-run Chinook salmon populations.

All of the same stressors on lack of suitable over-summering habitat described for fall-run Chinook salmon (Section 8.6.6.1) apply to spring-run Chinook salmon (Figure 22). However, the fraction of the population affected by poor over-summering conditions is expected to be larger for spring-run Chinook salmon than it is for fall-run Chinook salmon. Additionally, the yearling life history strategy is expected to be a key element of spring-run life history diversity on the Stanislaus River (as it is elsewhere in the Central Valley; Moyle 2002; Williams 2006). Thus, although there appears to be adequate over-summering habitat for spring-run Chinook salmon in the near term (i.e., a "minimal" magnitude stress), over the long term, as temperatures rise and the number of spring-run Chinook salmon in the Stanislaus River (and the number of yearling fish) increases dramatically (both of which are assumptions of this stressor-ranking exercise), the magnitude of this stress is expected to increase. Loss of over-summering habitat in the long term (e.g., during drought cycles when reservoir cold-water storage is low) would represent a significant impact to an important life history strategy for the spring-run population. The SEP Group notes that there may be synergies between efforts to provide for over-summer holding habitat for adult spring-run Chinook salmon and efforts to provide suitable over-summer habitat for rearing yearling Chinook salmon.

8.6.6.3 Steelhead

Lack of suitable habitat for juvenile steelhead to rear over the summer is a "minimal" magnitude stress to recovering steelhead populations in the near term with "high" certainty (Table 66).

In the long term, lack of summer rearing habitat will remain a “minimal” magnitude stress with “high” certainty (Table 66).

As described above in Figure 21, temperatures appear to be optimal for rearing *O. mykiss* between Oakdale and Orange Blossom Bridge throughout the summer of most years. At other times of year in and upstream of this area, temperatures are cooler than optimal for rearing *O. mykiss*. Thus, there does not appear to be a lack of over-summering habitat for juvenile *O. mykiss* and it seems unlikely that there will be significant loss of *O. mykiss* rearing habitat due to regional warming that may occur over the next 25 years (i.e., the “long term” in this exercise). It is possible that in the long term, sub-optimal over-summer temperatures could occasionally prevail throughout the river corridor below Goodwin Dam in the later years of a prolonged drought, but this seems unlikely to result in lasting damage to the *O. mykiss* population.

8.6.7 Stress: Lack of Fitness/Genetic Maladaptation (Juvenile Rearing and Migration)

Hatchery practices within the Central Valley have resulted in a large amount of straying of adult salmonids. Numerous studies have found negative fitness consequences when hatchery-origin adults reproduce with either other hatchery-origin adults or natural-origin adults in the wild (Araki et al. 2007; Heath et al. 2003; Christie et al. 2012). Traits that have been selected for in the hatchery environment can be passed to offspring, resulting in changes in behavior that are maladaptive. High straying rates that persist through time may lead to a wild population that is unable to adapt to the local conditions. Conversely, when the local population is very small, straying from hatchery sources can provide an opportunity to establish a local spawning population.

8.6.7.1 Fall-run Chinook Salmon

Lack of juvenile fitness due to continued influence of hatchery-selected genotypes is a “high” magnitude and “medium” certainty stress in the near term (Table 64).

Without corrective action, this stress will remain “high” magnitude, with “medium” certainty in the long term (Table 64).

High rates of straying prevent the Stanislaus River population of fall-run Chinook salmon from adapting to local conditions. The proportion of hatchery-origin fall-run Chinook salmon in the Stanislaus River escapement has been moderate to high. Sturrock et al. (2015) found 18% and 51% hatchery origin in 2000 and 2003, respectively. Constant fractional marking reports compiled by CDFW found 50% hatchery-origin fall-run Chinook in the 2010 escapement (Kormos et al. 2012), 83% in 2011 (Palmer-Zwahlen and Kormos 2013), and 83% in 2012 (Palmer-Zwahlen and Kormos 2015). These straying rates are well above the Hatchery Scientific Review Group's recommendations for managing an integrated (hatchery- and natural-origin fish are managed as a single population) salmon population (HSRG 2014).

8.6.7.2 Spring-run Chinook Salmon

Hatchery influence on the genetics of natural-origin spring-run Chinook salmon is believed to be a "minimal" magnitude stress in the near term; however, certainty of this stress is "minimal" as well (Table 65).

In the future, genetic influence on the fitness of spring-run Chinook salmon will become a "medium" magnitude stress with "medium" certainty in the long term (Table 65) unless corrective actions are implemented.

In the near term, reestablishment of spring-run Chinook salmon may benefit from straying of hatchery-origin and/or natural-origin spring-run produced elsewhere in the Central Valley. Straying Chinook salmon with genotypes needed to produce the spring-run phenotype can help to establish populations in non-natal watersheds. However, in the long term, after a substantial spring-run population has been established on the Stanislaus River, introgression of natural-spawned spring-run Chinook salmon with hatchery-origin spring-run, natural-origin fall-run, or hatchery-origin fall-run Chinook salmon is expected to become a problem that limits adaptation of spring-run Chinook salmon to conditions on the Stanislaus River along with the resulting production of juveniles that are maladapted to the local environment.

8.6.7.3 Steelhead

The genetic influence of hatcheries on juvenile steelhead is a "medium" magnitude stress in the near term, but certainty regarding this magnitude is "minimal" (Table 66).

In the long term, stress on the steelhead population associated with continuing input of hatchery genotypes will remain a "medium" magnitude stress. Without additional research into this issue, certainty will remain "minimal" certainty (Table 66).

Evaluation of steelhead genetics is complicated by the fact that resident and anadromous forms can freely interbreed. The Stanislaus River currently supports a robust resident population augmented with small numbers of returning adults. Weir monitoring for fall-run Chinook salmon adults has occasionally been extended into other months. In the 5 years that weir monitoring has occurred (2011 – 2015), 0 to 32 steelhead up-migrants have been observed (mean is 8.2, median is 5). The weir data also revealed that in 3 of 5 years, the percentage of adipose fin-clipped (hatchery-origin) steelhead exceeded 50% (annual percentages: 61.5%, 57.1%, 34.6%, 12.5%, and 80.0%). Because of these high numbers, it is assumed that the genetic influence of hatchery-origin fish on the Stanislaus River population is high. Introduction of a larger fraction of anadromous genes into the mostly resident population may help to increase anadromy, though possibly at the expense of local adaptation. With a larger anadromous population assumed for the future, the stress of hatchery-origin immigrants is expected to remain "medium."

8.6.8 Contributing Management Factors

Contributing management factors for each stressor on juvenile rearing and migration are provided in Sections 8.6.8.1 through 8.6.8.5.

8.6.8.1 Compression of the Rearing and Migration Time Window

Changes in the hydrograph attributable to dam construction, reservoir operations, and water diversion have reduced the duration of suitable temperature conditions required for successful salmonid smoltification. Large reservoirs and their current operations have changed the timing of natural river flows. Large snowmelt pulses in the unimpaired hydrograph are captured by reservoirs in the spring rather than providing suitable conditions and cues for migration. Dams block sediment transport and greatly attenuate flood flows, resulting in the following (Ock and Kondolf 2012):

- Scoured and armored channels,
- Disconnected floodplains and side channels,
- Reduced recruitment of riparian trees (which would provide local cooling), and
- Reduction of thermal refugia created by slower passage of water through gravel bars and islands.

In addition, destruction of functional riparian and inundated floodplain habitats along the Stanislaus River limits growth opportunities that might allow juvenile salmonids to attain sufficient size and growth rates that would support earlier smoltification (i.e., earlier in the season when temperatures would still support smoltification and successful migration).

8.6.8.2 Lack of Suitable Rearing Habitat and Migratory Conditions

Reservoir operation is a major driver of the environmental factors that control the impact of stressors that may lead to rearing failure among juvenile salmonids. Flow volume directly controls the amount of floodplain and side channel inundation as well as maintenance of gravel quality through sediment transport dynamics. Relatively high flow volume positively impacts the migratory speed of juveniles leaving the system as well as increased turbidity, which can increase visual cover for migrants. High flow volumes also dilute contaminants and moderate warmer temperatures in late spring or early summer. Lack of channel-forming flows has allowed willows to armor banks and resulted in loss of channel elevation—disconnecting the river from floodplains and side channels—leaving migrants in homogenous, in-channel habitats largely devoid of cover. Long-term management will need to ensure that cold water is available for temperature management during prolonged droughts. Conveyance of spring-run Chinook salmon to habitats upstream of currently impassable dams is a possible solution to this (and other) stressors. Providing groundwater recharge in proximity to the river and promoting development of riparian forests may also offer some respite from higher temperatures. Habitat restoration in the form of gravel augmentation could improve food resources and provide thermal refugia.

Other non-flow management practices may exacerbate or alleviate stressors on juvenile rearing. For example, levees (especially in the lower portions of the river) limit spatial distribution and overall access to large areas of periodically inundated floodplain habitat that would support faster growth of salmon and would export prey items to the main-channel habitats of *O. mykiss* (leading to greater anadromy in the latter population). This lack of habitat constrains the overall carrying capacity for salmonid populations in the Stanislaus River.

Inundated floodplains also reduce predation rates on migrating salmonids (Sommer et al. 2001b, 2004). Fabricated structures have been found to provide predation hotspots where migrating juveniles have a much higher risk of being preyed upon (Sabal et al. 2016). These areas could be restored to provide safer migration pathways and discourage predators through habitat modification.

The destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor; this can increase temperatures in the river. Urban and agricultural developments in the watershed have increased contaminant loads to the river. Adjustments to land-use practices or development of contaminant-control programs may reduce contaminant loads and the stress they generate for rearing juvenile salmonids. Groundwater depletions have likely terminated the hyporheic inputs that probably supplemented Stanislaus River surface flows and buffered the river against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the river during critical months.

8.6.8.3 Lack of Suitable Migratory Cues

The major drivers of this stress include the presence of dams on the system, altering the natural hydrograph and its associated flow variability, and the disconnection of in-stream and off-channel habitats. Water managers are attempting to provide a more natural hydrograph, which includes simulated runoff events (NMFS 2009b, 2009c, Action III.1.3). However, the release of water from reservoirs may not provide sufficient turbidity, and mismatches with scheduled releases and natural storm events may limit the success of these attempts. Whenever possible, the Stanislaus Operations Group recommends timing release pulses to augment natural storm events so that peak flows coincide with periods of cloud cover and changes in barometric pressure that may contribute to migratory success (Wikert 2014, pers. comm.). Habitat modification to allow more frequent inundation, followed by rapid dewatering of temporarily inundated habitats, will likely help to cue juveniles to migrate.

8.6.8.4 Lack of Suitable Over-summering Habitat

Reservoir operation is the largest management factor for insulating salmonids from the lack of suitable over-summering habitat. Long-term management must include ensuring that cold water is available for temperature management during prolonged droughts. Conveyance of spring-run Chinook salmon to habitats upstream of currently impassable dams is a possible solution to this (and other) stressors. Providing groundwater recharge in proximity to the Stanislaus River and promoting development of riparian forests may also offer respite from higher temperatures. Additionally, habitat restoration in the form of gravel augmentation could improve food resources and provide thermal refugia.

8.6.8.5 Lack of Fitness/Genetic Maladaptation

The main drivers of lack of fitness/genetic maladaptation are current hatchery management practices combined with failure to provide suitable flows and environmental conditions needed to attract returning hatchery-origin adults into the watersheds where they were produced. Hatchery straying is largely a result of the following three factors (Marston et al. 2012):

- Large scale production of hatchery fish (dwarfing natural production);
- Trucking fish (trucked juveniles lose the olfactory record needed to find their natal streams); and
- Failure of many hatchery systems to provide sufficient flow to guide fish home (including massive water exports in the Delta).

Failure to provide an easily detectable mark on 100% of hatchery-origin fish prevents any opportunity to manage hatchery and natural populations separately.

8.7 Summary and Prioritization of Stressors and Stressor Responses

This section summarizes the results of stressor analyses for each target species across life history stages. As discussed at the beginning of Section 8, stressor priorities were assigned for individual life history stages based on the combination of magnitude and certainty scores. Because scores in these categories were applied consistently using the adapted DRERIP methodology, specific stressor scores are comparable across life history stages for a given species. With this in mind, stressor priorities have been presented in Section 8, summarized across life history stages for fall-run Chinook salmon, spring-run Chinook salmon, and steelhead, respectively.

All of the stressors considered for the different species/life history stages are deemed to be significant and of concern to the species/life history stage to which they have been assigned. However, to facilitate the application of the stressor analysis to development and sequencing of conservation measures to alleviate stressors, the stressors have been prioritized and grouped according to a suite of combined magnitude and certainty score-based stressor responses in the categories of actions, research, and monitoring.

Stressors with both a high magnitude and certainty are considered the highest priority for response, in the form of Conservation Action(s) that will resolve the stressors and support attainment of Environmental Objectives (Figure 10). Low priority actions are defined as those with a lower magnitude, and a high degree of certainty. Stressors with a high magnitude, but low degree of certainty, are considered the highest priority for research, with other research priorities decreasing based on their relative magnitude scores. Low magnitude stressors are prioritized under baseline monitoring needs, where higher certainty indicates a higher priority for monitoring, principally to ensure that the magnitude does not increase.

8.7.1 Stressor Prioritization Tables

Stressor prioritization summary tables are presented for each species for coarse scale stresses (e.g., lack of suitable rearing habitat; Figures 23, 24, and 25) and fine scale stressors (e.g., lack of suitable rearing habitat as a function of temperature; Figures 26, 27, and 28). Each table is subdivided based on three prioritized groups of stressor response types: actions, research, and monitoring. The three response type groups are staggered relative to one another to present their relative priority based on magnitude and certainty scores. For example, Priority 1 Research has the same relative priority as Priority 2 Actions. A total of four figures and tables—1) coarse and 2) fine scale priorities for both 3) near-term and 4) long-term populations—are presented for each of the three focal species (Figures 23 through 28 provide near term; long term is provided in Appendix E).

Priority 1 (Highest)

Actions and Associated Monitoring:

Juvenile Rearing/Migration
- Lack of suitable rearing habitat
- Lack of suitable migratory conditions
- Compression of the rearing and migration window

Adult Spawning
- Interactions with hatchery fish and other runs

Priority 2 (High)

Actions and Adaptive Management:

Egg Incubation
- Inadequate incubation conditions

Juvenile Rearing/Migration
- Lack of suitable migratory cues

Research:

Adult Migration
- Late access to river (relative to migration window) due to impassable or unsuitable conditions

Priority 3 (Medium)

Actions and Adaptive Management:

Adult Migration
- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease)

Research:

Adult Holding
- Loss of fecundity

Adult Spawning
- Compression of the spawning window

Adult Migration
- Significant delay and/ or failure to reach natal stream (direct effects)

Priority 4 (Low)

Actions and Adaptive Management:

Adult Holding
- Lack of suitable habitat

Adult Spawning
- Inadequate availability of high-quality habitat

Research:

None

Priority 5 (Lowest)

Actions and Adaptive Management:

None

Research:

None

Monitoring Baseline:

Juvenile Rearing/Migration
- Lack of suitable over-summering habitat

Figure 23

Fall-run Chinook Salmon – Stressor Response Prioritization (Near Term/Coarse Scale)

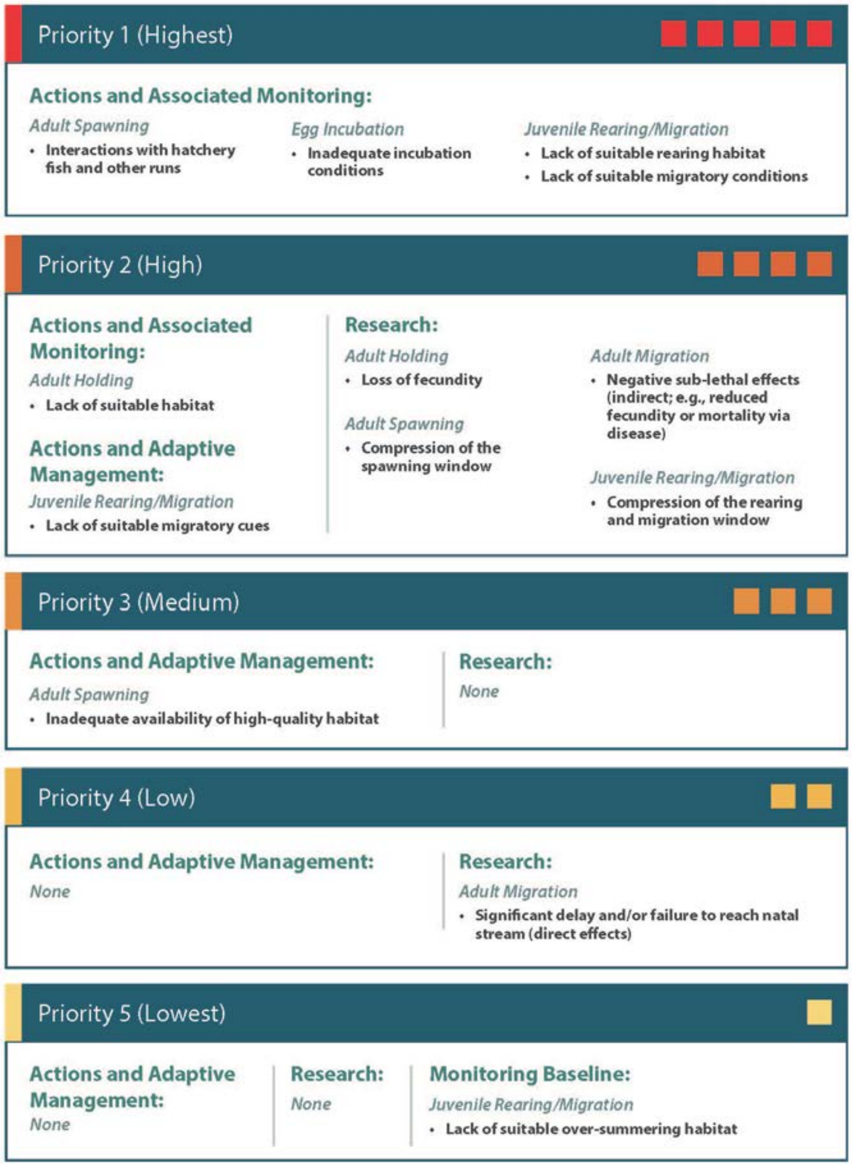


Figure 24

Spring-run Chinook Salmon – Stressor Response Prioritization (Near Term/Coarse Scale)

Figure 25

Steelhead – Stressor Response Prioritization (Near Term/Coarse Scale)

Priority 1 (Highest)

Actions and Associated Monitoring:

Adult Spawning

- Interactions with hatchery fish and other runs – Hatchery

Juvenile Rearing/Migration

- Compression of the rearing and migration window – Temperature

Priority 2 (High)

Actions and Adaptive Management:

Juvenile Rearing/Migration

- Lack of fitness/genetic maladaptation – Hatchery introgression
- Lack of suitable migratory cues – Velocity
- Lack of suitable rearing habitat – Contaminants/toxins

Actions and Associated Monitoring:

Juvenile Rearing/Migration

- Coarse sediment input
- Lack of suitable migratory conditions – Temperature

Research to Inform Action Design:

Adult Migration

- Late access to river (relative to migration window) due to impassable or unsuitable conditions – Temperature, contaminants/attraction flow, DO
- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Attraction flow, contaminants/toxins, DO

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Cover, velocity, habitat distribution
- Lack of suitable migratory cues – Temperature, turbidity

Adult Spawning

- Compression of the spawning window – Temperature

Priority 3 (Medium)

Actions and Adaptive Management:

Adult Migration

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Temperature

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Depth
- Lack of suitable rearing habitat – Cover, depth, temperature

Actions and Associated Monitoring:

Egg Incubation

- Inadequate incubation conditions – Temperature

Research to Inform Action Design:

Adult Holding

- Disease
- Lack of suitable habitat – Contaminants, cover
- Loss of fecundity – Contaminants, temperature
- Predator density

Adult Spawning

- Inadequate availability of high-quality habitat – Contaminants
- Coarse sediment input

Egg Incubation

- Inadequate incubation conditions – Fine sediments, flow fluctuation, redd scour, pesticides

Juvenile Rearing/Migration

- Disease
- Lack of suitable migratory conditions – Turbidity
- Lack of suitable rearing habitat – Turbidity, velocity

Research to Confirm Need for Action:

Adult Migration

- Late access to river (relative to migration window) due to impassable or unsuitable conditions – Contaminants/ toxins
- Significant delay and/or failure to reach natal stream (direct effects) – Attraction flow

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Prey density
- Predator density

Priority 4 (Low)

Actions and Adaptive Management:

Adult Holding
- Lack of suitable habitat – Temperature

Adult Spawning
- Inadequate availability of high-quality habitat – Temperature

Juvenile Rearing/Migration
- Lack of suitable migratory conditions – Contaminants/toxins
- Compression of the rearing and migration window – DO

Research to Evaluate Need for Action:

Adult Migration
- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Passable physical barriers (including low water)
- Significant delay and/or failure to reach natal stream (direct effects) – DO, temperature

Juvenile Rearing/Migration
- Lack of suitable over-summering habitat – Cover
- Lack of suitable rearing habitat – Prey density

Priority 5 (Lowest)

Actions and Adaptive Management:

None

Research to Confirm Action is Not Warranted:

Adult Holding
- Lack of suitable habitat – Depth, DO, velocity
- Loss of fecundity – Depth, DO, velocity
- Poaching

Adult Spawning
- Compression of the spawning window – DO
- Disease
- Inadequate availability of high-quality habitat – Cover, depth, velocity, DO
- Poaching

Juvenile Rearing/Migration
- Lack of suitable migratory conditions – DO
- Lack of suitable over-summering habitat – Contaminants/toxins, velocity
- Lack of suitable rearing habitat – DO

Research to Understand Magnitude:

Adult Migration
- Significant delay and/or failure to reach natal stream (direct effects) – Contaminants/toxins, poaching

Adult Spawning
- Predator density

Juvenile Rearing/Migration
- Lack of suitable migratory cues – DO
- Lack of suitable over-summering habitat – Depth, DO, turbidity

Monitoring to Ensure No Action is Warranted:

Adult Holding
- Coarse sediment input

Egg Incubation
- Inadequate incubation conditions – Flow fluctuation, redd dewatering

Juvenile Rearing/Migration
- Lack of suitable over-summering habitat – Temperature

Monitoring to Track Magnitude:

Adult Spawning
- Interactions with hatchery fish and other runs – Run segregation
- Inadequate availability of high-quality habitat – Spatial distribution

Egg Incubation
- Inadequate incubation conditions – Contaminants/toxins, DO

Figure 26

Fall-run Chinook Salmon – Stressor Response Prioritization (Near Term/Fine Scale)

Priority 1 (Highest)

Actions and Associated Monitoring:

Juvenile Rearing/Migration

- Coarse sediment input

Priority 2 (High)

Actions and Associated Monitoring:

Adult Holding

- Lack of suitable habitat – Temperature

Egg Incubation

- Inadequate incubation conditions – Temperature

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Temperature

Actions and Adaptive Management:

Adult Spawning

- Interactions with hatchery fish and other runs – Run segregation

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Velocity
- Lack of suitable migratory cues – Velocity
- Lack of suitable rearing habitat – Contaminants/toxins, velocity

Research to Inform Action Design:

Adult Holding

- Loss of fecundity – Contaminants

Adult Migration

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease – Temperature, attraction flow, DO

Adult Spawning

- Compression of the spawning window – Temperature

Juvenile Rearing/Migration

- Compression of the rearing and migration window – Temperature
- Lack of suitable migratory conditions – Cover, habitat distribution
- Lack of suitable migratory cues – Turbidity

Priority 3 (Medium)

Actions and Adaptive Management:

Adult Spawning

- Inadequate availability of high-quality habitat – Spatial distribution, temperature

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Depth
- Lack of suitable over-summering habitat – Contaminants/toxins
- Lack of suitable rearing habitat – Cover, depth, temperature

Research to Inform Action Design:

Adult Holding

- Disease
- Lack of suitable habitat – Contaminants, cover
- Loss of fecundity – Temperature
- Predator density

Egg Incubation

- Inadequate incubation conditions – Fine sediments, flow fluctuation, redd scour, pesticides

Adult Spawning

- Inadequate availability of high-quality habitat – Contaminants

Juvenile Rearing/Migration

- Disease
- Lack of suitable migratory conditions – Turbidity
- Lack of suitable rearing habitat – Turbidity
- Predator density

Priority 4 (Low)

Actions and Adaptive Management:

Adult Spawning

- Interactions with hatchery fish and other runs – Hatchery

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Contaminants/toxins

Research to Evaluate Need for Action:

Adult Migration

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Contaminants/toxins, passable physical barriers (including low water)
- Significant delay and/or failure to reach natal stream (direct effects) – Contaminants/toxins, DO, poaching, temperature, attraction flows

Adult Spawning

- Compression of the spawning window – DO

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Prey density
- Lack of suitable over-summering habitat – Cover
- Lack of suitable rearing habitat – Prey density

Priority 5 (Lowest)

Actions and Adaptive Management:

None

Research to Confirm Action is Not Warranted:

Adult Holding

- Lack of suitable habitat – Depth, DO, velocity
- Loss of fecundity – Depth, DO, velocity
- Poaching

Adult Spawning

- Disease
- Inadequate availability of high-quality habitat – Cover, depth, velocity, DO
- Poaching
- Predator density

Juvenile Rearing/Migration

- Compression of the rearing and migration window – DO
- Lack of suitable migratory conditions – DO
- Lack of suitable over-summering habitat – Velocity
- Lack of suitable rearing habitat – DO

Research to Understand Magnitude:

Juvenile Rearing/Migration

- Lack of fitness/genetic maladaptation – Hatchery introgression
- Lack of suitable migratory cues – DO
- Lack of suitable over-summering habitat – Depth, turbidity

Monitoring to Ensure No Action is Warranted:

Adult Holding

- Coarse sediment input

Adult Spawning

- Coarse sediment input

Egg Incubation

- Inadequate incubation conditions – Flow fluctuation, redd dewatering

Juvenile Rearing/Migration

- Lack of suitable over-summering habitat – Temperature, DO
- Lack of suitable migratory cues – Temperature

Monitoring to Track Magnitude:

Egg Incubation

- Inadequate incubation conditions – Contaminants/toxins, DO

Figure 27

Spring-run Chinook Salmon – Stressor Response Prioritization (Near Term/Fine Scale)

Priority 1 (Highest)

Actions and Associated Monitoring:

Juvenile Rearing/Migration

- Coarse sediment input

Priority 2 (High)

Actions and Associated Monitoring:

Adult Holding

- Lack of suitable habitat – Temperature

Egg Incubation

- Inadequate incubation conditions – Temperature

Actions and Adaptive Management:

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Velocity
- Lack of suitable migratory cues – Velocity
- Lack of suitable rearing habitat – Contaminants/toxins, velocity

Research to Inform Action Design:

Adult Holding

- Lack of suitable habitat – Contaminants

Adult Spawning

- Interactions with hatchery fish and other runs – Hatchery

Juvenile Rearing/Migration

- Predator density
- Lack of suitable migratory conditions – Cover
- Lack of suitable migratory cues – Turbidity, temperature
- Lack of suitable over-summering habitat – Depth

Priority 3 (Medium)

Actions and Associated Monitoring:

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Temperature

Actions and Adaptive Management:

Adult Holding

- Coarse sediment input

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Depth
- Lack of suitable over-summering habitat – Contaminants/toxins
- Lack of suitable rearing habitat – Cover, depth

Research to Inform Action Design:

Adult Holding

- Disease
- Lack of suitable habitat – Cover
- Poaching
- Predator density

Adult Migration

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Temperature, contaminants/toxins, attraction flows

Egg Incubation

- Inadequate incubation conditions – Flow fluctuation, redd scour, pesticides

Adult Spawning

- Inadequate availability of high-quality habitat – Contaminants, temperature
- Predator density

Juvenile Rearing/Migration

- Compression of the rearing and migration window – Temperature, DO
- Disease
- Lack of suitable migratory conditions – Turbidity
- Lack of suitable rearing habitat – Turbidity
- Lack of suitable migratory cues – Prey density
- Lack of fitness/genetic maladaptation – Hatchery introgression
- Lack of suitable habitat – Prey density

Priority 4 (Low)

Actions and Adaptive Management:

Adult Spawning

- Coarse sediment input

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Contaminants/toxins

Research to Evaluate Need for Action:

Adult Migration

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – DO
- Significant delay and/or failure to reach natal stream (direct effects) – DO, temperature, attraction flows

Adult Spawning

- Compression of the spawning window – DO, temperature

Egg Incubation

- Inadequate incubation conditions – Fine sediments

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – Prey density
- Lack of suitable over-summering habitat – Cover
- Lack of suitable rearing habitat – Prey density

Priority 5 (Lowest)

Actions and Adaptive Management:

None

Research to Confirm Action is Not Warranted:

Adult Holding

- Lack of suitable habitat – Depth, DO, velocity

Adult Spawning

- Disease
- Inadequate availability of high-quality habitat – Cover, depth, velocity
- Poaching

Juvenile Rearing/Migration

- Lack of suitable migratory conditions – DO
- Lack of suitable over-summering habitat – Velocity
- Lack of suitable rearing habitat – DO

Research to Understand Magnitude:

Adult Migration

- Significant delay and/or failure to reach natal stream (direct effects) – Contaminants/toxins, poaching

Adult Spawning

- Inadequate availability of high-quality habitat – Spatial distribution

Juvenile Rearing/Migration

- Lack of suitable migratory cues – DO
- Lack of suitable over-summering habitat – DO, turbidity

Monitoring to Ensure No Action is Warranted:

Adult Migration

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Passable physical barriers (including low water)

Adult Spawning

- Inadequate availability of high-quality habitat – DO

Egg Incubation

- Inadequate incubation conditions – Flow fluctuation, redd dewatering

Monitoring to Track Magnitude:

Egg Incubation

- Inadequate incubation conditions – Contaminants/toxins, DO

Juvenile Rearing/Migration

- Lack of suitable over-summering habitat – Temperature
- Lack of suitable rearing habitat – Temperature

Figure 28

Steelhead – Stressor Response Prioritization (Near Term/Fine Scale)

While the stressor response prioritization figures and tables prioritize stresses (by life stage), this is not meant to imply that stressor responses need to be carried out in the presented sequence in order to be effective. Stressor responses of different priorities can be addressed simultaneously. Additionally, the potential suite of actions necessary to resolve a single stressor may partially or completely resolve other stressors. There may also be a number of non-biological considerations (e.g., physical, political, and financial) that influence the timing and sequence with which conservation measures are implemented as stressor responses. However, the stressor response prioritization figures and tables are designed to provide guidance for the following:

- Which stressors are of greatest biological impact to the species;
- How conservation measures should be optimally sequenced for greatest biological benefit when not all stressors can be addressed simultaneously; and
- What the complete suite of stressor responses necessary to achieve Biological Objectives looks like.

The coarse scale stressor figures (Figures 23 through 25) and tables in Appendix E are designed to provide a high-level sense of the critical issues facing each species and the broad categories of responses necessary to achieve Biological and Environmental Objectives. The fine scale stressor figures (Figures 26 through 28) and tables in Appendix E detail the specific attributes of environmental conditions where objectives are not being met to help guide targeted remediation actions. Both the stress and stressor prioritization and response figures and tables are further subdivided based on near-term responses (current and recovering population; Figures 23 through 28) and long-term responses (target population; Appendix E). Changes in stressor magnitude from the near term to the long term are principally driven by higher fish population size, long-term forcing factors (e.g., climate change), or the hypothesized effect of current trends carried out over time (e.g., climate-driven warming). In order to highlight what is most immediately relevant for the development of conservation measures, the stressor prioritization discussion below focuses on near-term priorities for each of the three species.

8.7.2 Priority Stressors and Responses – Fall-run Chinook Salmon

8.7.2.1 Actions

For fall-run Chinook salmon in the Stanislaus River, the stressor analysis indicates that the juvenile life history stage is stressed to the greatest extent. At the coarse scale, stresses to juveniles necessitating high priority actions in the short term include lack of suitable rearing habitat, lack of suitable migratory conditions, compressions of the rearing and migration window, and lack of suitable migratory cues (Figure 23). Fine-scale stressors for juveniles driving coarse scale stress include compression of the migration window in response to unsuitable temperatures and temperature for migration (in both the main channel and off-channel/floodplain). The availability of high-quality rearing habitat is limited by contaminants and toxins present in the Stanislaus River during the rearing and migration windows; suitable migratory cues are limited by low velocity; and coarse sediment input is impacting rearing and migration conditions. A lack of fitness/genetic maladaptation is limited by hatchery introgression. Though to a lesser degree than the presence of contaminants and toxins, the availability of high-quality rearing habitat is also limited by suitable depth, cover, and temperature, and the availability of high-quality migratory conditions is limited by suitable depth (Figure 26).

High-priority actions in the near term are necessary to address stresses for spawning adults; to reduce interactions and introgression from hatchery stocks; and for eggs to improve incubation conditions in the area of temperature, as well as a number of other parameters for which the extent of limitation is still not well understood (Section 8.7.2.2). Also requiring near-term action, but at a slightly lower priority, are the negative sub-lethal effects on migrating adults from unsuitable temperature.

8.7.2.2 Research and Monitoring

Stressors for fall-run Chinook salmon that are the highest priority for research to inform actions relate to delay and the effects of potentially late access to spawning grounds for migrating adults. Of particular concern for migrating adults are the effects of reduced attraction flow, low DO levels, high contaminant levels, and unsuitable temperatures during the migration and spawning windows. Additional stressors that are a high priority for research are as follows: rearing habitat distribution, cover, and velocity as they relate to the in-channel migratory conditions for juveniles; and juvenile migratory cues related to temperature and turbidity (Figures 23 and 26).

8.7.3 Priority Stressors and Responses – Spring-run Chinook Salmon

8.7.3.1 Actions

For spring-run Chinook salmon in the Stanislaus River, the stressor analysis indicates that high-priority stressors affect almost all life history stages. Coarse-scale stress to juvenile spring-run Chinook salmon necessitating high priority actions in the near term include lack of suitable rearing habitat and lack of suitable migratory conditions (Figure 24). Fine-scale stressors driving these coarse scale stresses and in need of near-term remediation include lack of coarse sediment and substrate, temperature and velocity conditions throughout the migratory corridor (in both the main channel and off-channel), contaminant levels and velocity in rearing habitat, and lack of sufficient velocity to cue and support juvenile migration (Figure 27).

High-priority actions in the near term are also necessary to alleviate stressors for spawning adults, including interactions with hatchery fish and habitat segregation for salmon runs. Lack of suitable holding habitat for adults is also a high priority for action at the coarse scale, with unsuitable temperatures being the primary issue. Conditions for incubating eggs are also a high priority for spring-run, with temperature being the primary factor in need of remediation through action (Figure 27).

8.7.3.2 Research and Monitoring

Based on the stressor analysis, stresses for spring-run Chinook salmon that are the highest priority for research related to negative sub-lethal effects during adult migration, loss of fecundity in holding fish, and compressions of the spawning window. Specific concerns related to adult migration, holding, and spawning life history stages are principally related to lack of attraction flow (migration), unsuitable temperatures (migration and spawning), unsuitable DO levels (migration), and high contaminant levels (holding). Additional stressors that are a high priority for research include compression of the juvenile rearing and migration window as a result of unsuitable temperatures; suitable migratory conditions related to cover and habitat distribution for juveniles; and suitable migratory cues related to turbidity. Lower priority stressors that are important for research in the near term include the following (Figures 24 and 27):

- Inadequate egg incubation conditions as a function of contaminants and pesticides, redd scour due to flow fluctuation, and fine sediment impacts on egg survival;
- Impact of disease on adult holding and migrating and rearing juveniles;
- Contaminants present in adult holding and spawning areas;
- Loss of fecundity due to temperature conditions in holding areas;
- Predator density-driven predation in holding areas and on juvenile outmigrants; and
- Lack of suitable rearing habitat relative to turbidity.

8.7.4 Priority Stressors and Responses – Steelhead

8.7.4.1 Actions

For anadromous forms of *O. mykiss* in the Stanislaus River, high-priority stressors affect almost all life history stages. Lack of suitable rearing conditions, lack of migratory conditions, and lack of migratory cues are the highest priority stresses for juveniles. The lack of suitable holding habitat conditions for adults and inadequate incubation conditions for eggs and embryos also ranks among the highest priority. Fine-scale stressors driving the high priority for juvenile rearing include lack of coarse substrate, unsuitable (low) velocity (in channel), and high levels of contaminants and pesticides. For juvenile migration and migratory cues (Figure 26), lack of sufficient velocity and velocity variability are the most acute specific stressors in need of near-term remediation. Also in need of action to improve juvenile rearing and migration, though slightly lower priority, are suitability of depth and cover for in-channel habitat, temperature in the migratory corridor, and contaminants in over-summering habitat. For adult holding conditions and egg incubation conditions, temperature is the primary stressor driving the high priority for near-term action and, to a lesser extent, a lack of coarse sediment in holding areas (Figure 28).

8.7.4.2 Research and Monitoring

Stressors for anadromous *O. mykiss* that are the highest priority for research include the following (Figure 28):

- Lack of suitable temperature conditions as migratory cues for juveniles or variable or

unsuitable temperatures (to promote migration), especially during the summer months;
- Lack of turbidity and cover as a component of migratory conditions for juveniles;
- Lack of suitable over-summering habitat relative to depth; and
- Predator density-driven predation rates on juvenile outmigrants.

Also among the highest research priorities are the effects of contaminants and pesticides on adult holding conditions as well as the influence of hatchery introgression on adult spawning and reproductive success.

Additional stressors in need of research, though at a lower level of priority, include the following:

- Negative sub-lethal effects from lack of attraction flow, unsuitable temperatures, and contaminants and pesticide levels for migratory adults;
- Impacts to spawning habitat from the presence of contaminants, temperature, and predator density;
- Effects of disease, lack of cover, poaching, and predator density on adult holding conditions;
- Redd scour due to flow fluctuations and pesticide levels relative to egg incubation; and
- Limitations to juvenile rearing habitat quality resulting from low turbidity, low prey density, disease, lack of fitness from hatchery genetics, and temperature and DO effects on compressing the rearing and migration window.

8.7.5 Application of Stressors to Conservation Measure Development and Adaptive Management

When combined with the Biological and Environmental Objectives, the stressor analysis provides the basis for the following:

- Prioritizing conservation measures (including habitat enhancement actions and research) for maximum biological benefit;
- Understanding the full range and extent of conservation measures necessary to support population recovery; and

- Setting expectations related to the extent of conservation measures required to see progress towards the Biological Objectives for a given life history stage based on the extent of the stress to that life history stage that has been resolved.

Stressors are the obstacles to achieving the desired conditions identified through the Environmental Objectives process and are necessary for the species to attain the target population conditions quantified in the Biological Objectives. For these reasons, for any given life history stage, progress towards the Biological Objectives can only be expected once the high-priority stressors have been addressed and Environmental Objectives largely achieved. The efficacy of conservation measures designed to reduce stressors should therefore be measured based on the extent that those measures advance or achieve Environmental Objectives. Once Environmental Objectives have been significantly advanced, or achieved via the resolution of priority stressors, Biological Objectives become the following:

- Metrics to measure species response to the actions, and
- Triggers for adaptive management in the case where Environmental Objectives do not result in the predicted biological response.

Although Environmental Objectives and stressors do not have a one-to-one relationship with Biological Objectives, there are several core relationships among them that, for a given life history stage, can serve to guide expectations around biological response to the attainment of Environmental Objectives.

Habitat Quality → Survival

Given the carrying capacity associated with a given spatial area of habitat, fish condition and survival are largely linked with habitat quality as defined by Environmental Objectives and stressors for a given life stage. Attainment of Environmental Objectives for habitat quality via resolution of high priority stressors for a given life history stage should therefore trigger response in biological metrics (and make progress towards objectives) related to survival rate for individuals of that life history stage, given the limits to carrying capacity. For example, attainment of the habitat quality objectives for egg incubation should be measurable in terms of progress towards Biological Objectives for egg survival.

Habitat Spatial Extent → Abundance

Given habitat quality and suitability, as quantified by the Environmental Objectives, and associated survival rates, increased spatial extent of suitable habitat increases carrying capacity for that life history stage. Increases in habitat spatial extent should therefore be measurable in biological metrics (and make progress towards objectives) related to abundance for that life history stage to the extent that abundance is constrained by carrying capacity. For example, attainment of the habitat quantity objectives for adult holding and spawning habitat should be measurable in terms of progress towards Biological Objectives for adult in-river/spawner abundance.

Habitat Temporal Extent → Diversity and Resilience

Given sufficient habitat quality and spatial extent, the temporal extent and availability of habitat increases the potential for a given life history stage to express diversity. The range of diversity expressions for each life history stage, across life history stages, comprise the resilience of the cohort. Similarly, the resilience of the individual cohorts, across multiple cohorts, comprise the resilience of the population. Attainment of Environmental Objectives for habitat temporal availability for a given life history stage should trigger a response in biological metrics (and make progress towards objectives) related to diversity in that life history stage or, across life history stages, resilience in the cohort and population. For example, attainment of the temporal extent objectives for juvenile rearing and migration should be measurable in terms of progress towards Biological Objectives for juvenile diversity.

Even when the primary stressors for a given life history stage have been addressed, certain Biological Objectives (e.g., population growth and abundance) require success across multiple or all life history stages. Therefore, it becomes necessary for the high priority stressors to be addressed and the Environmental Objectives to be achieved for all life story stages in order to see meaningful progress towards the full suite of Biological Objectives.

9 MOVING FORWARD: DESIGN AND IMPLEMENTATION OF A CONSERVATION STRATEGY, MONITORING, AND ADAPTIVE MANAGEMENT

Good decisions are defined by the process in which they were generated and how the decision framework incorporates new information in order to reduce uncertainty and improve decision outcomes (Williams et al. 2012). The process of developing the SEP's objectives and stressor evaluations represents a significant advance in the application of science to improve understanding of restoration needs and challenges in the Stanislaus River and throughout the San Joaquin River basin. When the SEP began, participating organizations and agencies often had very different definitions of restoration success for the Stanislaus River, and those desired outcomes were often not clearly articulated. Similarly, many of the participating scientists entered the SEP with an internal (but unarticulated) conceptual model of the key problems and limits that prevented attainment of desired biological outcomes. The goals, objectives, and stressor rankings emerging from this process represent a new scientific consensus around a vision of what the Stanislaus River can be expected to attain with regard to salmon restoration, how this vision fits into the requirements of existing policy for the Central Valley as a whole, and a shared conceptual model regarding the numerous barriers to attainment of the vision generated by the current landscape and water management practices in the Stanislaus River.

There is no silver bullet for restoring populations of fall-run Chinook salmon, spring-run Chinook salmon, or *O. mykiss* on the Stanislaus River. The stressor evaluation presented in Section 8, which is based on comparisons of current conditions to the best available science regarding desired environmental conditions for salmonids, reveals that a comprehensive conservation strategy is needed, and that such a strategy must include a variety of actions to address a wide range of high priority barriers that occur throughout the freshwater life cycle of target salmonid populations. The SEP Group's products provide the essential framework for designing an effective and efficient conservation strategy that can produce desired outcomes on the Stanislaus River (Watershed-specific Goals) and ensure that this watershed is contributing to attainment of larger laws and policies regarding salmonid restoration throughout the Central Valley (i.e., Central Valley Goals and Objectives). These products will support the prioritization of restoration activities by allowing restoration planners to make good decisions based on the best available science and to avoid the misallocation of limited resources to actions or monitoring that are not part of the critical path to successful restoration outcomes.

9.1 Using SEP Products in Adaptive Management

Throughout this report, the SEP Group has described how the products developed in this report can serve in managing towards its vision of conservation success in an adaptive fashion; specific opportunities for adaptive management are identified in Section 8. Adaptive management is a systematic approach for improving resource management by learning and adapting from management outcomes through partnerships of managers, scientists, and other stakeholders who learn together how to create and maintain sustainable resource systems (Sexton et al. 1999). Three elements are necessary for a program to follow the USDOI adaptive management protocol (Williams et al. 2009). First, decisions must be recurrent to allow opportunities for learning to influence future decision-making. Second, decisions must be based on predictions that incorporate structural uncertainty; often this will be represented by two or more alternative models or hypotheses about system functionality. Third, there must be an objective-driven monitoring program. Programs that do not contain these essential elements are not, and properly should not be called "adaptive management." Where these elements are present, adaptive management is a critical component of resource management that allows implementation and improvement of conservation strategies in the face of uncertainty. These three elements either are described or are implicit in the framework, approach, and results presented in this report.

Each component of the SEP framework is essential to adaptively managing a comprehensive salmonid restoration strategy. Biological Objectives represent the minimum conditions necessary to achieve Watershed-specific Goals for the Stanislaus River and its contribution to Central Valley Goals and Objectives for anadromous fish restoration; all management activities must be oriented toward attainment of the Biological Objectives and modified over time, as necessary, to achieve those objectives. This means that, prior to selection and implementation of Conservation Actions, proposed actions must be evaluated based on their ability to support the Biological Objectives, and, following implementation, monitoring will be needed to assess whether the actions' expected benefits materialize. Because it is difficult to measure the direct effect of individual actions on phenomena described in the Biological

Objectives, the Environmental Objectives provide the physical design criteria against which Conservation Actions (individually and collectively) can be evaluated. Environmental Objectives represent hypotheses of the environmental conditions needed to achieve the Biological Objectives. Stressors, and their relative magnitude and certainty scores, represent hypotheses regarding existing and expected future barriers to attainment of Environmental and/or Biological Objectives. Finally, Conservation Actions will represent hypotheses about the best way to ameliorate stressors and attain Environmental and Biological Objectives.

9.2 Next Steps for the Stanislaus River: Designing, Evaluating, Implementing, and Monitoring Conservation Actions

The next steps in developing a comprehensive conservation strategy for salmonids in the Stanislaus River will be the design of a suite of specific Conservation Actions, including the monitoring elements needed to evaluate the performance of actions individually and collectively. Such actions can and should be evaluated based on their ability to alleviate the priority stressors identified in Section 8 and to produce the Biological and Environmental Objectives described in Sections 6 and 7, respectively. Taken together, stressors and Environmental Objectives display, in practical terms, the scale of the problems that need to be solved. For instance, many off-channel habitat restoration projects will be required to fully alleviate the stress generated by "Lack of suitable rearing habitat" for juvenile Chinook salmon and anadromous *O. mykiss* (Section 8 and Figures 23, 24, and 25). Without explicitly defined objectives and prioritization of stressors, those who develop and/or evaluate Conservation Actions would not have an appropriate biological basis for comparing competing sets of habitat restoration proposals. In addition, they would have no benchmark to determine how the need for this kind of action changes as more projects are implemented (i.e., no way to know when habitat restoration actions are approaching a level where "lack of suitable rearing habitat" is no longer the highest priority stressor).

By articulating Watershed-specific Goals; expressing those goals in S.M.A.R.T. terms in the Biological and Environmental Objectives; and identifying, describing, evaluating, and prioritizing stressors, this report provides a clear vision of desired biological outcomes and makes transparent the linkage between that vision and subsequent Conservation Actions. Prior to selection and implementation of Conservation Actions, stakeholders, resource managers, and decision-makers can evaluate the specific contributions of different Conservation Actions (alone and together) to the Biological and Environmental Objectives. Following implementation of Conservation Actions, information developed through monitoring can be synthesized to allow measurement of an action's effects in terms of the environmental conditions (Stressors and Environmental Objectives) it was intended to modify. This comparison enables efficient adjustment of Conservation Actions and adaptation of the conservation strategy, as needed. If monitoring indicates that Conservation Actions are not performing as intended, changes to the actions or additional actions will be implemented to ensure that Environmental Objectives and Biological Objectives are reached. Conversely, if Biological Objectives are attained prior to implementing the full suite of Conservation Actions, then the conservation strategy can be modified.

Implementation of the Conservation Actions will require various levels of monitoring, including site-specific monitoring to document compliance and performance of specific measures and system-wide monitoring to evaluate overall effectiveness. Monitoring activities will need to produce data that is relevant to assessing progress at all levels of the "logic chain" structure (Figure 2). Monitoring results should inform managers whether progress is being made towards:

1. Intended performance of individual Conservation Actions
2. Stressor reduction/elimination
3. Environmental Objectives
4. Biological Objectives

Clearly, monitoring needed to assess performance of Conservation Actions can only be determined after the conservation strategy is described in detail. However, the monitoring needed to evaluate progress towards larger desired outcomes (items 2-4 in the list above) has been defined by the performance metrics presented in this report.

Measurability of Biological and Environmental Objectives was a key consideration in their design and expression. Indeed, established monitoring programs already provide information to track changes in biological and environmental conditions that are described in the objectives (Tables 67 and 68). These monitoring efforts may need to be refined or expanded in order to fully evaluate progress, but the long data series already established by these programs make them particularly valuable in evaluating changes in environmental conditions and biological responses to those conditions. For example, the duration and frequency of operation of RSTs and the salmon counting weir may need to be expanded and juvenile sampling at Mossdale may need to be refined. Where current monitoring in the Stanislaus and lower San Joaquin rivers does not directly address Biological Objectives, the SEP Group considered whether monitoring was possible (i.e., that all objectives are measureable) with currently available technology. Several new elements of a monitoring and assessment plan needed to track objectives and stressors developed by the SEP Group are identified in Tables 67 and 68, though the information in these tables is not comprehensive.

Table 67

Current and Potential Monitoring that Could be Used to Measure Progress Towards SEP Biological Objectives

Biological Objective Type	Species	Life Stage	Specific Objective	Relevant Current Monitoring (Monitoring Agency)	Relevant Monitoring Needed
Productivity	All	Egg	Egg-emergence to Oakdale RST Survival	Adult escapement at counting weir (USFWS weir – Tri-Dam funds); life history investigations (e.g., escapement and carcass surveys; CDFW); Oakdale RST catch (Tri-Dam – currently not shared)	To be determined
Productivity	All	Egg	Viability	None	Requires incubation chamber (in hatchery or on site) measured by surrogates (e.g., egg trays) and/or as projected by monitoring of temperature, flow, sediment deposition, and scour
Productivity	All	Egg	Incubation success	None	Spawning surveys, redd mapping (superimposition), redd capping
Life History Diversity	Chinook salmon fall-run (FR) and spring-run (SR)	Adult migration	Migration timing	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	To be determined
Productivity	Chinook salmon FR-SR	Adult migration and spawning	Abundance	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	To be determined
Productivity	Chinook salmon FR-SR	Adult migration and holding	Survival	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	Include surveys for SR
Life History Diversity	Chinook salmon FR-SR	Adult migration and spawning	Spawning timing	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	Include surveys for SR
Productivity	Chinook salmon FR-SR	Adult migration and spawning	Prespawn mortality	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	Include surveys for SR
Productivity	Chinook salmon FR-SR	Juvenile emigration	in river (egg to delta) survival	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW); Caswell RST catch (USFWS); Mossdale trawl (CDFW)	Include surveys for SR; Add or modify surveys at Mossdale to more accurately/frequently survey migrating salmonids, and smaller fish in particular; Ototlith microchemistry to distinguish juveniles from different natal streams in the lower San Joaquin
Genetic	Chinook salmon FR-SR	Adult migration and spawning	Percentage of hatchery origin spawners	Adult Escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW)	Include surveys for SR
Genetic	Chinook salmon FR-SR	Juvenile emigration	Percent introgression (SR-FR)	None	Genetic testing of outmigrating juveniles
Life History Diversity	Chinook salmon FR-SR	Juvenile emigration	Size, timing, and proportion of migrants; number of yearlings	Caswell RST catch (USFWS)	Include surveys for SR; Add or modify surveys at Mossdale to more accurately/frequently survey migrating salmonids, and smaller fish in particular; Otolith microchemistry to distinguish juveniles from different natal streams in the lower San Joaquin

Biological Objective Type	Species	Life Stage	Specific Objective	Relevant Current Monitoring (Monitoring Agency)	Relevant Monitoring Needed
Productivity	*O. mykiss* (steelhead)	Juvenile emigration	Smolt survival down the river and size and proportion of smolt migrants	None	Inclined-screen traps and video cameras, Didson cameras (imaging sonar system), or mark-resight estimates based on PIT tagging (some data from RST)
Productivity	*O. mykiss* (steelhead)	Juvenile emigration	Number of smolts (> 150 mm) per female spawner and total number of smolts per female spawner	Adult escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW); Caswell RST catch (USFWS)	Inclined-screen traps and video cameras, Didson cameras (imaging sonar system), or mark-resight estimates based on PIT tagging (some data from RST)
Productivity	*O. mykiss* (steelhead)	Juvenile rearing	Parr density	Snorkel surveys (USBR)	Electrofishing or other appropriate sampling
Productivity	*O. mykiss* (resident)	Juvenile rearing	Number of smolts (> 150 mm) per female spawner and total number of smolts per female spawner	Adult escapement at counting weir (USFWS weir – Tri-Dam funds); Life history investigations (e.g., escapement and carcass surveys; CDFW); Caswell RST catch (USFWS)	Inclined-screen traps and video cameras, Didson cameras (ARIS), or mark-resight estimates based on PIT tagging (some data from RST)
Productivity	*O. mykiss* (resident)	Juvenile rearing	Parr growth rates	None	Growth rates could either be measured by capturing, PIT tagging, and recaptured juvenile *O. mykiss* in the river or estimated by back calculating lengths at age from scales
Life History diversity	*O. mykiss*	Adults	Percentage of anadromous and resident adults	None	Resident: adult snorkel surveys or masks and recapture; Anadromous: weir counts, snorkel surveys, or redd surveys, otolith microchemistry
Life History diversity	*O. mykiss* (steelhead)	Juvenile rearing	Proportion of anadromous mothers	None	Otolith microchemistry
Life History diversity	*O. mykiss* (resident)	Adults	Minimum abundance of resident adults	None	Resident: adult snorkel surveys, mark and recapture, or electrofishing
Life History diversity	*O. mykiss* (steelhead)	Juvenile emigration	Detection of emigrating smolts	Caswell RST catch (USFWS); Oakdale RST catch (Tri-Dam – not currently shared); Mossdale trawl (CDFW)	Modifications to Mossdale trawl (CDFW) to detect juvenile-size ranges

Table 68

Current and Possible New Monitoring that Could be Used to Measure Progress Towards SEP Environmental Objectives

Environmental Objective Type	Species	Life Stage	Specific Objective	Relevant Current Monitoring	Relevant Monitoring Needed
Temperature	All	All	Appropriate timing and ranges for all life stages through the corresponding river reaches	Current CDEC and USGS stations include Goodwin Canyon, Knights Ferry, Orange Blossom Bridge, Oakdale, Ripon, Vernalis, and numerous Delta locations.	Special studies may be necessary to measure temperatures in currently unmeasured habitats (e.g., floodplains, intra-gravel, and cold-water refugia).
DO	All	All	Appropriate timing and ranges of DO in the mainstem river, floodplain habitat, and gravels (eggs)	CDEC stations at Ripon, Vernalis, and Delta locations	DO monitoring is needed in the main channel upstream of Ripon, in floodplain habitats, and in spawning gravels.
Pesticides	All	All	Maximum frequency of pesticide levels that will elicit detrimental conditions (e.g., direct and indirect) throughout the watershed	Some historical pesticide monitoring data are available for the Caswell area, and some pesticide modeling has provided baseline condition information.	Pesticide monitoring must continue in the future, and existing monitoring must be expanded to include the upstream mainstem and other aquatic habitats. Optionally, pesticide modeling may be able to provide better spatial and temporal resolution to estimate the pesticide impacts to the river.
Mercury and Selenium	All	All	Maximum concentrations of mercury and selenium in fish tissue	None	Adult tissue mercury and selenium monitoring every 5 – 10 years to ensure conditions have not degraded. Female spawner concentrations can be used to estimate mercury and selenium maternal transfer to eggs. Multi-year special study to verify that juvenile, yearling, and resident *O. mykiss* bioaccumulation of mercury and selenium is not at levels that will cause harm. Then, juvenile tissue mercury and selenium monitoring every 5 – 10 years to ensure conditions have not degraded.
Nutrients	All	All	Maximum average concentrations of ammonia, nitrate, and nitrite to prevent direct toxicity	No comprehensive, long-term monitoring of these constituents exists in the Stanislaus River; however, the limited recent and historical data suggest that nutrient concentrations are in the optimal range for toxicity impacts.	Nutrients should be monitored at a set of locations along the river corridor every 3 – 5 years to ensure conditions have not degraded over time
Nutrients	All	All	Nutrient levels (minimum and maximum) that support ecological use	A recent CDFW aerial assessment of rivering macrophytes was performed; however, there is no comprehensive long-term monitoring of macrophytes in place. DO levels are also an indicator of ecological use.	Nutrient concentrations, benthic and sestonic chlorophyll levels, and other environmental conditions (e.g., DO) should be evaluated to determine if nutrient or other biostimulatory factors are contributing to sub-optimal conditions in the river.
Habitat	All	Adult migration	Minimum riffle depths	Routine river monitoring by CDFW and USFWS (e.g., float trips) could be used to identify when dramatic channel morphological changes might create conditions that could restrict migration.	To be determined

Environmental Objective Type	Species	Life Stage	Specific Objective	Relevant Current Monitoring	Relevant Monitoring Needed
Habitat	Primarily Spring-run, but any holding species	Adult holding	Minimum water depth and maximum velocity	None	As the spring-run population approaches recovery, holding habitats should be identified and quantified to ensure adequate depths and velocities to fully support population recovery.
Habitat	All	Adult Spawning	Spawning habitat quantity and distribution	Spawning habitat quantity is an aggregate of multiple environmental objectives that define suitable spawning habitat. Many of these are already monitored (as listed in this table).	The monitoring for this objective requires the quantification of the acres of suitable spawning habitat. The required suitable habitat must be distributed spatially and temporally to prevent superimposition or introgression among species. This will require integration of monitoring for relevant objectives in a spatially explicit (GIS) format.
Habitat	All	Adult Spawning	Appropriate water depths and velocities for spawning	USBR and USFWS have a 2-dimensional (2D) habitat model and routinely conduct post-project mapping of gravel augmentation projects.	To be determined
Habitat	All	Adult Spawning	Appropriate sediment size distribution	Recent gravel augmentation projects actively monitor for appropriately sized gravel prior to/during augmentation activities.	To be determined
Habitat	All	Egg incubation	Maximum percentage of fine sediment (< 4.8 mm)	None	Fine sediment monitoring may be performed in conjunction with sediment size distribution surveys. However, additional monitoring may need to be conducted throughout the incubation period to ensure storm water inputs do not import large loads of fine sediment and degrade redd habitats.
Habitat	All	Juvenile rearing and migration	Spatial extent, distribution, and timing of rearing and migration habitat	Rearing and migration habitat quantity and distribution are aggregates of the environmental objectives that define the qualities of suitable habitat. Modeling of off-channel habitat inundation of various durations is available (FlowWest).	Field monitoring of timing, duration, annual frequency, quantity, and other physical characteristics of inundated habitat are needed to verify and calibrate model predictions under different flow regimes. Bioassessments may be necessary to ensure that primary and secondary production and export/transport is occurring as predicted in both shallow inundated and in-channel habitats.
Habitat	All	Juvenile rearing and migration	Appropriate water depths and velocities in floodplain habitats	Water depths and velocities, in part, define the quality and benefits of floodplain habitats for salmonids. Modeling of off-channel habitat inundation depths is available (FlowWest).	Site-specific modeling of water velocities in floodplain habitats will be needed (as part of project design) and field monitoring of both inundation depths and velocities will be needed to verify and calibrate models and ensure that an adequate area of suitable habitat is available under a range of flows.
Habitat	*O. mykiss* (steelhead)	Juvenile rearing and migration	In-channel flow variability	Unimpaired flow estimates are available from rim station dams (DWR and other agencies) in order to mimic natural hydrograph variability that would contribute to the expression of anadromy in *O. mykiss*.	Additional temperature monitoring at rim station dams may be necessary in order to model/mimic temperature variability that would contribute to the expression of anadromy in *O. mykiss*.
Habitat	All	Juvenile rearing and migration	Minimum cover, structure, and substrate metrics in floodplain and in-channel habitats	USFWS and USBR incorporate these habitat measures in their 2D model.	To be determined

Note:
FlowWest = FlowWest SRH2d Model, available from: http://public.tableau.com/profile/mark.tompkins#!/vizhome/20160203_CVPIA_Floodplain/Floodplain

The SEP's goals, objectives, and stressors also encourage targeted and efficient monitoring of individual Conservation Actions. When Conservation Actions are developed, their projected effect on relevant stressors must be described along with their expected contribution towards attainment of Environmental Objectives. Proposed Conservation Actions should also describe appropriate monitoring and assessment protocols to track performance of the action with respect to Stressors and Environmental Objectives; the monitoring proposed should be specific to the problems that the Conservation Action is designed to address. In certain cases, the stressors addressed by a Conservation Action may transcend the effect of any particular physical or chemical environmental condition; actions that are designed to reduce predation pressure fall into this category. In such cases, monitoring plans that accompany the proposed action should be specific with regard to the way in which the action is expected to reduce the stress so that the effect of the action can be tracked by relevant monitoring.

9.3 Next Steps for the SEP Group

The SEP Group intends to move forward on two fronts. The first will be to develop goals and objectives and evaluate stressors for the San Joaquin River's other major tributaries (the Tuolumne River and Merced River) as well as for the lower mainstem San Joaquin River (downstream of its confluence with the Merced River). Restoring these waterways is critical to the attainment of Central Valley Goals and Objectives identified in this report; additionally, several of the challenges identified in restoring salmonid populations to the Stanislaus River (e.g., hatchery influence, migration of juvenile and adult salmon through the lower San Joaquin River corridor) are problems that require a basin-wide perspective.

The second avenue for the SEP involves an evaluation of the proposed Conservation Actions in relation to the comprehensive conservation strategies for salmonid restoration throughout the San Joaquin Basin. Panels of scientists and managers that evaluate proposed conservation strategies will consist of SEP participants (excluding any who were involved in developing the Conservation Actions that will be reviewed) and scientists with relevant experience who did not participate in the SEP Group. Scientific evaluations will rely on the SEP products developed in this report and will employ a structured assessment protocol similar to that developed for the DRERIP,[13] a multi-agency project to regulate salmonid restoration activities in the Central Valley Watershed.

[13] Available from
http://www.dfg.ca.gov/erp/conceptual_models.asp)http://www.dfg.ca.gov/erp/conceptual_models.asp

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APPENDIX A
STANISLAUS RIVER SURVIVAL MODE

APPENDIX B
ENVIRONMENTAL OBJECTIVES FOR ACHIEVING THE STANISLAUS RIVER BIOLOGICAL OBJECTIVES

These matrices have been created to assist the SEP Group in evaluating conservation measures within a comprehensive framework documenting habitat needs (and stressors) of three runs of anadromous salmonids in the Stanislaus River.

APPENDIX C
ENVIRONMENTAL OBJECTIVES THAT APPLY ACROSS ALL SPECIES AND LIFE STAGES

APPENDIX D
ESHE MODEL DESCRIPTION

APPENDIX E
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Appendix H. Central Valley Chinook Salmon Rearing Habitat Required to Satisfy the Anadromous Fish Restoration Program Doubling Goal

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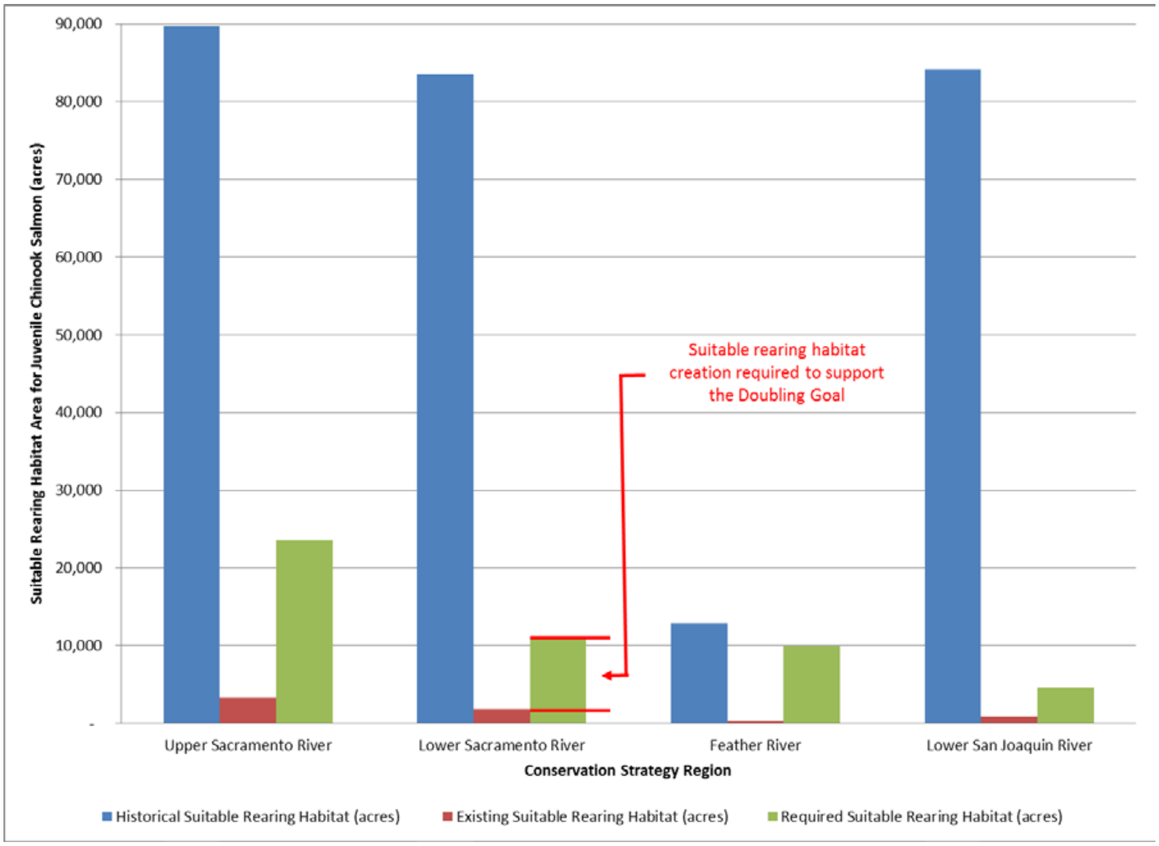
1.0 Executive Summary

NewFields and Cramer Fish Sciences, in collaboration with the California Department of Water Resources FloodSAFE Environmental Stewardship and Statewide Resources Office Conservation Strategy team, applied best available tools and data to estimate the area of suitable juvenile salmonid rearing habitat required in each of the Conservation Planning Areas (CPAs) to achieve the Anadromous Fish Restoration Program (AFRP) "doubling goal" for Chinook salmon populations. The AFRP goal was used to align the Conservation Strategy objectives with existing, long-standing efforts by partner resource management agencies. Historical and existing suitable rearing habitat area for juvenile salmonids was estimated with the Estimated Annual Habitat approach that uses measured hydrology and modeled hydraulic relationships between river flow and inundation area to calculate areas of inundation with timing, duration, and frequency suitable for juvenile California Chinook salmon rearing. The rearing habitat required to support the doubling goal populations was estimated using the Emigrating Salmonid Habitat Estimation model. The details of the approach and the full range of calculated results are presented in the following sections and appendices.

Figure 1-1 is a comparison of average estimates of historical, existing, and required suitable rearing habitat for juvenile salmonids (to achieve the AFRP doubling goal) in each CPA. "Historical Rearing Habitat" is the area of physically suitable habitat historically (i.e., before construction of Central Valley dams and levees) inundated with timing, duration, and frequency suitable for juvenile Chinook salmon rearing. "Existing Rearing Habitat" is the area of physically suitable habitat currently inundated (i.e. after construction of Central Valley dams and levees) with timing, duration, and frequency suitable for juvenile Chinook salmon rearing. "Required Rearing Habitat" is the area of suitable habitat needed to support the AFRP doubling goal for Chinook salmon in the Central Valley. The area of suitable rearing habitat creation that would support the doubling goal is the difference between Required Rearing Habitat and Existing Rearing Habitat. Historical Rearing Habitat provides an unimpaired frame of reference for each CPA. It is important to note that creating sufficient suitable rearing habitat to bridge the gap between Required Rearing Habitat and Existing Rearing Habitat calculated for each CPA is not necessarily the charge of the Central Valley Flood Protection Plan. However, the Conservation Strategy will be able to use the information from this analysis as a measure to evaluate incremental progress toward satisfying suitable rearing habitat required to support the doubling goal in each CPA.



Note: Historical and existing values assume average suitability of the total area inundated by flows with timing, duration, and frequency suitable for juvenile California Chinook salmon rearing. Required values assume migration, growth, and survival rates averaged for early and late migration strategy juvenile salmonid life histories.

Figure 1-1. Summary of *Average* Historical, Existing, and Required Suitable Rearing Habitat Area to Support the AFRP Doubling Goal in Each of the CPAs

2.0 Introduction and Purpose

To restore degraded river corridors and develop large-scale, sustainable watershed strategies, it is essential for managers to consider the habitat requirements of keystone (focal) species and reestablish the amount and range of habitat features under which such species prosper. An important component of a habitat restoration plan is development of an evaluation strategy to assess the effectiveness of restoration efforts and improve future programs. To maximize the benefits of restoration activities and to increase the likelihood of success and cost-effectiveness of restoration programs, decisions about locations and amounts of habitat to be restored should be guided by quantitative measures of preferred habitat features for focal species; this also applies to the maintenance of appropriate habitat for long-term sustainability of vital populations of focal species.

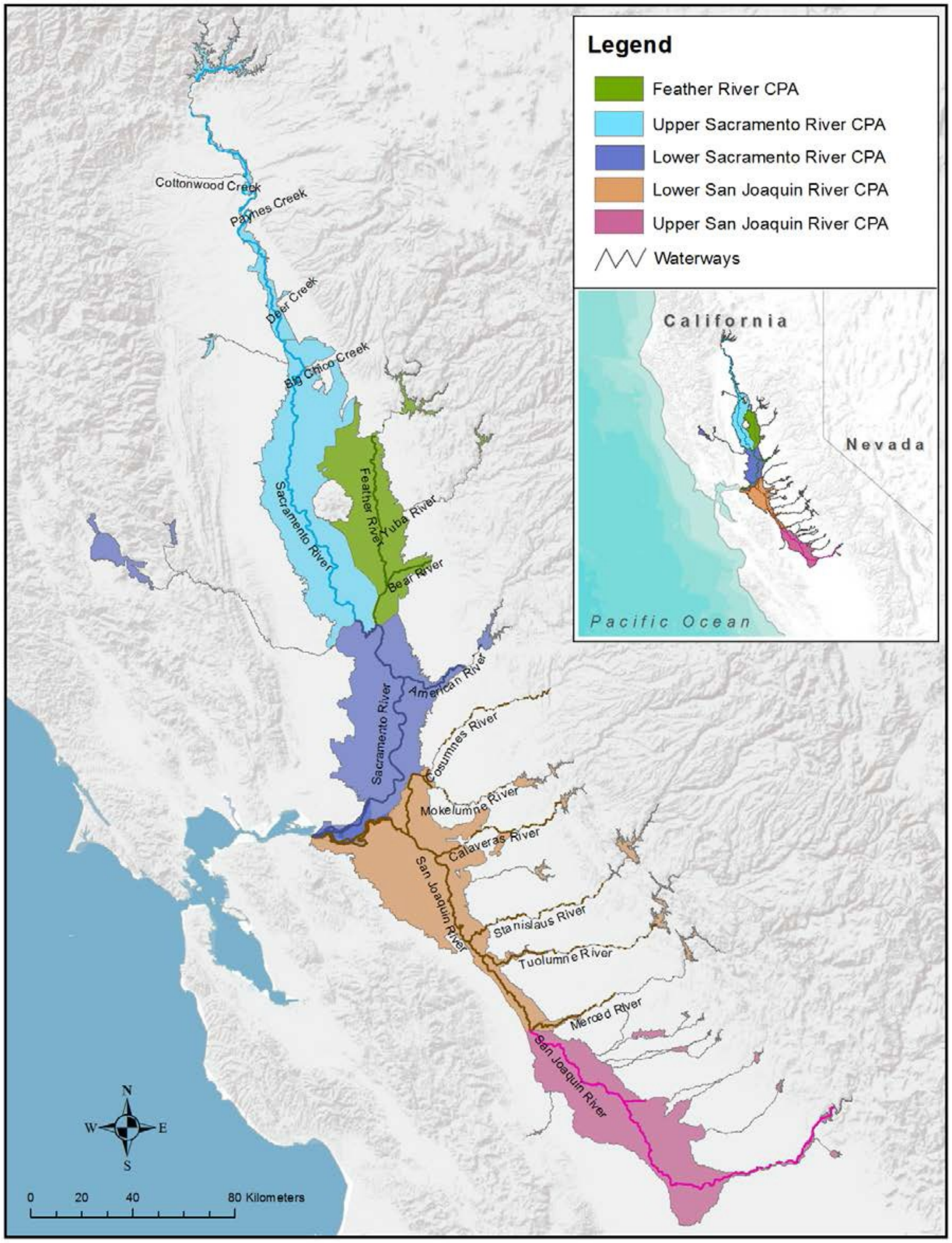
The purpose of this analysis is to refine previously developed suitable rearing habitat objectives for the Conservation Strategy of the Central Valley Flood Protection Plan (CVFPP). The juvenile rearing habitat needs of Central Valley (CV) Chinook salmon[1], an iconic species with significant ecological, social, and financial implications for the State of California, are the focus of this effort. The results of this investigation provide initial targeted area estimates for creation of suitable rearing habitat for juvenile salmonids in each Conservation Planning Area (CPA) (Figure 2-1), and a means of prioritizing creation of rearing habitat within and across CPAs. The best available tools and supporting data were used to estimate suitable rearing habitat required in the Central Valley CPAs to support the doubling goal[2], existing suitable rearing habitat within the highly modified CPA environment, and historical suitable rearing habitat likely present in Central Valley CPAs prior to dam operation, levee construction, and large scale development.

Existing and historical suitable rearing habitat was estimated using the Estimated Annual Habitat (EAH) approach (Matella and Jagt 2013) that uses measured hydrology and modeled hydraulic relationships between flow and inundation area to calculate areas of inundation with timing, duration, and frequency to support juvenile Chinook salmon. Suitable rearing habitat required to satisfy the doubling goal was calculated using the Emigrating Salmonid Habitat Estimation (ESHE) model, which considers territory size required for emigrating juvenile salmonids, using empirically derived migration rates, growth rates, and survival rates. In implementing these two approaches, consistent assumptions were adopted about the duration, timing, and frequency of flows and the physical suitability of inundated areas required to provide suitable rearing habitat for juvenile salmonids.

[1] "CV Chinook salmon" includes the following Evolutionarily Significant Units: CV fall- and late fall–run Chinook salmon, Sacramento River winter-run Chinook salmon, and CV spring-run Chinook salmon.

[2] Section 3406(b)(1) of the CVPIA (enacted in 1992), states that the AFRP is to "develop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967–1991…"

In the future, creation of new suitable rearing habitat will be evaluated and designed using the approach described here and accounted for by comparing each new increment of suitable rearing habitat to the suitable rearing habitat required to support the doubling goal. It is important to note that creation of the required suitable rearing habitat calculated for each CPA is not necessarily the charge of the CVFPP. However, the Conservation Strategy will be able to use the information from this analysis as a measure to evaluate incremental progress toward achieving suitable rearing habitat required in each CPA to satisfy the doubling goal. Not only do seasonal floodplains provide critical habitat that is essential for the growth and development of juvenile salmonids, but annual inundation of floodplains is the principal force determining productivity and biotic interactions in river-floodplain systems (Junk et al. 1989; Sommer et al. 2001). Therefore, for natural production of CV Chinook salmon to approach long-term, sustainable abundance levels (the objective of the doubling goal) , the Sacramento–San Joaquin River system must support sufficient floodplain habitat critical to fish production.



Note: This analysis considered the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs. This analysis did not include the Upper San Joaquin River CPA because a previous study was completed as part of the San Joaquin River Restoration Program (SJRRP) to recommend the minimum area of suitable rearing habitat for juvenile salmonids required to meet fall- and spring-run Chinook salmon targets for the Upper San Joaquin River CPA (SJRRP 2012).

Figure 2-1. Map of Conservation Planning Areas

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3.0 Historical Suitable Rearing Habitat for Juvenile Salmonids

3.1 General Approach

Historical suitable rearing habitat area for juvenile salmonids was estimated using a combination of historical habitat suitability mapping, historical hydrology data and analysis, historical hydraulic analysis, and spatial modeling in a Geographic Information System (GIS). The following analysis steps detail the general approach implemented to estimate the historical suitable rearing habitat in each CPA:

1) Subreaches of the mainstem Sacramento River, San Joaquin River, Feather River, and all tributaries with AFRP doubling goals were delineated based on a review of relevant historical hydrology data from U.S. Geological Survey (USGS), California Data Exchange Center (CDEC) and other gages (Table 3-1) to create subreaches within which hydrologic conditions were generally similar (Figure 3-1).

Table 3-1. Summary Information for Streamflow Gages Used in the Analysis of Historical Suitable Rearing Habitat for Juvenile Salmonids

CPA	Sub-CPA River Reach	Gage Name	Gage ID	Evaluation Period	Criteria Flow (cfs)*
Upper Sacramento	Paynes to Deer	Bend Bridge Near Red Bluff - Sacramento River	11377100	1891 to 1948	20,731
Upper Sacramento	Colusa to Verona	Wilkins Slough - Sacramento River	11390500	1938 to 1948	17,882
Feather	Thermalito to Yuba	Gridley - Feather River	GRL	1964 to 1968	14,700
Feather	Yuba to Bear	Gridley - Feather River	N/A	1964 to 1968	14,700
Feather	Bear River	Bear River near Wheatland	11424000	1928 to 1964	1,167
Feather	Bear to Sutter	Gridley and Bear River combined	N/A	1964 to 1968	15,408
Lower Sacramento	Verona to American	Verona - Sacramento River	11425500	1929 to 1967	41,878
Lower Sacramento	American River	American River at Fair Oaks	11446500	1904 to 1955	9,370
Lower San Joaquin	Merced River	Stevinson - Merced River	11272500	1940 to 1966	1,022
Lower San Joaquin	Merced to Tuolumne	Newman - San Joaquin River	11274000	1912 to 1941	5,127
Lower San Joaquin	Tuolumne River	Modesto - Tuolumne River	11290000	1895 to 1969	2,237
Lower San Joaquin	Stanislaus River	Ripon - Stanislaus River	11303000	1940 to 1977	2,257
Lower San Joaquin	Stanislaus to Stockton	Vernalis - San Joaquin River	11303500	1923 to 1941	8,808

*Criteria: Timing = December 1 to May 31; Duration = 14 days continuous; Frequency = 50% (once every two years)

2) Historical streamflow data from the gages used in #1 above were queried for pre-dam hydrology data (Table 3-1) determined by identifying the date of completion of the nearest controlling dam in each subreach and selecting streamflow data for the period before completion of that dam.

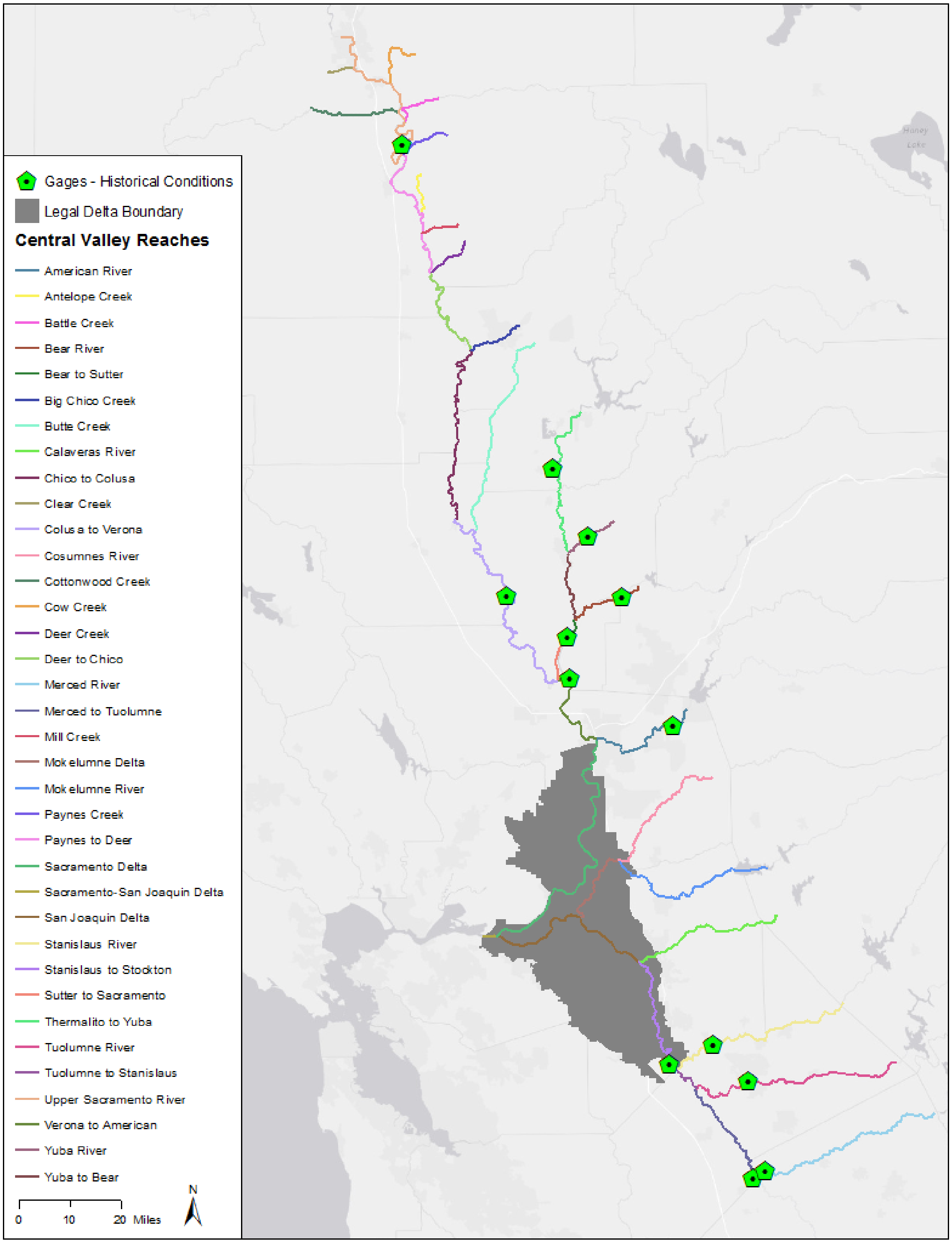


Figure 3-1. Location of Streamflow Gages Used in the Analysis of Historical Suitable Rearing Habitat for Juvenile Salmonids

3) Using the EAH approach[3] (Matella and Jagt 2013), maximum flows satisfying the following criteria were calculated for each subreach:

   - Timing: December 1– May 31
   - Duration: 14 days
   - Frequency: Once every 2 years (50 percent)

   These criteria were drawn from literature on California Central Valley salmonids and ensure that suitable rearing habitat used in this analysis would at a minimum benefit each generation of fish (assuming average adult salmon spawning age of 3 years as reported by Moyle 2002) and achieve primary production, zooplankton and invertebrate colonization, and juvenile salmonid growth needs for successful rearing (Merz and Chan 2005; Jeffres et al. 2008; Grosholz and Gallo 2006).

4) Using the California Central Valley Floodplain Evaluation and Delineation Program (CVFED) Hydrologic Engineering Center River Analysis System (HEC-RAS) 1-D hydraulic model (Figure 3-2), water surface profiles were generated for each subreach at the flows satisfying the juvenile salmonid rearing habitat suitability criteria described in #3 above.

5) Using the water surface profiles generated in #4 above and the CVFED Light Detection and Ranging (LiDAR)-based topography, total inundated areas were calculated for each subreach assuming pre-levee topography (i.e., no levees).

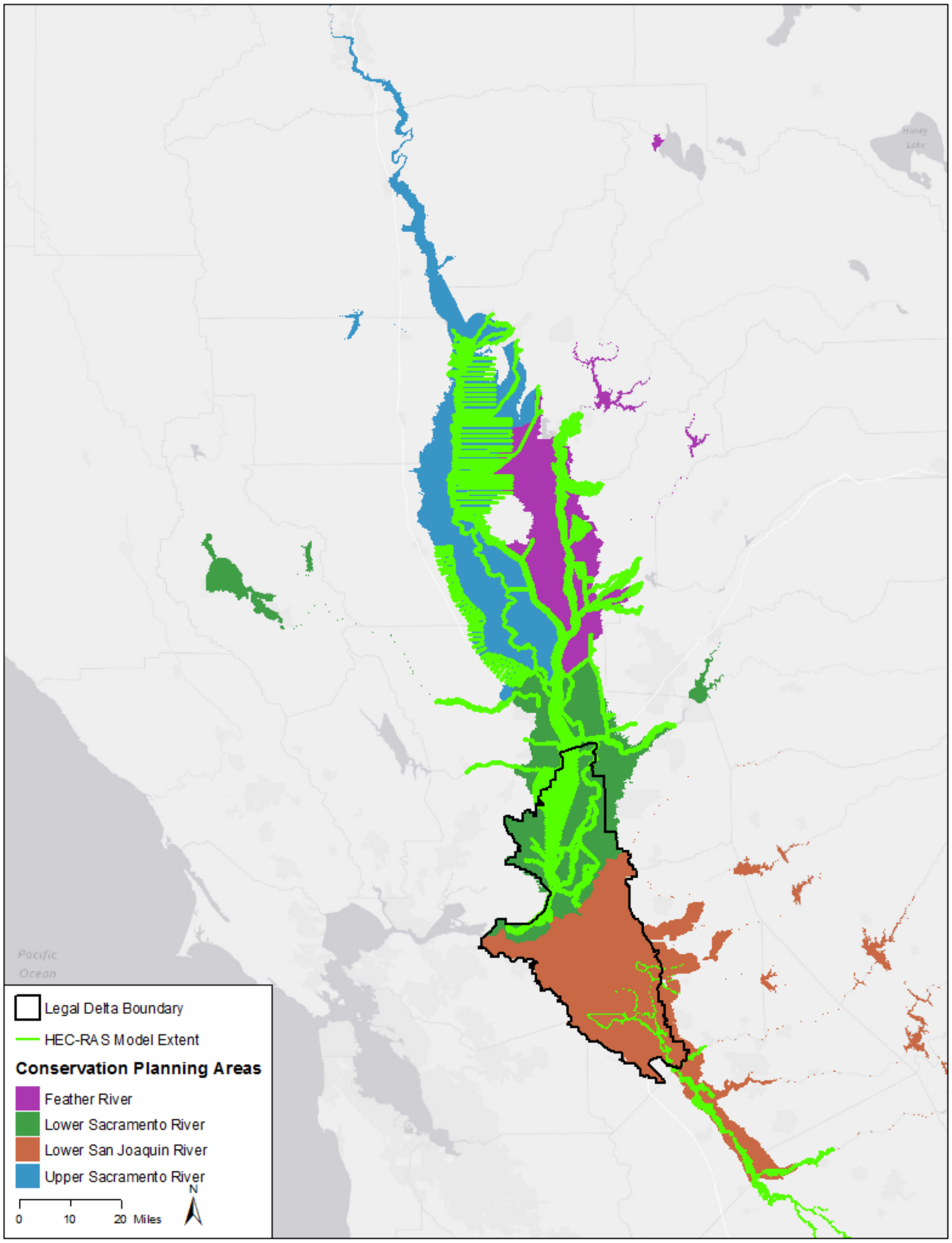
6) Inundated areas outside of the CPAs were clipped out using a GIS application and not counted in this analysis.

7) Inundated areas outside of historical channel, riparian, floodplain and wetland areas mapped in *From the Sierra to the Sea*[4] (The Bay Institute 1998) (Figure 3-3) were clipped out using a GIS application and not counted in this analysis.

8) Inundated areas inside of historical channel, riparian, floodplain and wetland areas mapped in *From the Sierra to the Sea* were all multiplied by a suitability factor for floodplain that ranged from a low value of 22 percent suitable to a high value of 27 percent suitable (San Joaquin River Restoration Program [SJRRP] 2012). This range of values is the upper quartile of the 7- to 27-percent range from SJRRP 2012 and assumes that historical floodplain suitability was more similar to the high suitability floodplain areas measured in the SJRRP 2012 study. While

[3] The EAH metric quantifies the area inundated by a flow of a given duration for all possible frequencies (i.e., zero to 100 percent). Although this is a good general metric to use in screening a wide variety of potential inundated area benefits, EAH could overestimate or underestimate the potential to increase the area inundated by flows that satisfy a specific frequency criteria. Therefore, because this analysis focuses on the 2-year recurrence interval flows for juvenile salmonid rearing, results are presented as frequency-specific areas rather than presenting the EAH metric that considers all possible frequencies.

[4] From the Sierra to the Sea was completed by The Bay Institute in 1998 and was designed to provide a coherent and defensible ecological framework and information base for restoration California's Central Valley and Bay Delta ecosystem.



Note: The upper reach of the Upper Sacramento River CPA and several Sacramento River and San Joaquin River tributaries are not covered by the CVFED HEC-RAS model.

Figure 3-2. Map of CPAs, CVFED HEC-RAS Model Extent, and Legal Delta Used in Both the Historical and Existing Suitable Rearing Habitat Calculations

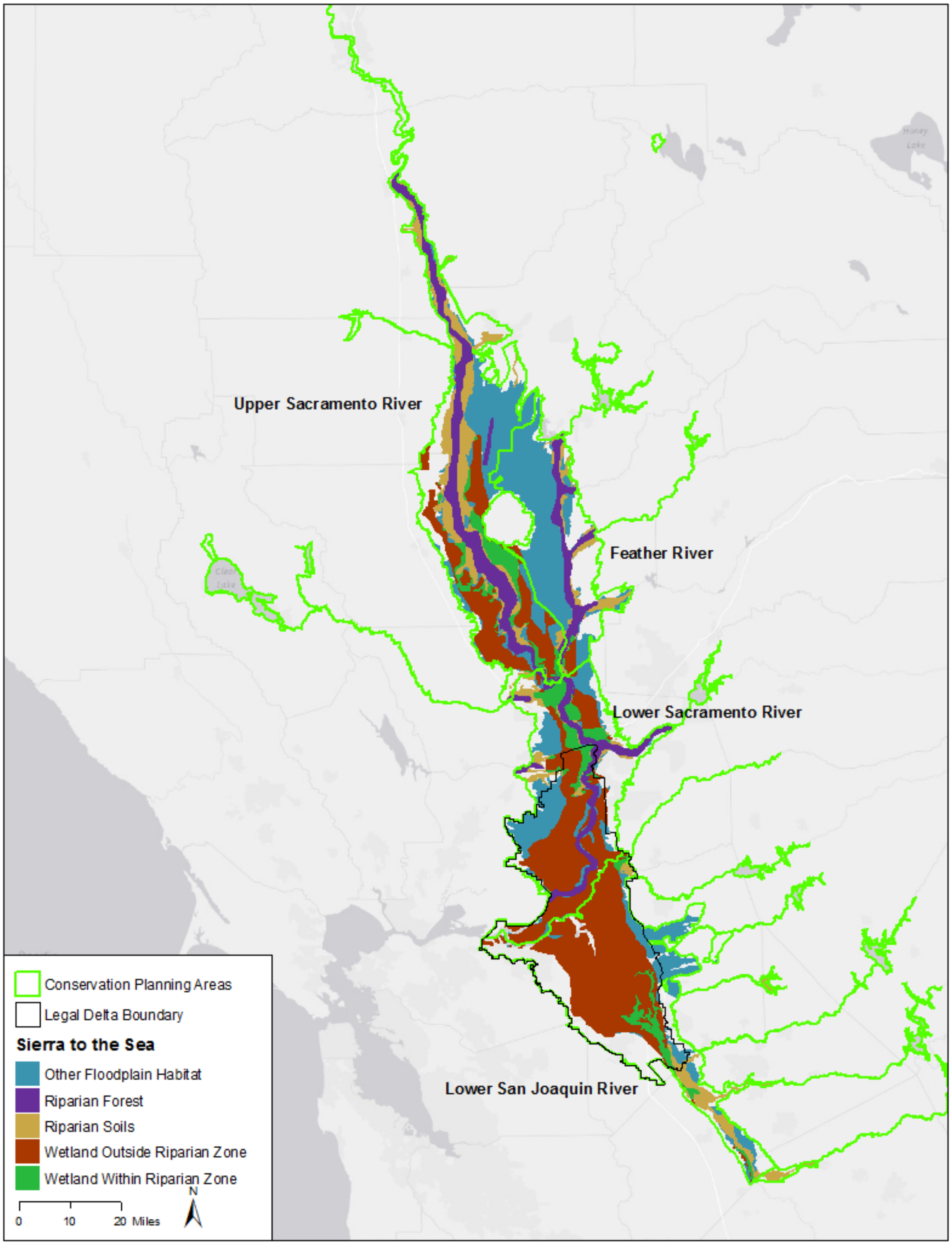


Figure 3-3. Map of CPA Boundaries, *From the Sierra to the* Sea Historical Inundated Habitat Types, and Legal Delta Boundary Used in the Historical Suitable Rearing Habitat Calculations

this likely overestimates the suitability of historical active river channel areas, the active river channel comprised only a small fraction of the total historically inundated area.

9) Suitable inundated areas were summed by subreach for each CPA and counted as historically suitable rearing habitat for juvenile salmonids.

3.2 Exceptions to General Approach

3.2.1 Delta

For the portions of the Lower Sacramento River and the Lower San Joaquin River CPAs inside the Legal Delta boundary (Figures 3-1 and 3-2), all areas mapped in *From the Sierra to the Sea* as waterways, intertidal wetland, tidal wetland, and other floodplain habitat were multiplied by the floodplain suitability factor (22–27 percent) described above, and the resulting area was counted as historically suitable rearing habitat for juvenile salmonids. While this likely overestimates the suitability of historical waterway areas in the Delta, these waterways comprised only a small fraction of the total historically inundated area in the Delta.

3.2.2 Tributaries and Mainstem Channels without HEC-RAS Model

The CVFED HEC-RAS model used in this analysis does not cover all of the main-stem river channels and tributaries included in the doubling goal regions (Figure 3-2). Therefore, in the channel areas without a HES-RAS model, an alternative method was used to estimate historical suitable rearing habitat. All of the areas mapped as historical channel, riparian, floodplain, and wetland in *From the Sierra to the Sea* were multiplied by the floodplain suitability factor (22–27 percent) described above, and the resulting area was counted as historically suitable rearing habitat for juvenile salmonids in these non-HES-RAS modeled areas. Again, while this approach likely overestimates the suitability of historical channel areas, channels were only a small fraction of the total historically inundated area.

3.3 Results

Tables 3-2 through 3-5 summarize historical suitable rearing habitat estimates for juvenile Chinook salmon by subreach in the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs, respectively. Total inundated areas at flows satisfying rearing criteria were 366,300 acres, 341,000 acres, 52,400 acres, and 343,700 acres in the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs, respectively. Suitable rearing habitat areas assuming low suitability of inundated areas were 80,586 acres, 75,020 acres, 11,528 acres, and 75,614 acres in the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs, respectively. Suitable rearing habitat areas assuming high suitability of inundated areas were 98,901 acres, 92,070 acres, 14,148 acres, and 92,799 acres in the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs, respectively.

Table 3-2. Summary of Historical Conditions Suitable Rearing Habitat in the Upper Sacramento River CPA

Upper Sacramento River CPA		**Suitable Inundated Area**	
Reach Description	**Total Inundated Area (acres)**	**Assuming Low Suitability (22% Factor Applied)**	**Assuming High Suitability (27% Factor Applied)**
Upper Sacramento River	72,600	15,972	19,602
Sacramento River - Chico to Colusa	155,500	34,210	41,985
Sacramento River - Colusa to Verona	130,000	28,600	35,100
Feather River - Sutter to Sacramento	8,200	1,804	2,214
TOTAL	**366,300**	**80,586**	**98,901**

Table 3-3. Summary of Historical Conditions Suitable Rearing Habitat in the Lower Sacramento River CPA

Lower Sacramento River CPA		**Suitable Inundated Area**	
Reach Description	**Total Inundated Area (acres)**	**Assuming Low Suitability (22% Factor Applied)**	**Assuming High Suitability (27% Factor Applied)**
Sacramento River - Verona to American	64,300	14,146	17,361
American River	8,400	1,848	2,268
Delta	268,300	59,026	72,441
TOTAL	**341,000**	**75,020**	**92,070**

Table 3-4. Summary of Historical Conditions Suitable Rearing Habitat in the Feather River CPA

Feather River CPA		Suitable Inundated Area	
Reach Description	Total Inundated Area (acres)	Assuming Low Suitability (22% Factor Applied)	Assuming High Suitability (27% Factor Applied)
Feather River - Thermalito to Yuba River	12,300	2,706	3,321
Yuba River	400	88	108
Feather River - Yuba River to Bear River	11,900	2,618	3,213
Bear River	16,300	3,586	4,401
Feather River - Bear River to Sutter Bypass	11,500	2,530	3,105
TOTAL	**52,400**	**11,528**	**14,148**

The total and suitable inundated areas presented above depend on several assumptions that should be considered when interpreting these results. First, that the timing, duration, and frequency criteria applied to flows are representative of juvenile salmonid rearing requirements, and second, that the suitability factors applied are consistent with juvenile salmonid rearing habitat use. The sensitivity of the results presented here to the first assumption is relatively low, as historical inundation fills most of the area in each CPA. The sensitivity of the analysis to suitability factors is captured in the range of results presented for low to high suitability assumptions. Another important assumption is that the pre-dam hydrology used in this analysis accurately represents historical variability of flows. Since pre-dam hydrology records are quite limited, it is likely that this approach underestimates historical flows that would have satisfied rearing criteria.

Perhaps the most significant assumption, however, is that the use of recent topography (without levees) accurately represents the historical land surface. It is likely that the historical land surface was significantly more varied in elevation, which could have significantly changed (both increased and decreased, depending on location) the suitable rearing habitat values calculated in this analysis. Taken together, these assumptions and limitations have likely resulted in an underestimate of historically suitable rearing habitat for juvenile Chinook salmon.

Table 3-5. Summary of Historical Conditions Suitable Rearing Habitat in the Lower San Joaquin River CPA

Lower San Joaquin River CPA		Suitable Inundated Area	
Reach Description	Total Inundated Area (acres)	Assuming Low Suitability (22% Factor Applied)	Assuming High Suitability (27% Factor Applied)
Merced River	400	88	108
San Joaquin River - Merced to Tuolumne	2,400	528	648
Tuolumne River	600	132	162
San Joaquin River - Tuolumne to Stanislaus	1,000	220	270
Stanislaus River	100	22	27
Delta	339,200	74,624	91,584
TOTAL	**343,700**	**75,614**	**92,799**

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4.0 Existing Suitable Rearing Habitat for Juvenile Salmonids

4.1 General Approach

The general approach used to estimate existing suitable rearing habitat was very similar to the approach used to estimate historical suitable rearing habitat, except that post-dam hydrology and post-levee topography were used in the hydrologic and hydraulic evaluations, and existing condition suitability factors (described below) were applied to total inundated areas. In addition, Sierra to the Sea mapping was not used on the existing suitable rearing habitat calculations. The following steps detail the approach implemented to estimate existing suitable rearing habitat in each of the CPAs:

1) Subreaches of the mainstem Sacramento River, San Joaquin River, Feather River, and all tributaries with AFRP doubling goals were delineated based on a review of all relevant existing hydrology data from U.S. Geological Survey (USGS), California Data Exchange Center (CDEC) and other gages (Table 4-1) to create subreaches within which hydrologic conditions were generally similar (Figure 4-1).

2) Existing conditions streamflow data from the gages used in #1 above were queried for post-dam hydrology data (Table 4-1) determined by identifying the date of completion of the controlling dam in each subreach and selecting streamflow data for the period after completion. This analysis assumes that recent post-dam hydrology is representative of existing and near-term future hydrology, perhaps with the exception of basins where dams are undergoing Federal Energy Regulatory Commission relicensing and the outcomes for instream flow agreements are uncertain. While future hydrology will likely change, most significantly as climate change effects become more pronounced, this analysis has not yet considered alternative future hydrology.

3) Using the EAH approach, maximum flows in each subreach satisfying the following criteria (same as for historical suitable rearing habitat) were calculated:

   - Timing: December 1– May 31
   - Duration: 14 days
   - Frequency: Once every 2 years (50 percent)

4) Using the CVFED HEC-RAS 1-D hydraulic model (Figure 3-2), water surface profiles were generated for each subreach at the flows satisfying the juvenile salmonid rearing habitat suitability criteria in #3 above.

Table 4-1. Summary Information for Streamflow Gages Used in the Analysis of Existing Suitable Rearing Habitat for Juvenile Salmonids

CPA	Sub-CPA River Reach	Gage Name	Gage ID	Evaluation Period	Criteria Flow (cfs)*
Upper Sacramento	Paynes to Deer	Bend Bridge Near Red Bluff - Sacramento River	11377100	1950 to 2013	20,963
Upper Sacramento	Deer Creek to Chico	Hamilton City - Sacramento River	HMC	1991 to 2013	22,482
Upper Sacramento	Big Chico Creek	Big Chico Creek near Chico	BIC	1997 to 2013	336
Upper Sacramento	Chico to Colusa	Ord Ferry - Sacramento River	ORD	1993 to 2013	24,194
Upper Sacramento	Colusa to Verona	Colusa - Sacramento River	11389500	1950 to 2013	23,741
Upper Sacramento	Colusa to Verona	Wilkins Slough - Sacramento River	11390500	1950 to 2013	20,730
Feather	Thermalito to Yuba	Gridley - Feather River	GRL	1969 to 2013	6,983
Feather	Yuba River	Marysville - Yuba River	MRY	1997 to 2013	3,181
Feather	Yuba to Bear	Gridley - Feather River	GRL	1969 to 2013	6,983
Feather	Bear River	Bear River near Wheatland	11424000	1966 to 2013	927
Feather	Bear to Sutter	Gridley and Bear River combined	N/A	1969 to 2013	7,686
Lower Sacramento	Verona to American	Verona - Sacramento River	11425500	1969 to 2013	39,019
Lower Sacramento	American River	American River at Fair Oaks	11446500	1957 to 2013	5,570
Lower Sacramento	Sacramento Delta	Freeport - Sacramento River	11447650	1950 to 2013	47,643
Lower Sacramento	Sacramento Delta	Delta Cross Channel - Sacramento River	11447890	1992 to 2013	23,393
Lower Sacramento	Sacramento Delta	Georgiana Slough - Sacramento River	11447905	1993 to 2013	10,662
Lower Sacramento	Yolo Bypass	Yolo Bypass near Woodland	11453000	1969 to 2013	5,010
Lower Sacramento	Sacramento Delta	Rio Vista - Sacramento River	11455420	1995 to 2013	49,213
Lower San Joaquin	Merced River	Merced Falls - Merced River	MMH	1998 to 2013	1,925
Lower San Joaquin	Merced River	Stevinson - Merced River	11272500	1968 to 2013	876
Lower San Joaquin	Merced to Tuolumne	Newman - San Joaquin River	11274000	1943 to 2013	2,214
Lower San Joaquin	Merced to Tuolumne	Crow's Landing - San Joaquin River	11274550	1995 to 2013	2,360
Lower San Joaquin	Merced to Tuolumne	Patterson - San Joaquin River	SJP	1999 to 2013	1,540
Lower San Joaquin	Tuolumne River	Modesto - Tuolumne River	11290000	1972 to 2013	1,674
Lower San Joaquin	Tuolumne to Stanislaus	Patterson and Modesto combined	N/A	1999 to 2013	2,685
Lower San Joaquin	Stanislaus River	Ripon - Stanislaus River	11303000	1980 to 2013	1,658
Lower San Joaquin	Stanislaus to Stockton	Vernalis - San Joaquin River	11303500	1943 to 2013	6,449

*Criteria: Timing = December 1 to May 31; Duration = 14 days continuous; Frequency = 50% (once every two years)

Note: Sub-CPA river reaches use hydrology data from the accompanying streamflow gage.

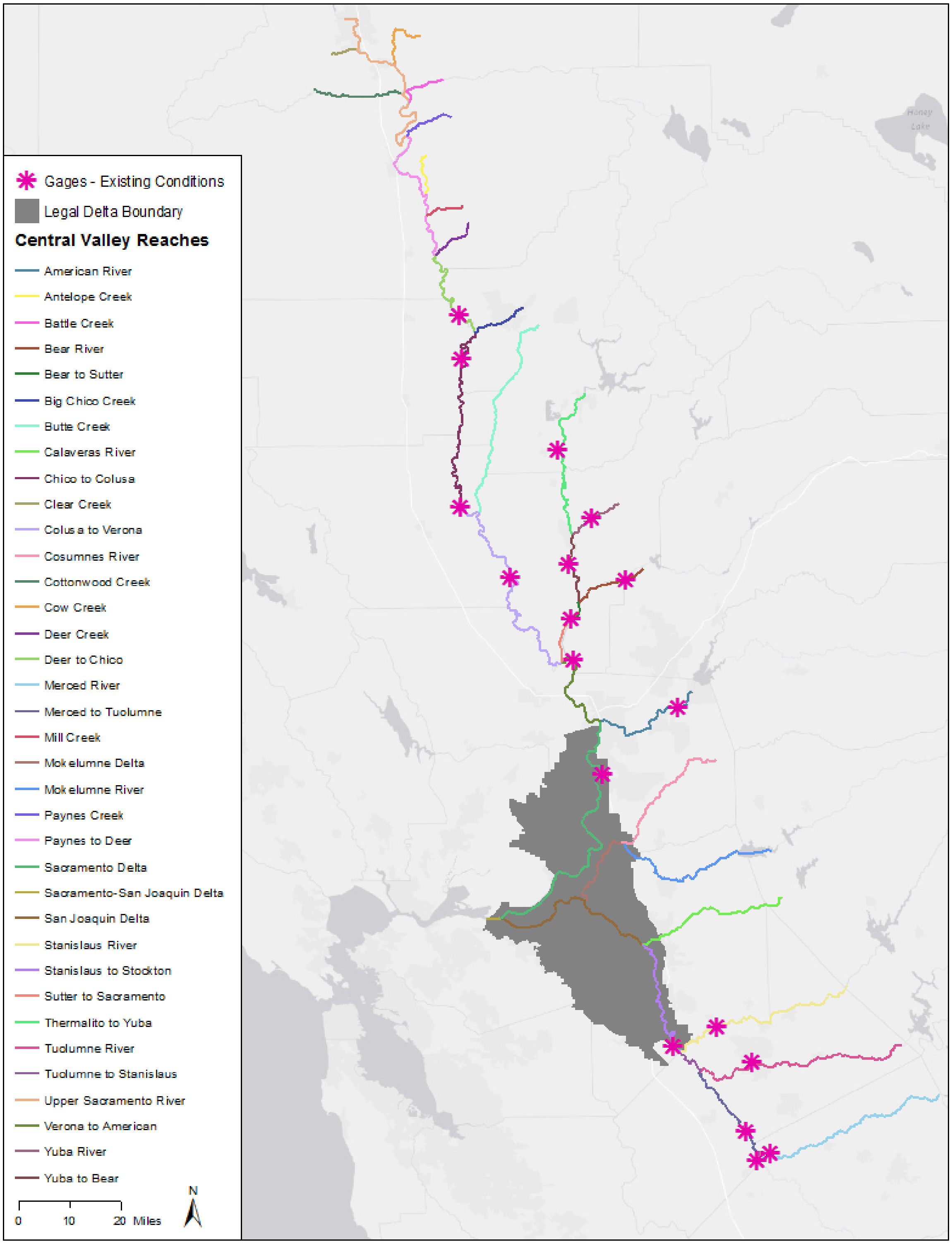

Figure 4-1. Location of Streamflow Gages Used in the Analysis of Existing Suitable Rearing Habitat for Juvenile Salmonids

5) Using the water surface profiles generated in #4 above and the CVFED LiDAR-based topography, total inundated areas (primarily between existing levees) were calculated for each subreach.

6) Inundated areas outside of the CPAs were clipped out using a GIS application and not counted in this analysis.

7) Inundated areas were assigned to channel, floodplain, and tributary[5] categories based on Central Valley riparian vegetation and land use mapping (Geographical Information Center 2011).

8) The suitability factor for the channel category (Table 4-2) in each CPA was determined by calculating the percentage of channel area with depth less than 4 feet (Aceituno 1993; Aceituno and Rutherfurd 1990) at the flow satisfying the criteria in #3 above for representative reaches throughout the Central Valley. This resulted in an average suitability of 0.9 percent across all CPAs. This relatively low value reflects the condition that existing mainstem rivers in the Central Valley typically have only a narrow margin area with suitable rearing habitat conditions for juvenile Chinook salmon.

Table 4-2. Inundated Area Suitability Factors for Existing Conditions Analysis

CPA	Channel Suitability Factor (%)[1]	Floodplain Suitability Factor (%)[2]		Tributary Suitability Factor (%)[3]	
		Low	High	Low	High
Upper Sacramento River	0.9	7	27	2.5	5.2
Lower Sacramento River	0.9	7	27	4.4	8.8
Feather River	0.9	7	27	0.5	1.7
Lower San Joaquin River	0.9	7	27	4.7	7.5

[1] Average channel area less than 4 feet deep at the flow satisfying rearing criteria in representative reaches throughout all CPAs.

[2] Full range from SJRRP 2012.

[3] Upper Sacramento from this study Section 4.3.2 #4; Lower Sacramento from Beakes et al. 2012; Feather from USFWS 2010; Lower San Joaquin from Cramer Fish Sciences 2013.

9) The suitability factor for the floodplain category (Table 4-2) was determined from a detailed study of the depth, velocity, and cover conditions for a range of existing floodplain types along the San Joaquin River (SJRRP 2012) and ranged from 7 to 27 percent.

[5] Approach for tributaries described in Section 4.2.2.

10) Total inundated area in each category was multiplied by the suitability factor for the appropriate category and resulting suitable rearing habitat areas were summed by subreach for each CPA and counted as existing suitable rearing habitat for juvenile salmonids.

4.2 Exceptions to General Approach

4.2.1 Delta

Because the existing tidal Delta has very different habitat types than the historical Delta and existing channel and floodplain areas in the Central Valley, the following approach was used to calculate existing suitable rearing habitat in the Delta portions of the Lower Sacramento River and Lower San Joaquin River CPAs:

1) The Legal Delta boundary (Figures 3-1 and 3-2) was used to delineate areas considered in this category.

2) USGS bathymetry data (Foxgrover et al. 2003) was used to determine depths in all inundated areas of the Delta (primarily leveed channels).

3) Inundated areas with depths less than 4 feet were considered potentially suitable for juvenile Chinook salmon rearing (Aceituno 1993; Aceituno and Rutherfurd 1990).

4) Inundated areas with suitable depths adjacent to land areas with natural cover types including wetland, riparian, floodplain vegetation, and other relatively natural cover types (Geographic Information Center 2011) were counted as existing suitable habitat for rearing juvenile salmonids.

5) Inundated areas with suitable depths adjacent to land areas with urban, agriculture, and other highly impacted cover types were not counted as existing suitable habitat for rearing juvenile salmonids.

4.2.2 Tributaries and Mainstem Channels without HEC-RAS Model

For the portion of the Upper Sacramento River CPA and tributaries to the mainstem rivers in the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs without a CVFED HEC-RAS model (Figure 3-2), the following approach was used to calculate existing suitable rearing habitat:

1) Total inundated area was estimated as the area within mapped active channel areas (Geographic Information Center 2011). This assumes that higher river corridor gradient conditions exist in tributaries, and that existing suitable habitat for rearing juvenile salmonids occurs primarily in the active channel and near-channel riparian portions of these areas.

2) Total inundated area on the Upper Sacramento mainstem was apportioned to channel and floodplain categories based on the average proportion of floodplain and channel habitat in modeled reaches of the Upper Sacramento River CPA.

3) Channel and floodplain suitability on the Upper Sacramento River mainstem were determined as 0.9 percent and 7–27 percent, respectively, using the approach described in #8 and #9 in Section 4.2, above.

4) Tributary suitability in the Upper Sacramento River CPA was determined by calculating the percentage of channel area with depth less than 4 feet (Aceituno 1993; Aceituno and Rutherfurd 1990) using measured stages in tributaries at flows satisfying rearing criteria and ranged from 2.5 to 5.2 percent (Table 4-2).

5) Tributary suitability in the Lower Sacramento River CPA was determined as the range in percent of Weighted Usable Area (WUA) that was considered suitable for juvenile Chinook salmon across a range of instream flow values in the American River, a tributary of the Sacramento River (Beakes et al. 2012). Tributary suitability ranged from 4.4 to 8.8 percent (Table 4-2) in this CPA.

6) Tributary suitability in the Feather River CPA was determined as the range in percent of WUA that was considered suitable for juvenile Chinook salmon across a range of instream flow values in the Yuba River, a tributary of the Feather River (U.S. Fish and Wildlife Service [USFWS] 2010). Tributary suitability ranged from 0.5 to 1.7 percent (Table 4-2) in this CPA.

7) Tributary suitability in the Lower San Joaquin River CPA was determined as the percent of wetted channel habitat that was considered suitable for fry and juvenile salmonids in the Stanislaus River, a tributary of the San Joaquin River (Cramer Fish Sciences 2013). Tributary suitability ranged from 4.7 to 7.5 percent (Table 4-2) in this CPA.

8) Total inundated areas were multiplied by the appropriate suitability factor and the resulting areas added to the existing suitable habitat for rearing juvenile salmonids in each CPA.

4.3 Results

Tables 4-3 through 4-6 summarize existing suitable rearing habitat estimates for juvenile salmonids by subreach in the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs, respectively. Total inundated areas at flows satisfying rearing criteria were 27,800 acres, 12,300 acres, 3,700 acres, and 7,900 acres in the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs, respectively. Suitable rearing habitat areas assuming low suitability of inundated areas were 1,399 acres, 767 acres, 107 acres, and 419 acres in the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs, respectively. Suitable rearing habitat areas assuming high suitability of inundated areas were 5,169 acres, 2,862 acres, 352 acres, and 1,404 acres in the Upper Sacramento River, Lower Sacramento River, Feather River, and Lower San Joaquin River CPAs, respectively.

Table 4-3. Summary of Existing Conditions Suitable Rearing Habitat in the Upper Sacramento River CPA

Upper Sacramento River CPA		*Inundated Area Category*								Total Suitable Rearing Habitat Area (acres)	
		Channel		Floodplain			Tributary				
Reach Description	Total Inundated Area (acres)	Total Inundated Channel Area (acres)	Suitable Inundated Channel Area (acres)	Total Inundated Floodplain Area (acres)	Suitable Inundated Floodplain Area (acres) @ Low (7%) Suitability	Suitable Inundated Floodplain Area (acres) @ High (27%) Suitability	Total Inundated Tributary Area (acres)	Suitable Inundated Tributary Area (acres) @ Low (2.5%) Suitability	Suitable Inundated Tributary Area (acres) @ High (5.2%) Suitability	Assuming Low Suitability	Assuming High Suitability
Upper Sacramento River	2,600	1,500	13	1,100	77	297				90	310
Sacramento River - Paynes Creek to Deer Creek	2,100	1,200	10	900	63	243				73	253
Sacramento River - Deer Creek to Chico Creek	1,400	800	7	600	42	162				49	169
Mill Creek							10	0	1	0	1
Deer Creek							30	1	2	1	2
Sacramento River - Chico Creek to Colusa	4,400	2,700	23	1,700	119	459				142	482
Sacramento River - Colusa to Verona	3,800	2,100	18	1,700	119	459				137	477
Butte Creek	300						300	8	16	8	16
Sutter Bypass	12,800			12,800	896	3,456				896	3,456
Feather River - Sutter to Sacramento	400	400	3	-	-	-				3	3
TOTAL	**27,800**	**8,700**	**75**	**18,800**	**1,316**	**5,076**	**340**	**9**	**18**	**1,399**	**5,169**

Table 4-4. Summary of Existing Conditions Suitable Rearing Habitat in the Lower Sacramento River CPA

Lower Sacramento River CPA		*Inundated Area Category*								Total Suitable Rearing Habitat Area (acres)	
		Channel		Floodplain			Tributary				
Reach Description	Total Inundated Area (acres)	Total Inundated Channel Area (acres)	Suitable Inundated Channel Area (acres)	Total Inundated Floodplain Area (acres)	Suitable Inundated Floodplain Area (acres) @ Low (7%) Suitability	Suitable Inundated Floodplain Area (acres) @ High (27%) Suitability	Total Inundated Tributary Area (acres)	Suitable Inundated Tributary Area (acres) @ Low (4.4%) Suitability	Suitable Inundated Tributary Area (acres) @ High (8.8%) Suitability	Assuming Low Suitability	Assuming High Suitability
Sacramento River - Verona to American	1,400	1,200	10	200	14	54				24	64
American River	800						800	35	70	35	70
Delta	2,000			2,000	140	540				140	540
Yolo Bypass	8,100			8,100	567	2,187				567	2,187
TOTAL	**12,300**	**1,200**	**10**	**10,300**	**721**	**2,781**	**800**	**35**	**70**	**767**	**2,862**

Table 4-5. Summary of Existing Conditions Suitable Rearing Habitat in the Feather River CPA

Feather River CPA		*Inundated Area Category*								Total Suitable Rearing Habitat Area (acres)	
		Channel		Floodplain			Tributary				
Reach Description	Total Inundated Area (acres)	Total Inundated Channel Area (acres)	Suitable Inundated Channel Area (acres)	Total Inundated Floodplain Area (acres)	Suitable Inundated Floodplain Area (acres) @ Low (7%) Suitability	Suitable Inundated Floodplain Area (acres) @ High (27%) Suitability	Total Inundated Tributary Area (acres)	Suitable Inundated Tributary Area (acres) @ Low (0.5%) Suitability	Suitable Inundated Tributary Area (acres) @ High (1.7%) Suitability	Assuming Low Suitability	Assuming High Suitability
Feather River - Thermalito to Yuba River	2,200	1,100	9	1,100	77	297				86	306
Yuba River	100						100	0.5	2	1	2
Feather River - Yuba River to Bear River	1,000	900	8	100	7	27				15	35
Feather River - Bear River to Sutter Bypass	400	400	3	20	1	5				5	9
TOTAL	**3,700**	**2,400**	**21**	**1,220**	**85**	**329**	**100**	**1**	**2**	**107**	**352**

Table 4-6. Summary of Existing Conditions Suitable Rearing Habitat in the Lower San Joaquin River CPA

Reach Description	Total Inundated Area (acres)	Total Inundated Channel Area (acres)	Suitable Inundated Channel Area (acres)	Total Inundated Floodplain Area (acres)	Suitable Inundated Floodplain Area (acres) @ Low (7%) Suitability	Suitable Inundated Floodplain Area (acres) @ High (27%) Suitability	Total Inundated Tributary Area (acres)	Suitable Inundated Tributary Area (acres) @ Low (4.7%) Suitability	Suitable Inundated Tributary Area (acres) @ High (7.5%) Suitability	Assuming Low Suitability	Assuming High Suitability
Merced River	500						500	24	38	24	38
San Joaquin River - Merced to Tuolumne	1,100	700	6	400	28	108				34	114
Tuolumne River	600						600	28	45	28	45
San Joaquin River - Tuolumne to Stanislaus	900	300	3	600	42	162				45	165
Stanislaus River	500						500	24	38	24	38
San Joaquin River - Stanislaus to Stockton	800	700	6	200	14	54				20	60
Delta	3,500			3,500	245	945				245	945
TOTAL	**7,900**	**1,700**	**15**	**4,700**	**329**	**1,269**	**1,600**	**75**	**120**	**419**	**1,404**

The total and suitable inundated areas presented above depend on two key assumptions that should be considered when interpreting these results. First, that the timing, duration, and frequency criteria applied to flows are representative of juvenile salmonid rearing requirements, and second, that the suitability factors applied are consistent with juvenile salmonid rearing habitat use. The sensitivity of the results presented here to the first assumption is relatively low, as existing inundation is more strongly controlled by levees than by the flow level. The sensitivity of the analysis to suitability factors is captured in the range of results presented for low to high suitability assumptions. A third assumption—that the CVFED HEC-RAS model accurately models hydraulics for the range of flows evaluated here—could also limit the accuracy of the results. This model was developed for extreme flood flows and therefore may overestimate water surface elevations for the relatively low flows considered in this analysis. There are also several important assumptions and limitations related to the treatment of the bypasses, which are described below.

4.3.1 Yolo Bypass

The Yolo Bypass was included in the calculation of existing suitable rearing habitat in the Lower Sacramento CPA based on Sommer et al.'s (2001) finding that the Sacramento River was connected to the bypass for an average of 23 days in 58 percent of years between 1956 and 1998 and the finding in this study that flows in the bypass at and downstream of significant West Side tributaries, including Cache Creek, satisfied timing, duration, and frequency criteria. While the hydraulic modeling used in this analysis may not capture Yolo Bypass inundation dynamics perfectly, it appears to be consistent with ongoing analyses being conducted to satisfy the National Marine Fisheries Service (NMFS) Biological Opinion (BO) (NMFS 2009) requirements. More detailed analysis should be considered because the Yolo Bypass has been shown to provide valuable rearing habitat for juvenile salmonids (Sommer et al. 2001).

4.3.2 Sutter Bypass

Nearly the entire area of the Sutter Bypass was included in this analysis because it is inundated at flows satisfying criteria. However, this bypass comprises a large proportion of the existing suitable rearing habitat for the Upper Sacramento CPA, and because suitability of Sutter Bypass is not well understood, future efforts should refine this understanding to improve the estimate of existing suitable rearing habitat provided by the bypass.

4.3.3 Butte Basin

The inundated area in the Butte Basin was not included in the calculation of existing floodplain rearing habitat for the Upper Sacramento River CPA because it is not directly connected to the main Sacramento River channel at flows satisfying criteria. Therefore, although it is recognized that floodplain rearing habitat is likely available to juvenile salmonids produced in the Butte Creek watershed, it is not expected that this rearing habitat would be accessible to juvenile salmonids produced upstream or downstream of Butte Creek in the Upper Sacramento River CPA. And because our resolution for calculating available and required suitable habitat is at the CPA-level, we decided to exclude inundated area in Butte Basin because only fish originating in Butte Creek would be exposed to this habitat. Butte Creek origin fish only make up 2 percent of spring-run and less than 1 percent of fall-run Chinook salmon entering the Upper Sacramento River CPA.

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5.0 Calculating Suitable Juvenile Salmonid Rearing Habitat Required to Support the AFRP Doubling Goal

5.1 Background

This section describes the calculation of the floodplain rearing habitat needed to support the AFRP doubling goals. The Central Valley ESHE model was built to estimate the amount of usable habitat, including valuable floodplain rearing habitat, needed in selected portions of the CPAs (Figure 5-1), with AFRP adult doubling goals. In the results section of this document, the habitat need was combined with the existing and historical habitat described in the previous section to quantify the current need for additional floodplain rearing habitat in the CPAs.

5.2 Chinook Salmon Life History

The Sacramento–San Joaquin River system supports four races of Chinook salmon: the fall, late fall, winter, and spring runs. These races and the large runs they once supported (at least 1–2 million adults annually) (Yoshiyama et al. 1998, 2000) reflect the diverse and productive habitats that historically existed within the region. The four CV Chinook salmon races (runs) are named for the season when the majority of the adult spawning run enters freshwater; the timing of runs varies from stream to stream. The majority of young salmon of these races migrate to the ocean during the first few months following emergence, although some may remain in freshwater and migrate as yearlings.

Newly emerged young are often found in shallow, slow-moving water and transition to deeper, faster water as they increase in size (see Cramer and Ackerman 2009). Habitat complexity (e.g., woody debris, overhanging vegetation, and seasonally inundated areas) provides juveniles with hiding, resting, and feeding habitat, increasing their ability to grow, develop, and survive emigration. Juvenile diets often vary by habitat type, but terrestrial and aquatic invertebrates and larval fish and eggs are important prey for juvenile salmon upstream of the Delta (Merz and Vanicek 1996; Sommer et al. 2001). Prey size and ingestion rates are affected by juvenile size and water temperature (Merz 2002). At times, floodplains provide better juvenile rearing opportunities because they often create optimum temperatures, offer habitats rich in prey items and away from salmon predators, and provide refuge from high flows (Sommer et al. 2001; Jeffres et al. 2008). Habitat availability, water quality, and predation are examples of environmental factors that can affect successful rearing (Lindley and Mohr 2003).

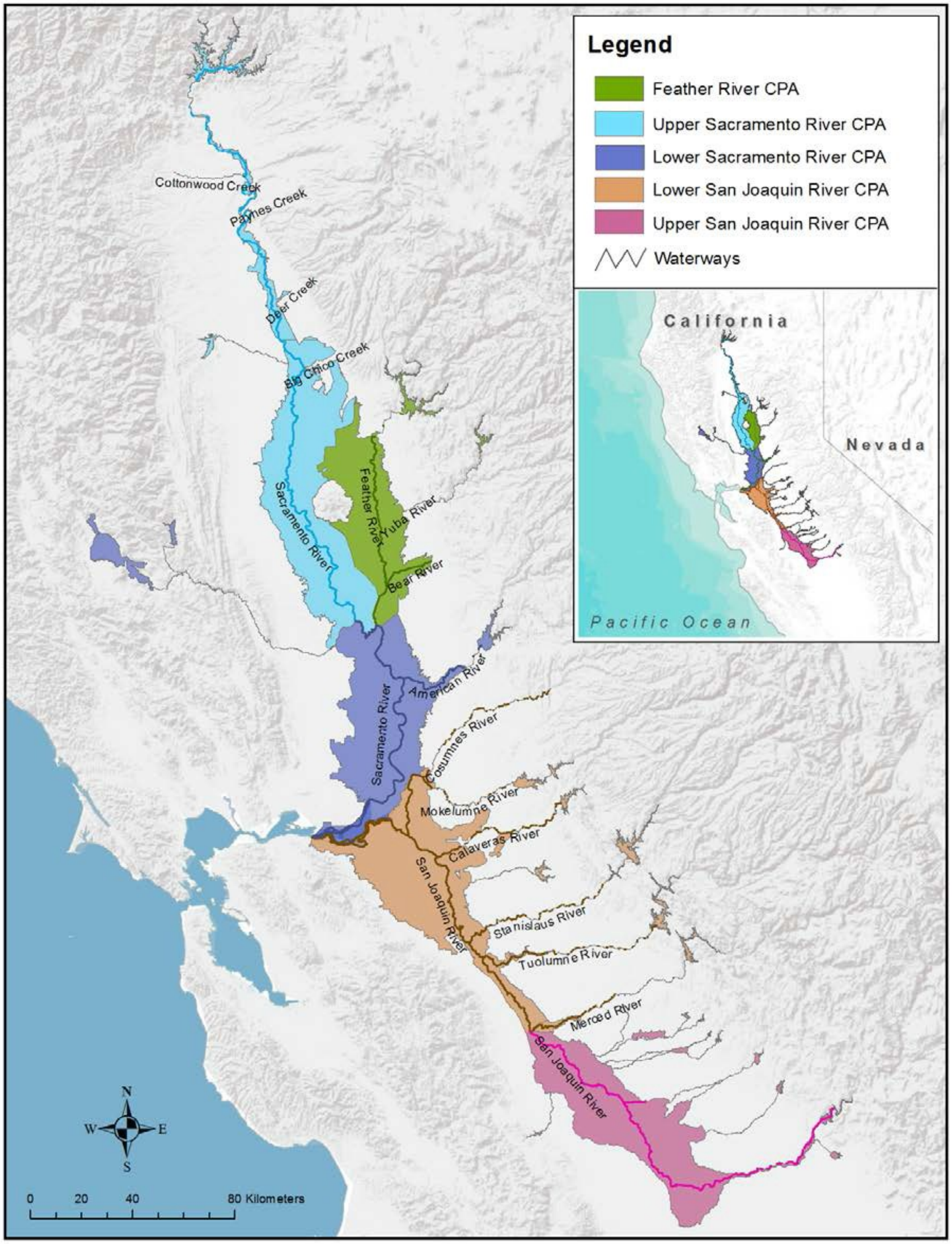


Figure 5-1. Watersheds and CPAs Where Central Valley Chinook Salmon Juvenile Emigrants Are Modeled by the Central Valley ESHE Model

For some juvenile Chinook salmon, leaving the tributary stream (emigration) takes place relatively quickly (i.e., over a few days or weeks). For other members of the same population, emigration is drawn out, with individuals presumably stopping and establishing territories along the way (i.e., over months). Regardless of life-history strategy, territories such as holding, resting, and feeding areas are likely the most useful predictors of the space required by an individual member of the salmon family (salmonid) and are therefore the most useful way to determine required habitat during emigration (Grant et al. 1998; Keeley 2000).

Observations of the combination of salmonid feeding and territorial behavior have been of interest to fisheries biologists for some time, because territory size is thought to limit the density and production of stream-dwelling salmonids (Chapman 1966; Allen 1969; Grant and Kramer 1990). Territory size requirements of individual fish of a given size are generally constant regardless of the local numbers of fish (abundance) (Grant and Kramer 1990; Cramer and Ackerman 2009). In open (i.e., natural) systems, territory requirements result in competition for space and displacement of smaller and weaker individuals (Titus 1990; Keeley 2003; Cramer and Ackerman 2009). Smaller and weaker individuals in turn occupy suboptimal territories (see Titus 1990) and are likely to experience increased stress, which reduces growth and fitness, causing increased mortality. Therefore, providing an adequate quantity and quality of rearing territory during emigration can reduce the negative effects associated with competition for space on a population level.

5.3 Modeling Approach

The approach used was to build the Central Valley ESHE model, a deterministic simulation model that tracks the rearing and emigration of individual daily groups (cohorts) of juvenile CV Chinook salmon from spawning grounds to San Francisco Bay entry (at Chipps Island). The model tracks their abundance and size and the amount of suitable rearing and emigration habitat required to sustain the number of juvenile salmon present within a region. The model runs through a 1-year period, from 1 October through 31 September of the following year. Model outputs provide daily estimates of the number of juvenile spring-run, fall-run, late fall–run and winter-run Chinook salmon present in each region and the required area of suitable habitat (ASH) needed to support them throughout the rearing and emigration period. ASH is the typical term used to report output from the ESHE model; however, in this report ASH is also referred to as “total habitat need.”

The simulation model approach has been successfully applied to evaluate the effects of other restoration actions on CV Chinook salmon populations; some examples are as follows:

- The San Joaquin River ESHE model was used to quantify the rearing and emigration habitat needs of future restored populations of fall-run and spring-run Chinook salmon in the San Joaquin River as part of the San Joaquin River Restoration Program (2012).

- The Interactive Object-Oriented Simulation (IOS) life cycle model (Zeug et al. 2012) was used to evaluate the effects of the National Marine Fisheries Service’s alternative scenarios for Central Valley water operations on the life cycle and abundance trends of winter-run Chinook salmon.

- The Delta Passage Model (DPM) was used to evaluate the effects of Bay Delta Conservation Plan water scenarios on the Delta emigration survival of all Central Valley runs of Chinook salmon.

5.3.1 Territory Concept

Drawing from experimental salmonid studies (see Grant and Kramer 1990 and Grant et al. 1998), the Central Valley ESHE model relies on the finding that the maximum number of individuals a habitat area can support is limited by territory size. Therefore, the juvenile salmon carrying capacity, or the abundance of fish that can be supported in a given area (capacity), is a function of the available ASH and average fish territory size:

capacity = ASH / territory size (Equation 1)

Salmon require specific habitat conditions for rearing, including suitable water depths, velocities (Raleigh et al. 1986; Keeley and Slaney 1996), and temperatures (Marine and Cech 2004).

Therefore, juvenile salmon will generally only rear (and set up territories) in habitat that meets their preferred range of habitat conditions. This defines the ASH as the total area of habitat meeting rearing requirements. In most natural systems, ASH is only a small fraction of total inundated area. Therefore, ASH can also be defined as the proportion of total inundated area that has suitable components, such as depths and velocities. Within ASH, habitat complexity (e.g., woody debris) and food abundance influence habitat quality, which in turn increases or decreases fish territory size.

In order for the Central Valley EHSE model to enumerate the amount of suitable rearing and emigration habitat required to support future population abundance goals, Equation 1 was reorganized to calculate ASH as a function of fish abundance and territory size:

ASH = abundance • territory size (Equation 2)

When applied in the Central Valley ESHE model, Equation 2 estimates the date-specific and CPA-specific ASH required to support the cumulative territory size requirements of the total number (abundance) of juvenile salmon present in the CPAs throughout the juvenile rearing and emigration period.

5.3.2 Modeling Platform

The Central Valley ESHE model was built in NetLogo, a multiagent programmable modeling environment. NetLogo is readily accessible because it is free, open source, and cross-platform. The highly readable syntax of the programming language, thorough documentation, and widgets for graphical-user-interface elements allow for rapid prototyping of new models in NetLogo.

These elements allow users to explore the effects of changing parameters on model behavior without any programming experience. NetLogo is also a powerful tool for scientific modeling (Lytinen and Railsback 2012) with a built-in parameter-sweeping feature and parallel processing.

5.3.3 Model Components

The Central Valley ESHE model is made up of several components that are supported by functions and parameter values taken from appropriate literature and regional studies (Table 5-1). These components are (1) initial abundance—the abundance of juvenile salmon entering the model; (2) entry location—the entry of juveniles into the model in each watershed at the downstream end of observed spawning grounds; (3) initial timing and size—the timing and average size of juvenile salmon entering the model in each watershed; (4) growth—the daily growth and resulting size of juvenile salmon in each region; (5) migration rate—the daily downstream movement of juvenile salmon in each region; (6) survival—the daily survival and abundance of juvenile salmon in each region; and (7) territory size—the territory size requirements of juvenile salmon in each region.

Table 5-1. Central Valley ESHE Model Components Applied as Fish Enter the Model and as Fish Emigrate through Model Reaches, Data Sources, and the Spatial Level at Which Each Component Is Applied in the Model

	Component	Data Source	Spatial Level
Model entry	Initial abundance	AFRP escapement targets	Watershed
	Entry location	Various State and federal agency reports	Watershed
	Initial timing and size	Rotary screw traps	Watershed
Emigration	Growth	Laboratory studies	Global
	Migration rate	Tagging studies	Regional
	Survival	Estimated by matrix model	Global
	Territory size	Field and lab studies	Global

Where possible, model components were developed using watershed-specific data or literature sources (e.g., initial abundance, entry location). However, owing to time constraints and data limitations, most model components were informed with fish sampling data from a few, relevant surrogate watersheds (e.g., initial timing and size), or regional (e.g., migration rate) or global (e.g., growth, survival, territory size) scales. The model components are described in detail in Section 5.3.5, “Model Entry,” and Section 5.3.6, “Emigration,” below.

5.3.4 Modeled Scenario

The Central Valley ESHE model was used to estimate the total amount of suitable rearing habitat needed to support sustainable CV Chinook salmon populations that annually meet the AFRP adult doubling goals. Therefore, the AFRP adult doubling goals were used to inform initial spawner abundances in the model (see "Initial Abundance," below, for details), and in-river survival rates were set at values that would ultimately sustain the population at AFRP adult doubling goal levels (see "Survival" section, below).

To incorporate uncertainty in model outputs and provide a range of estimates of required suitable habitat, a range of observed CV Chinook salmon emigration strategies was modeled. The model was run under the range of emigration behaviors of Chinook salmon, observed at Central Valley rotary screw traps (RSTs), with both early and late emigration strategies, with the early migrants beginning their migration earlier in the season at a smaller size, and late emigrants beginning their migration later in the season at a larger size (see "Initial Timing and Size" section, below).

Because the CVFPP may call for construction of setback levees and the creation of additional floodplain habitat, and because increasing CV Chinook salmon abundance to AFRP doubling goal levels will likely require floodplain habitat restoration, juveniles in the Central Valley ESHE model exhibited growth and migration rates observed in Central Valley floodplain habitats. More specifically, juveniles in the model were set to grow faster and emigrate slower than the majority of present-day CV Chinook salmon juveniles that emigrate in mainstem habitats.

5.3.5 Model Entry

Initial Abundance

AFRP adult doubling goals were converted to juvenile emigrants to determine the initial abundances of juveniles from each race of Chinook salmon entering the model in each watershed (Table 5-2). The AFRP, as defined in Section 3406(b)(1) of the Central Valley Project Improvement Act, is to ensure that "natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967–1991." "Natural production" is defined as "the number of fish recruited to adulthood in a given year, including newly recruited fish that are harvested." Therefore, for each watershed, the offspring of these AFRP natural production targets and their required suitable habitat during emigration were modeled.

To convert adult abundance to juveniles, AFRP adult abundances were converted to female spawners by assuming a sex ratio of 0.5. Next, female spawners were converted to deposited eggs by multiplying by 5,423, the average observed fecundity of fall-run Chinook salmon on the Mokelumne River (Kaufman et al. 2009). Finally, eggs were converted to juveniles by multiplying by 0.25, the approximate average egg-fry survival rate estimated in the upper Sacramento River (Martin et al. 2001). The resulting number of juveniles entering the model in each watershed for each race is presented in Table 5-2.

Entry Location

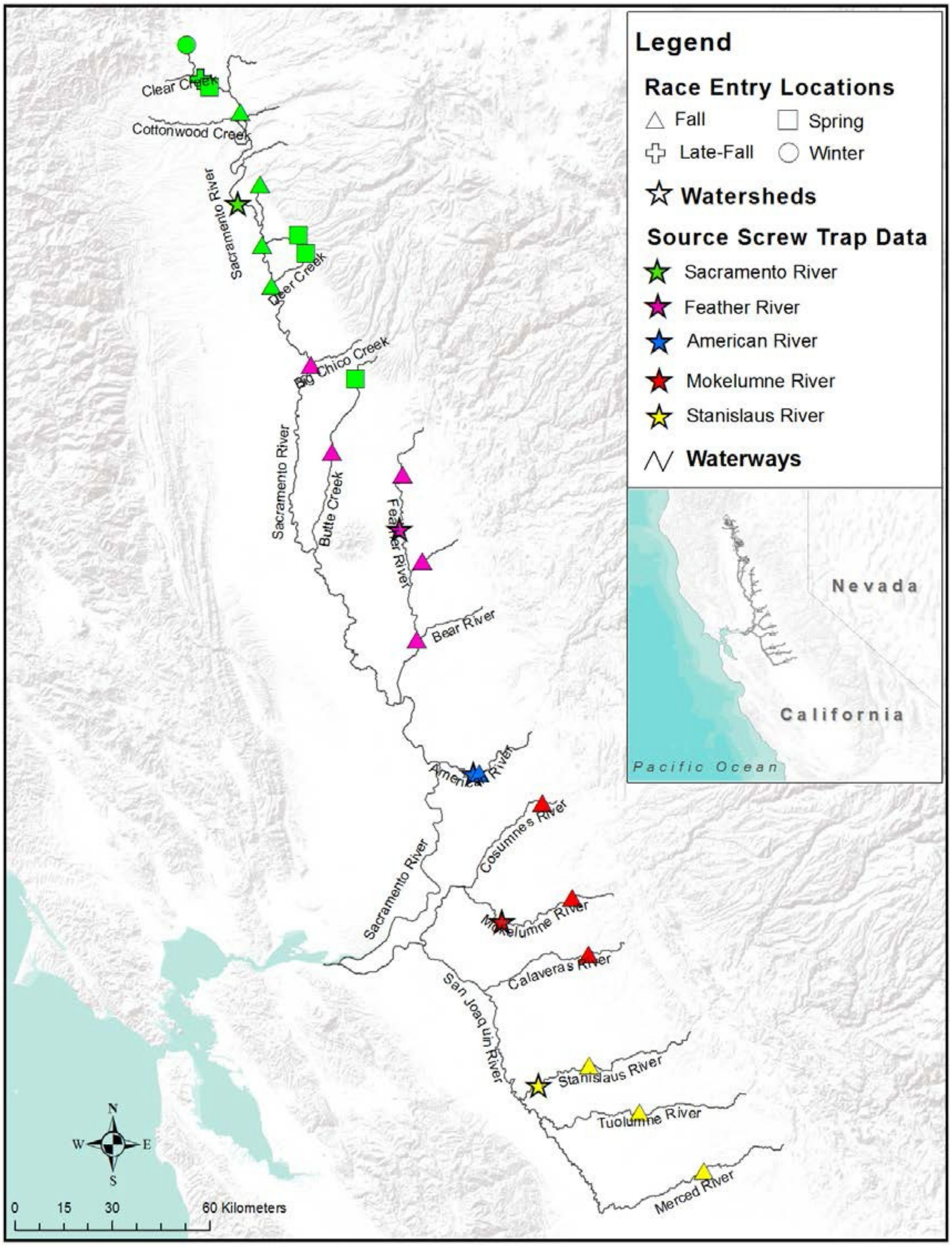
The entry location was set for each Chinook salmon race in each watershed at the end of the spawning grounds, under the assumption that juveniles would begin their emigration downstream of the habitat where they first emerged from the gravel (Figure 5-2, Table 5-3). State and federal agency reports were used as sources to define the approximate locations of the ends of the

Table 5-2. AFRP Adult Doubling Goal Values and Resulting Number of Juveniles Entering the Model in Each Watershed for Each Race

Region	River	Run	AFRP Doubling Goal	Juveniles Entering The Model
Lower San Joaquin	Cosumnes River	Fall	3,300	2,236,988
	Mokelumne River	Fall	9,300	6,304,238
	Calaveras River	Fall	2,200	1,491,325
	Tuolumne River	Fall	38,000	25,759,250
	Stanislaus River	Fall	22,000	14,913,250
	Merced River	Fall	18,000	12,201,750
Feather River	Feather River	Fall	170,000	115,238,750
	Yuba River	Fall	66,000	44,739,750
	Bear River	Fall	450	305,044
Lower Sacramento	American River	Fall	160,000	108,460,000
Upper Sacramento	Sacramento River and Tributaries above RBDD	Fall	258,700	175,366,263
		Late-fall	44,550	30,199,331
		Winter	110,000	74,566,250
		Spring	59,000	39,994,625
	Antelope Creek	Fall	720	488,070
	Mill Creek	Fall	4,200	2,847,075
		Spring	4,400	2,982,650
	Deer Creek	Fall	1,500	1,016,813
		Spring	6,500	4,406,188
	Butte Creek	Fall	1,500	1,016,813
		Spring	2,000	1,355,750
	Big Chico Creek	Fall	800	542,300

spawning grounds (Table 5-3). The ends of the spawning grounds in the ESHE model coincided with the beginnings of potential rearing habitat evaluated using the EAH-based approach described above.

For all mainstem Sacramento River and Sacramento tributary populations above the Red Bluff Diversion Dam (RBDD), a single model entry location was calculated for each race, weighted by spawner abundance (Table 5-3). Race-specific spawner distribution data in the mainstem Sacramento River was applied using the 3 most recent years (2007–2009) of aerial redd surveys conducted by USFWS. Reach-specific spawner proportions were then multiplied by the AFRP doubling goal estimates for each race to estimate the number of mainstem spawners of each race entering at each river kilometer (RKM). Next, for tributary populations entering above RBDD (Paynes Creek, Battle Creek, Cottonwood Creek, Cow Creek, Clear Creek, and other



Note: Colors for each entry location match the RST data applied for that particular race and watershed.

Figure 5-2. The Model Entry Locations (Ends of Spawning Grounds) for Each Chinook Salmon Race in Each Watershed and RST Locations Used to Define Entry Timing and Size for Juvenile Emigrants in the Model

Table 5-3. Model Entry Locations for Each Chinook Salmon Race in Each Watershed, References Used to Inform the Approximate Locations of the Ends of the Spawning Grounds, and RST Data Applied to Each Population to Inform Initial Timing and Size of Juvenile Emigrants

Watershed	Run	Model Entry (RKM)	Reference	RST Used
Cosumnes River	Fall	42	Snider and Reavis 2000	Mokelumne
Mokelumne River	Fall	90	Bilski and Rible 2010	Mokelumne
Calaveras River	Fall	39	Marsh 2006	Mokelumne
Tuolumne River	Fall	42	California Department of Fish and Game 2002	Stanislaus
Stanislaus River	Fall	34	Pyper et al. 2006	Stanislaus
Merced River	Fall	44	Johnson 2002	Stanislaus
Feather River	Fall	85	Hartwigsen et al. 2002	Feather
Yuba River	Fall	5	Campos and Massa 2012	Feather
Bear River	Fall	0	Jones & Stokes 2005	Feather
American River	Fall	16	Healey 2005	American
Sacramento River and tributaries above RBDD	Fall	441	Killam 2012	RBDD
	Late fall	460	Killam 2012	RBDD
	Winter	476	Killam 2012	RBDD
	Spring	455	Killam 2012	RBDD
Antelope Creek	Fall	56	Arrison 2008	RBDD
Mill Creek	Fall	0	Arrison 2008	RBDD
	Spring	25	Arrison 2008	RBDD
Deer Creek	Fall	0	Arrison 2008	RBDD
	Spring	29	Arrison 2008	RBDD
Butte Creek	Fall	32	McReynolds et al. 2006	Feather
	Spring	58	McReynolds et al. 2006	RBDD
Big Chico Creek	Fall	21	McReynolds et al. 2006	Feather

miscellaneous creeks) the respective AFRP doubling goal estimates were applied to their Sacramento River entry location (RKM). Finally, the overall model entry location (RKM) for each race in the upper Sacramento River mainstem was determined by calculating the average location of the spawning grounds weighted by spawner abundance.

Initial Timing and Size

The available RST data from Central Valley watersheds were used to inform initial timing and size of juveniles entering the model. RST data were applied from five different focal watersheds across the Central Valley (Table 5-3). Because variation in daily catch rates of RSTs can be highly influenced by variability in capture efficiency, RST data were used only if catch was corrected for trap efficiency, thereby reducing bias in estimates of emigration timing. In watersheds where no RST existed or catch data were not corrected for trap efficiency, data from the closest RST that captured the race of interest were used. The daily proportion of the annual abundance of juvenile emigrants of each race captured at each RST was estimated to inform entry timing, and the average daily fork length of emigrating juveniles of each race was applied to inform initial size (see individual RST data below).

Because juvenile emigration was defined as beginning at the ends of the spawning grounds, and all the RSTs from the five focal watersheds were located downstream of the spawning grounds, a back-calculation algorithm was developed to estimate the initial entry timing and initial sizes of juveniles that were captured in the RSTs. To do this, the average migration rates of coded-wire tagged (CWT) juvenile Chinook salmon observed in Central Valley watersheds was applied to the distance between the RST location and the bottom of the spawning grounds.

The back-calculation algorithm started by applying a growth curve developed for juvenile Sacramento River fall-run Chinook salmon by Fisher (1992) to estimate the age of the fish captured at the RST based on the measured fork length (FL) (Figure 5-3):

$$FL = \exp(3.516 + 0.007*age) \quad \text{(Equation 3)}$$

Then, each fish was classified as presmolt (<70 millimeters [mm]) or smolt (≥70 mm) based on fork length, a common length cutoff used for the transition to smolts in the Central Valley (Brandes and McLain 2001). CWT mark-recapture data from Butte Creek (Hill and Webber 1999; Ward and McReynolds 2004; Ward et al. 2004a, 2004b, 2004c; McReynolds et al. 2005, 2006, 2007) was used to estimate the median migration rate of presmolts (13 kilometers [km]/day) and smolts (34 km/day) for the focal watersheds in the Sacramento River Valley (i.e., American River, Feather River, Sacramento River). A combination of CWT, acoustic tag, and mark-recapture data from the Stanislaus River (Demko et al. 1999; Demko and Cramer 2000; Watry et al. 2007, 2008, 2009) was used to estimate the median migration rate of presmolts (5 km/day) and smolts (10 km/day) for the focal watersheds in the San Joaquin River Valley (i.e., Mokelumne River and Stanislaus River).

The algorithm then iterated through the process of moving fish upstream at the average migration rate on a daily basis (and updating age and size) until they had either reached the bottom of the spawning grounds or had an estimated age of zero. The age was then used along with the Fisher (1992) growth curve to determine the fork length of that fish at the bottom of the spawning grounds.

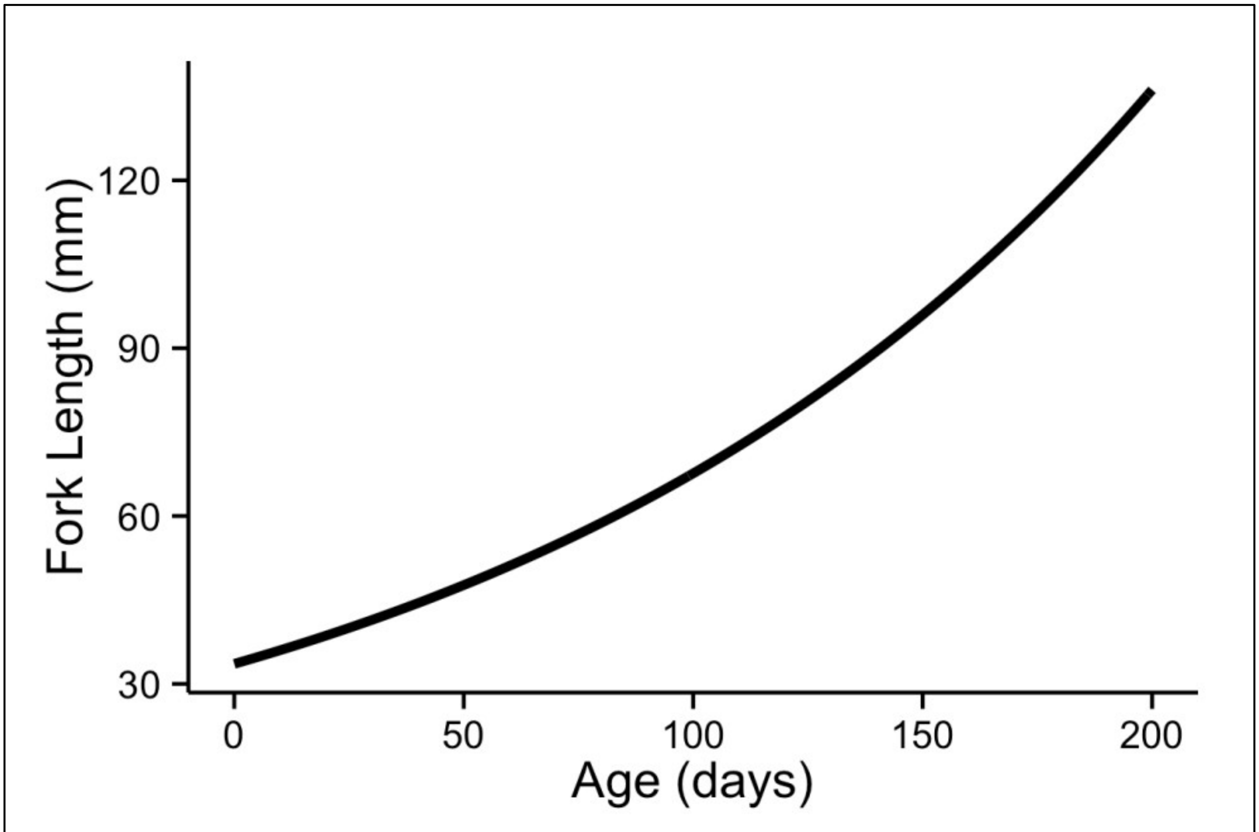


Figure 5-3. Age-Length Curve Developed for Juvenile Sacramento River Fall-Run Chinook Salmon by Fisher (1992), Used in the Model to Back-Calculate Fish Size from the RST Location to the Ends of the Spawning Grounds

To model a range in entry timing and size distributions, RST data were used from 2 example water years that captured the most extreme differences in emigration strategies. For each RST, a water year was selected when juveniles exhibited a characteristic “early” emigration strategy, with emigrants beginning their migration earlier in the season, and a second water year was selected when juveniles exhibited a characteristic “late” emigration strategy, with emigrants beginning their migration later in the season. For the American River, initial timing and size curves were applied for only a single water year (1999) because all water years examined (1994–1999) appeared to exhibit an “early” emigration strategy.

Mokelumne River Rotary Screw Trap

Chinook salmon daily abundance and average fork length data from the Mokelumne River RST, located at Woodbridge Dam (63 RKM), were used from years 2002 (late emigration strategy) and 2006 (early migration strategy) (Figures 5-4 and 5-5). RST data were collected by the East Bay Municipal Utility District.

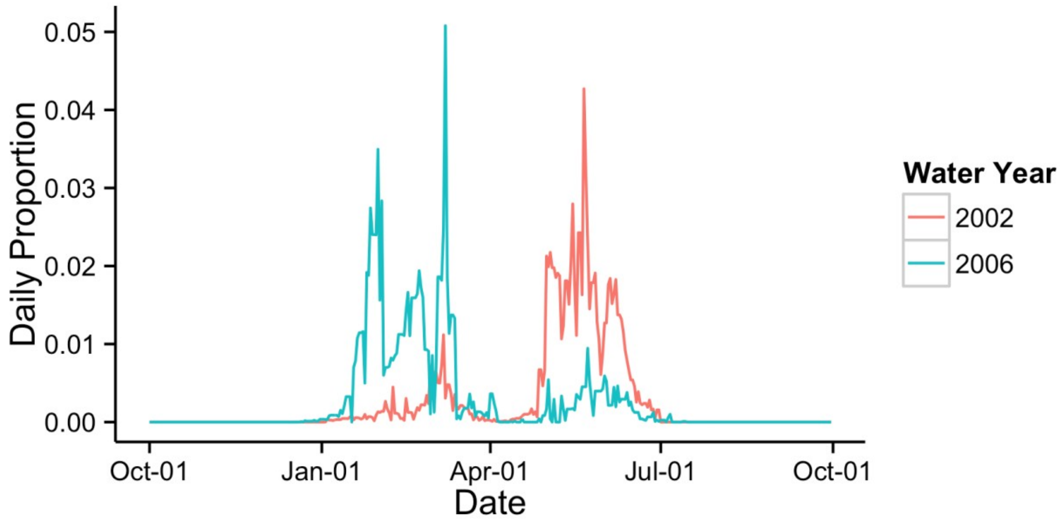


Figure 5-4. The Daily Proportion of the Annual Abundance of Juvenile Chinook Salmon Captured in the Mokelumne River RST in Years 2002 and 2006

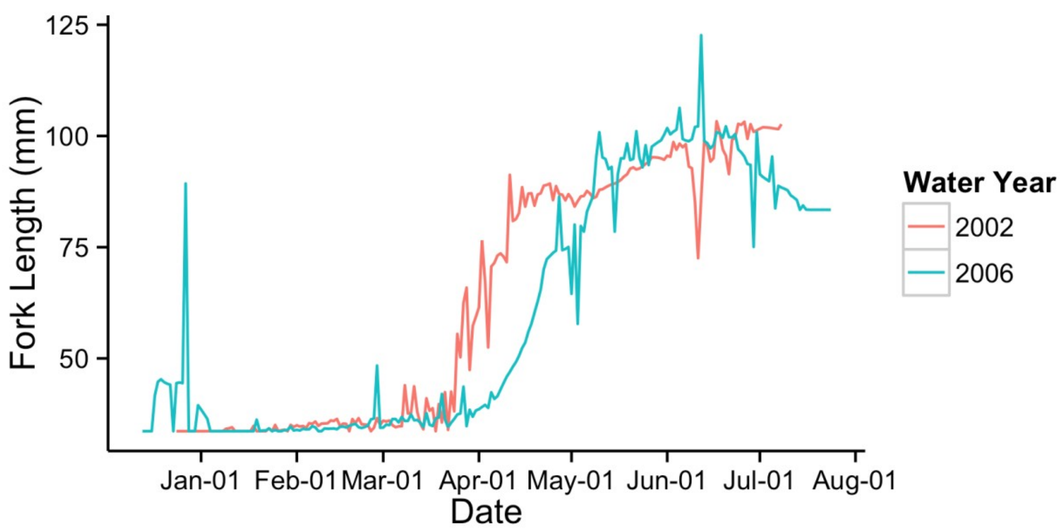


Figure 5-5. Average Daily Fork Lengths of Juvenile Chinook Salmon Captured in the Mokelumne River RST in Years 2002 and 2006

Stanislaus River Rotary Screw Trap

Chinook salmon daily abundance and average fork length data from the Stanislaus River RST, located at Caswell Memorial State Park (10 RKM), were used from years 2012 (late emigration strategy) and 1998 (early migration strategy) (Figures 5-6 and 5-7).

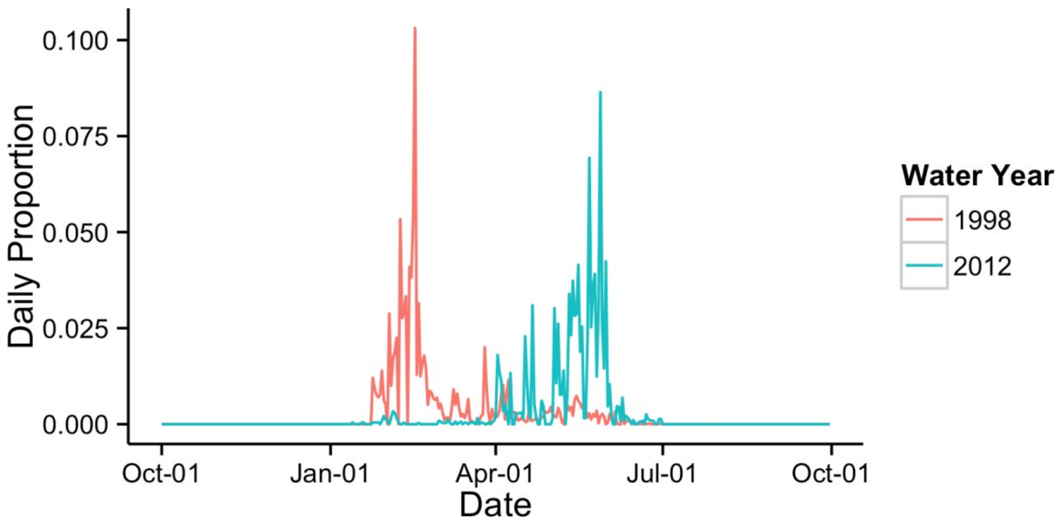


Figure 5-6. Daily Proportion of the Annual Abundance of Juvenile Chinook Salmon Captured in the Stanislaus River RST in Years 1998 and 2012

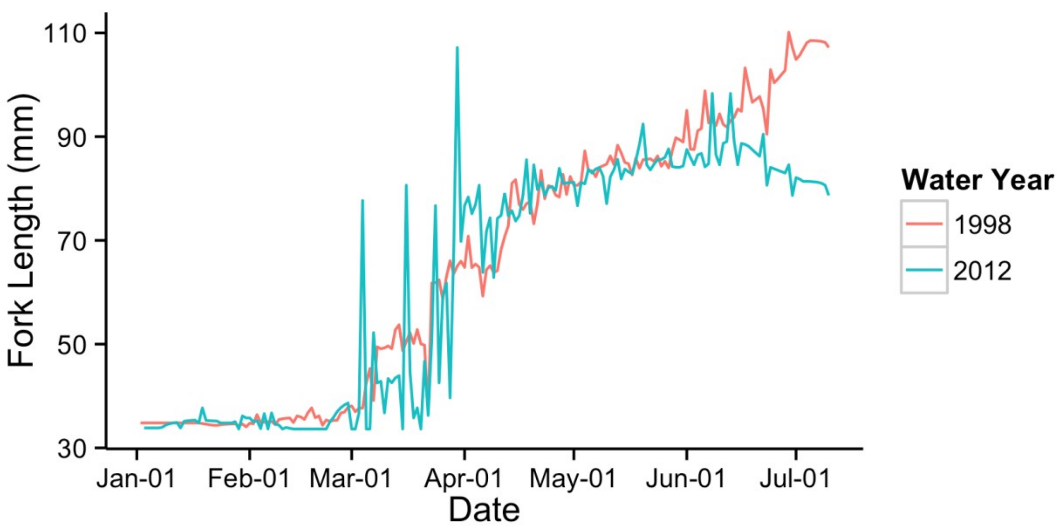


Figure 5-7. Average Daily Fork Lengths of Juvenile Chinook Salmon Captured in the Stanislaus River RST in Years 1998 and 2012

Feather River Rotary Screw Trap

Chinook salmon daily abundance and average fork length data from the Feather River RST, located in the high-flow channel (64 RKM), were used from years 2002 (late emigration strategy) and 2011 (early migration strategy) (Figures 5-8 and 5-9). RST data were collected by the California Department of Water Resources.

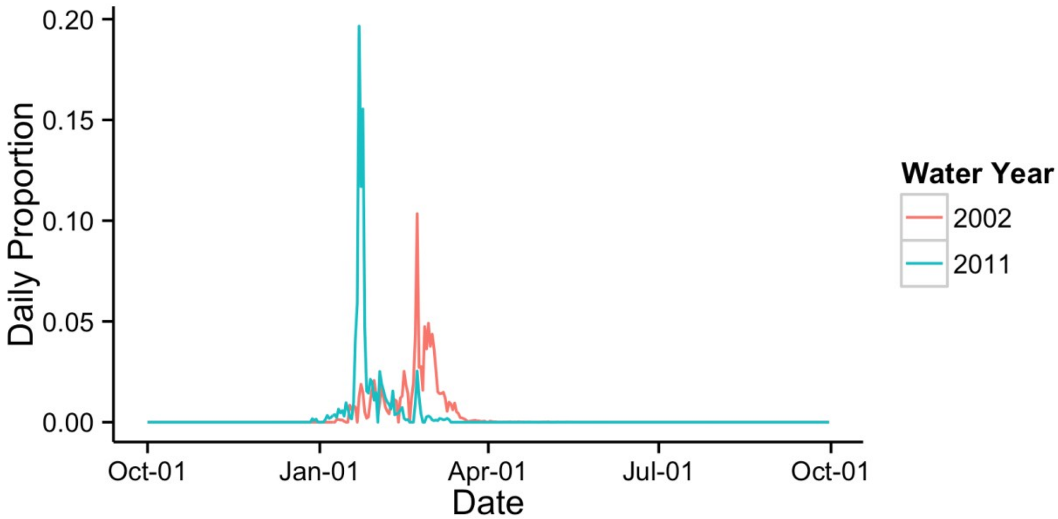


Figure 5-8. Daily Proportion of the Annual Abundance of Juvenile Chinook Salmon Captured in the Feather River RST in Years 2002 and 2011

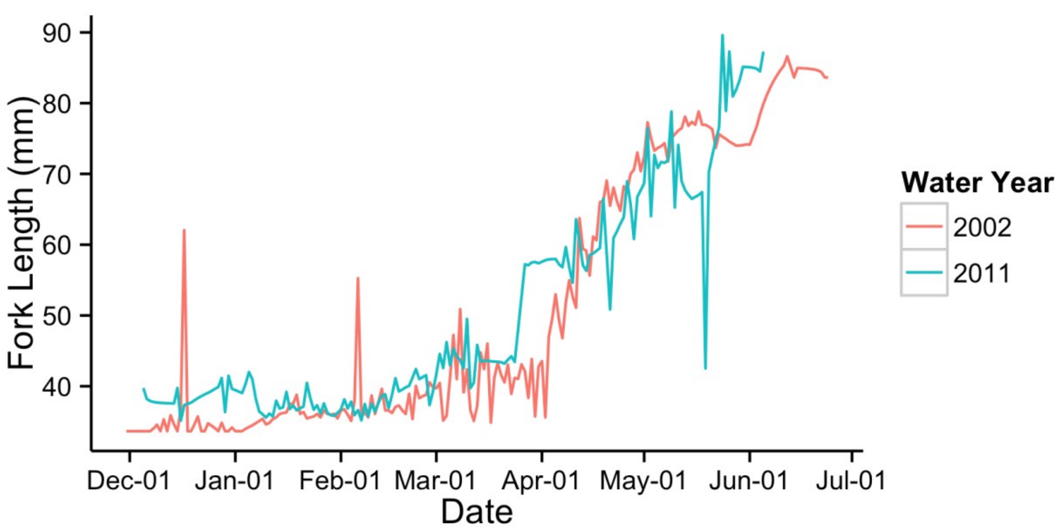


Figure 5-9. Average Daily Fork Lengths of Juvenile Chinook Salmon Captured in the Feather River RST in Years 2002 and 2011

American River Rotary Screw Trap

Chinook salmon weekly abundance and average fork length data from the American River RST, located at RKM 14, were used from 1999 (Figures 5-10 and 5-11). RST data were collected by the California Department of Fish and Wildlife.

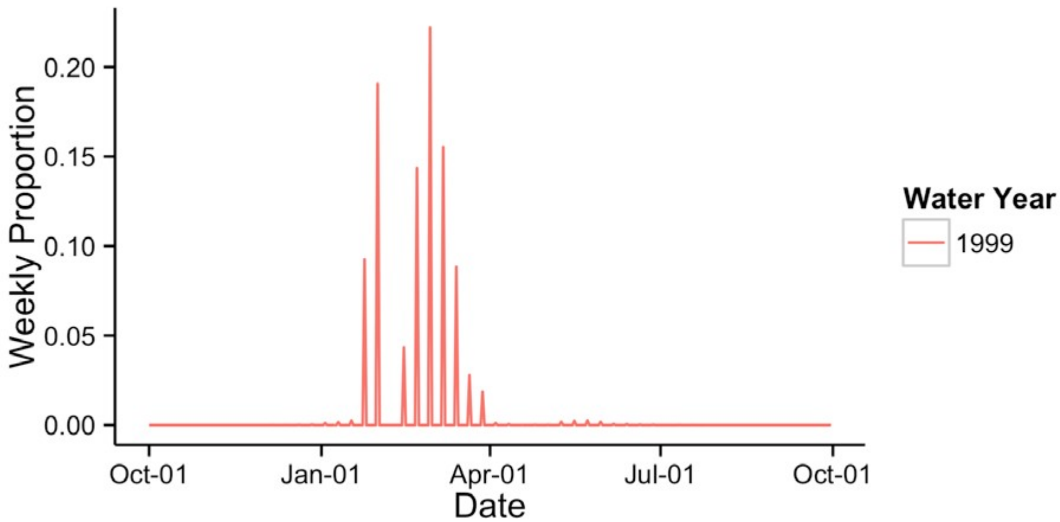


Figure 5-10. Weekly Proportion of the Annual Abundance of Juvenile Chinook Salmon Captured in the American River RST in 1999

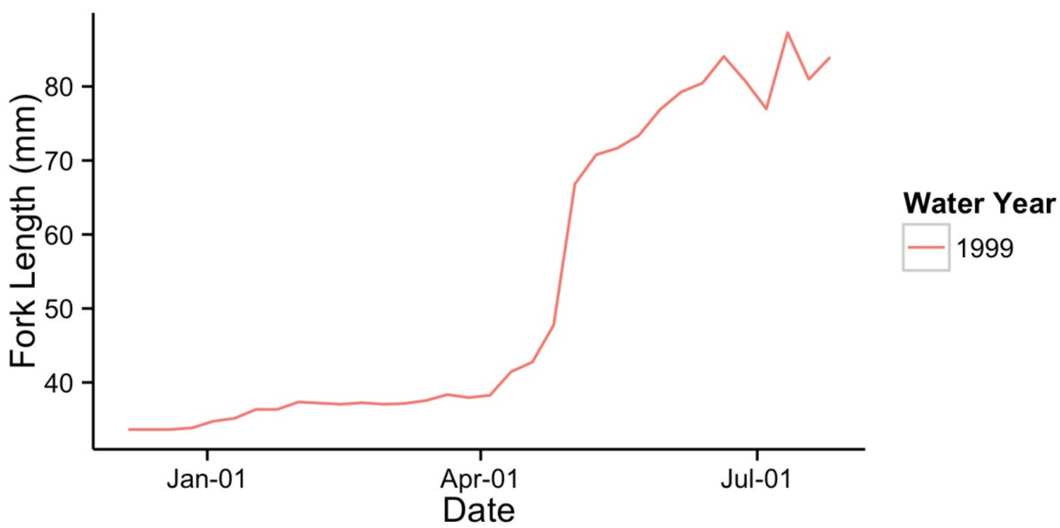


Figure 5-11. Average Weekly Fork Lengths of Juvenile Chinook Salmon Captured in the American River RST in 1999

Sacramento River Rotary Screw Trap at Red Bluff Diversion Dam

Chinook salmon daily abundance and average fork length data from the Sacramento River RST, located at the RBDD (391 RKM), were used from years 2009 (late emigration strategy) and 2006 (early migration strategy) (Figures 5-12 and 5-13). RST data were collected by USFWS.

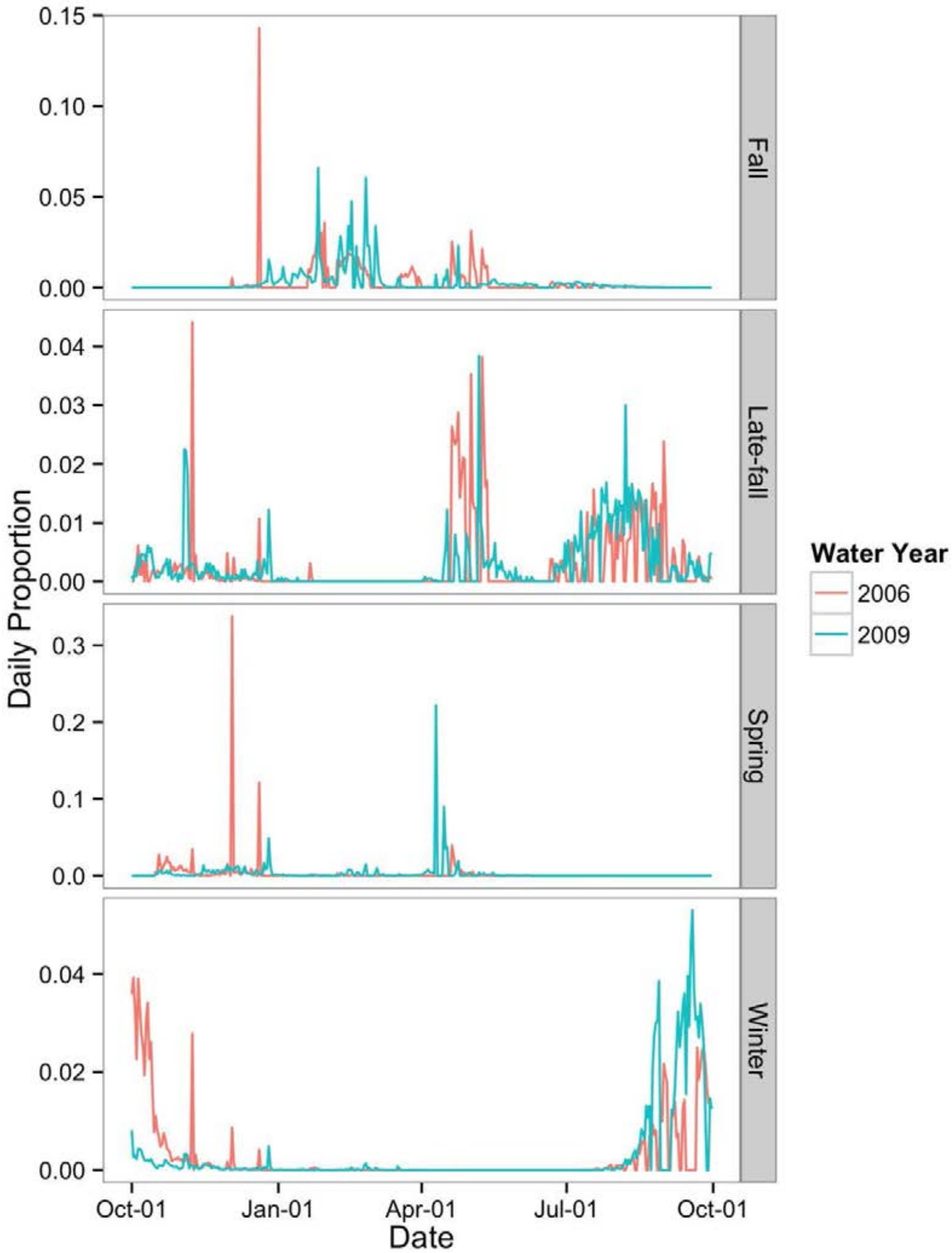


Figure 5-12. Daily Proportion of the Annual Abundance of Juvenile Chinook Salmon Captured in the Sacramento River RST at RBDD in Years 2006 and 2009

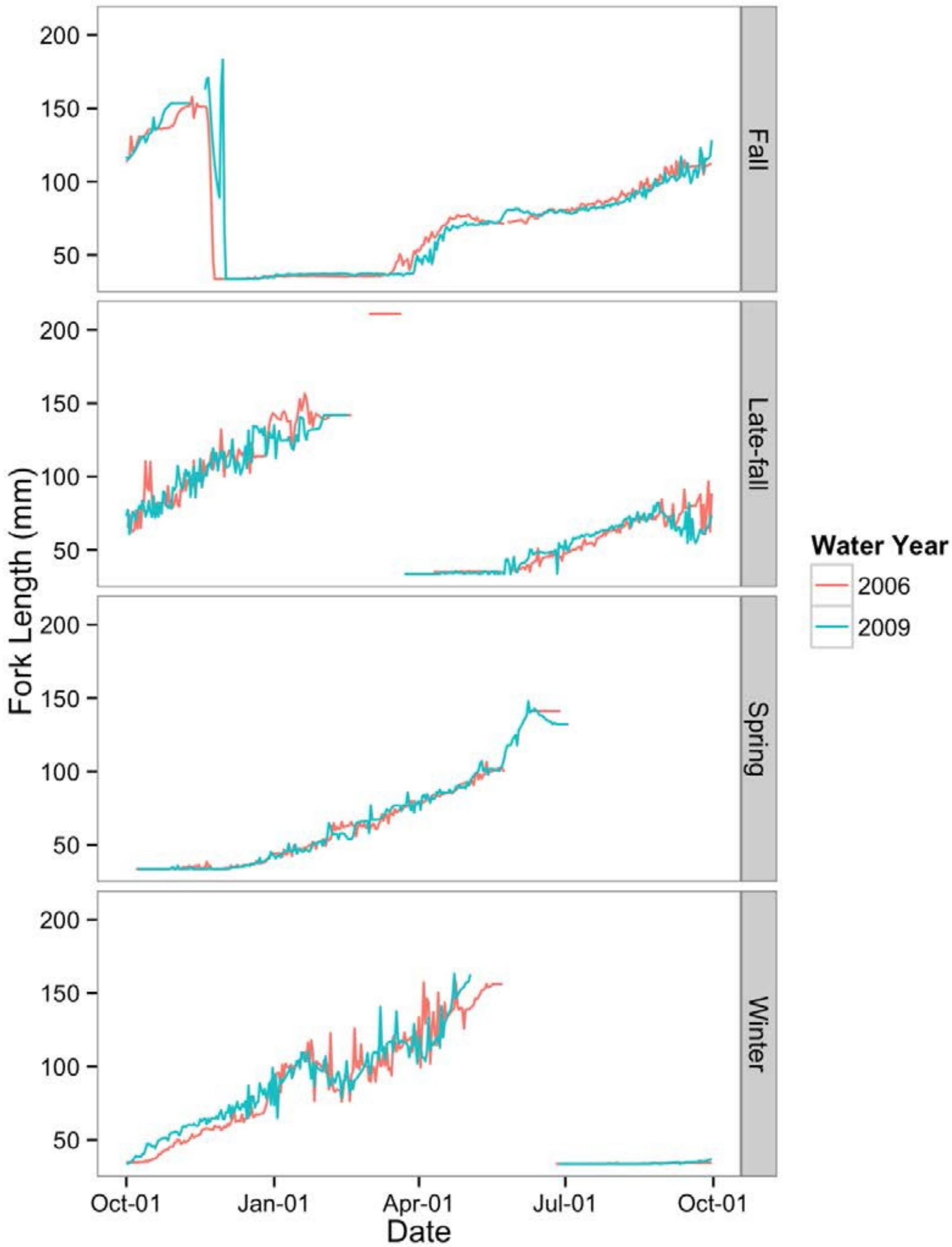


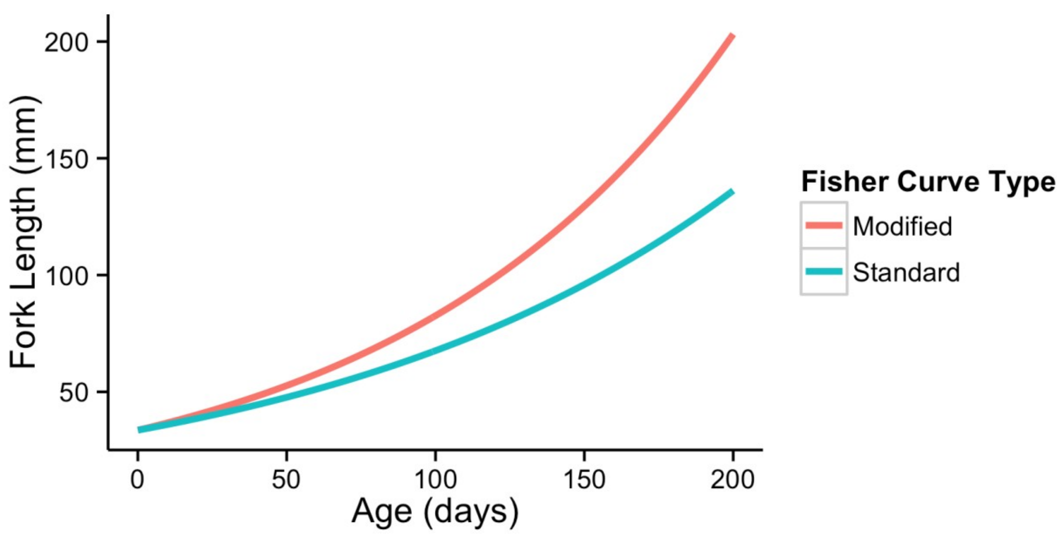
Figure 5-13. Average Daily Fork Lengths of Juvenile Chinook Salmon Captured in the Sacramento RST at the RBDD in Years 2006 and 2009

5.3.6 Emigration

Growth and Migration Rate

Because it was assumed that CVFPP actions could result in the creation of additional floodplain habitat, and because increasing CV Chinook salmon abundance to AFRP doubling goal levels will likely require floodplain habitat restoration, juveniles in the Central Valley ESHE model exhibited growth and migration rates observed in Central Valley floodplain habitats. It assumed that juveniles that rear on a floodplain will greatly increase their migration rates once they meet a threshold size and begin directed seaward migration. The Yolo Bypass was used as a representative example of floodplain rearing habitat and growth and migration rates observed during experimental studies in the Yolo Bypass (Sommer et al. 2001) were applied to all fish in the model. Residence time and initial and final size of fish released in the Yolo Bypass were used to estimate migration rates and modify the Fisher (1992) age-length curve, by fitting it to observed juvenile Chinook salmon growth and migration rates in the Yolo Bypass (Figure 5-14; Attachment H1). The resulting modified growth curve is based on a higher proportionate growth rate than was the original Fisher (1992) curve:

$$\text{Fork Length (FL)} = \exp(3.516 + 0.009 * \text{age}) \quad \text{(Equation 4)}$$



Note: The blue line is the age-length curve developed for juvenile Sacramento River fall-run Chinook salmon by Fisher (1992), used in the model to back-calculate fish size from the RST location to the ends of the spawning grounds. The red line is the modified curve fitted to growth rates of juvenile Chinook salmon in the Yolo Bypass, used in the model to predict daily sizes of juveniles during emigration (see Attachment H1).

Figure 5-14. Comparison of Age-Length Curves

The resulting size threshold for increased migration rate was 88 mm, with migration rates of 1 km/day and 21.3 km/day for fish <88 mm and fish ≥88 mm, respectively.

Survival

Even though AFRP adult doubling goals were used to inform initial spawner abundances in the model (see "Initial Abundance" for details), the goal was to estimate the total amount of suitable rearing habitat needed to support sustainable CV Chinook salmon populations that annually meet the AFRP adult goals. Therefore, in-river survival rates had to be set at values that would ultimately sustain the population at AFRP adult doubling goal levels. A matrix model created for Chinook salmon in the Columbia River Basin (Kareiva et al. 2000) was modified to estimate the in-river (spawning grounds to Chipps Island) survival value for emigrating juveniles. We modified the parameter values applied by Kareiva et al. (2000) to better reflect Chinook salmon life history in the Central Valley, California (Table 5-4).

Table 5-4. Modified Parameter Values and Supporting References of a Matrix Model from Kareiva et al. (2000) Used to Estimate In-river (Spawning Grounds to Chipps Island) Survival Value for Emigrating Juveniles

			This Study	
Category	Parameter	Kareiva et al. 2000	Proportion	Reference
Survival	Survival from egg to yearling	0.022	0.001	
	egg survival	N/A	0.25	Martin et al. 2001
	outmigration	N/A	0.05	*solved for
	estuary	N/A	0.05	*solved for
	yearling to age 2	0.729	0.8	
	age 2 to age 3	0.8	0.8	
	age 3 to age 4	0.8	0.8	
	age 4 to age 5	0.8	N/A	
	upstream migration	0.7	0.95	PFMC 2011
Return Rate	age 2	N/A	0.08	Grover et al. 2004
	age 3	0.013	0.96	Grover et al. 2004
	age 4	0.159	1	Grover et al. 2004
	age 5	1	N/A	
Fecundity	age 2	N/A	4185	Kaufman et al. 2009
	age 3	3257	5838	Kaufman et al. 2009
	age 4	4095	5994	Kaufman et al. 2009
	age 5	5149	N/A	

* = these parameter values were solved for using the matrix model

Many model parameters from Kareiva et al. (2000) were modified to reflect the life history of CV Chinook salmon. Egg survival was set at 0.25, the approximate average egg-fry survival rate estimated in the upper Sacramento River (Martin et al. 2001). Unlike Kareiva et al. (2000), we assumed that all fish emigrate during their first year of life and therefore included outmigration survival and estuary survival in our calculation of survival from egg to yearling. We set yearling to age 2 survival at 0.8 because we assumed that Central Valley yearlings to 2-yr-olds reside in the ocean, and therefore set survival at the same annual survival rate Kareiva et al. (2000) used for all ocean dwelling age classes. We set upstream migration survival of adults to 0.95 because

5 percent is the approximate average annual in-river harvest rate of fall-run Chinook salmon (Pacific Fishery Management Council 2011). We set age-specific return rates from the ocean at values observed for Central Valley spring-run Chinook salmon (Grover et al. 2004). Lastly, we set age-specific fecundities at values observed for fall-run Chinook salmon in Mokelumne River, California (Kaufman et al. 2009).

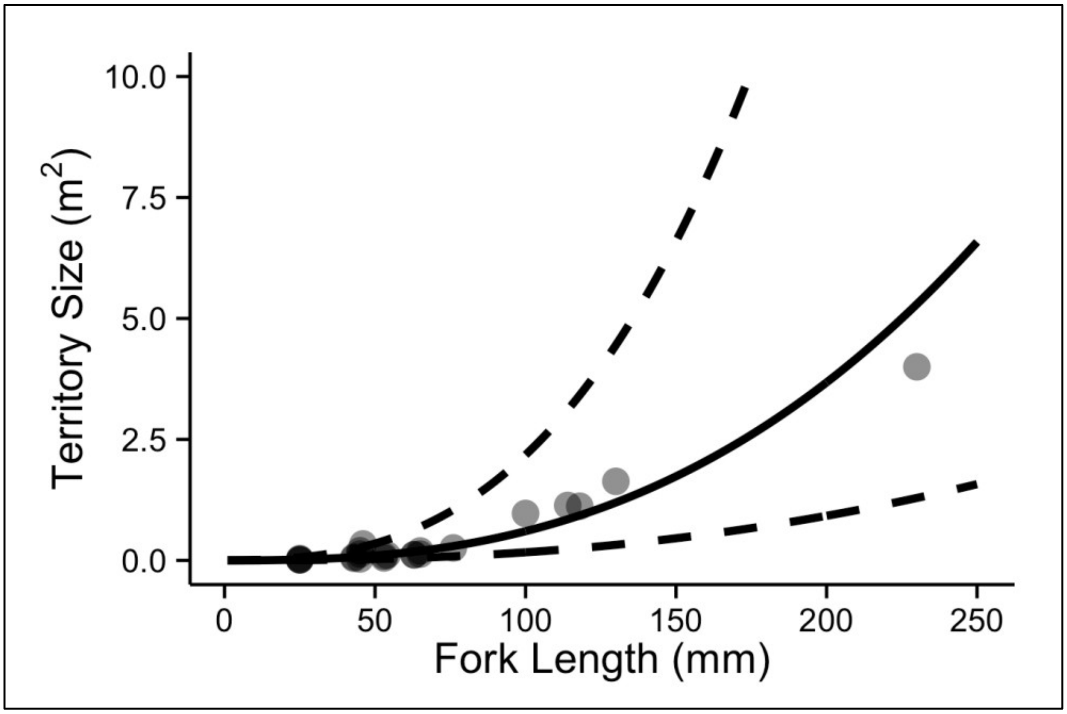
We solved for survival of juvenile Chinook salmon in the estuary and during in-river outmigration under the assumption that survival from ocean entry to age 3 typically ranges from 2 to 4 percent on average (Satterthwaite et al. 2014). The matrix model resulted in estimates of estuary and in-river survival of 5 percent. The outmigration survival rate was applied on a per-kilometer basis in the model for each Central Valley population.

Territory Size

Territory size of juveniles was modeled as a function of fork length based on a territory-size versus fork-length relationship estimated for salmonids from Grant and Kramer (1990) (Figure 5-15). The territory-size fork-length curve may vary depending on food availability, intruder pressure, water depth, and current velocity (Grant and Kramer 1990). When habitat quality is high, juvenile salmonids require less space (smaller territory size) to avoid predation and meet energetic demands through feeding. Conversely, when habitat quality is poor, juvenile salmonids require more space (larger territory size) to avoid predation and meet energetic demands. Because the quality of habitat available in the CPAs is unknown, a conservative (i.e., to limit underestimation of habitat needs) approach was applied when estimating fish territory size, using the upper 95-percent prediction interval curve from the Grant and Kramer (1990) relationship when calculating territory size from fork length (Figure 5-15):

> territory size = 10^(-5.44 + 2.61*log10(fork length) + 0.54 * sqrt(1.04 + ((log10(fork length) - 1.76)^2)/1.36)) (Equation 5)

The model calculated the amount of suitable habitat area required (required ASH) to sustain the number of juvenile salmon present within a CPA on a given day. The daily required ASH in each CPA was calculated by multiplying the predicted territory size by the abundance of each cohort present in a given CPA, and summing across all cohorts. The total required ASH for all Central Valley populations combined in each CPA was estimated as the maximum of the summed daily required ASH values for each population.



Note: Circles are fish observations, the solid line is mean relationship, and dashed lines are upper and lower 95-percent prediction interval limits. The upper 95-percent prediction interval curve was applied in the model to estimate fish territory size.

Figure 5-15. Territory Size versus Fork Length Relationship for Salmonids from Grant and Kramer (1990)

5.4 Results: Total Juvenile Salmonid Rearing Habitat Needed

Table 5-5 summarizes the total juvenile salmonid rearing habitat needed in each CPA (reported as ASH) for both the late and early emigration strategy model runs.

Table 5-5. Overall Required ASH for All Central Valley Populations Combined for Each Emigration Strategy and CPA

Emigration Strategy	CPA	Required ASH (acres)
Late	Upper Sacramento River	23,000
	Lower Sacramento River	10,000
	Feather River	10,000
	Lower San Joaquin River	5,000
Early	Upper Sacramento River	24,000
	Lower Sacramento River	12,000
	Feather River	10,000
	Lower San Joaquin River	4,000

5.5 Assumptions and Limitations

Several assumptions were required to achieve model outcomes under a constrained timeline and limited resources, including lack of watershed-specific data. The following assumptions and limitations were included:

- Juveniles of different races and from different regions do not differ in growth rate, migration rate, survival rate, or territory size needs.
- The Yolo Bypass is representative of rearing habitat that might occur throughout the Central Valley.
- Survival is not size-specific.
- Survival depends on travel distance but not on travel time.
- Migration rate, growth rate, and survival rate do not depend on flow conditions.
- Overall survival is the same for each population throughout the Central Valley.
- Two years of initial timing and size data are representative of the range of emigration strategies present for that watershed.
- Timing and size distributions from RSTs are representative of juveniles emerging from the gravel (once they are backed up to the ends of spawning grounds).
- Juveniles likely switch from rearing to migrating many times throughout their emigration (or even during a single day), resulting in variation in territory needs, growth rates, migration rates, and survival rates. However, data on such fine-scale movement and rearing behavior is unavailable to inform more realistic, subdaily, fish emigration behavior modeling. Therefore, modeling was limited to a representation of the average daily movement and behavior of emigrating juveniles.
- RST data from five focal watersheds where high-quality data are available is representative of other nearby watersheds where high-quality RST data are lacking.

Despite these limitations this model provides an instructive broad scale view of rearing habitat requirements for juvenile Chinook salmon and is a step forward in developing a baseline understanding of habitat needs of CV Chinook salmon for the purpose of refining previously developed floodplain habitat objectives for the Conservation Strategy of the CVFPP. The constraint of limited pre-regulation, natural salmon behavior requires the reconciliation of numerous parameter estimates. Furthermore, this initial emigration and rearing modeling process highlights data gaps and provides direction for future research.

6.0 Results: Historical, Existing, and Required Suitable Habitat for Rearing Juvenile Salmonids

Table 6-1 summarizes the historical, existing, and total required suitable rearing habitat for juvenile salmonids in each CPA. Historical and existing values are presented for the low and high suitability factors described in Sections 3.0 and 4.0, and for an average of the low and high suitability values. Total required rearing habitat is presented for both the late and early emigration strategies, and for an average between these two migration strategies. The additional habitat needed to provide the required suitable rearing habitat is the difference between required and existing habitat acreages in Table 6-1. The corresponding area of inundated floodplain required to provide this additional suitable rearing habitat will depend on the suitability of the restored habitat (e.g., if a restored floodplain area is 20-percent suitable, the total inundated floodplain area required would be five times greater than the required suitable rearing habitat area). Regional objectives for suitable juvenile salmonid rearing habitat, and the design details of projects developed to provide this habitat should be refined on a site-specific basis in consultation with salmon ecology, hydrology, and hydraulic experts for the area of interest.

Table 6-1. Summary of Historical, Existing, and Required Suitable Rearing Habitat for Juvenile Chinook Salmon to Achieve the AFRP Doubling Goal in Each of the Analyzed CPAs

CPA Region	Historical Suitable Rearing Habitat (acres)			Existing Suitable Rearing Habitat (acres)			Required Suitable Rearing Habitat (acres)		
	Assuming Low Suitability	Assuming Average Suitability	Assuming High Suitability	Assuming Low Suitability	Assuming Average Suitability	Assuming High Suitability	Assuming Late Migration Strategy	Assuming Average of Late and Early Migration Strategies	Assuming Early Migration Strategy
Upper Sacramento River	80,586	89,744	98,901	1,399	3,284	5,169	23,000	23,500	24,000
Lower Sacramento River	75,020	83,545	92,070	767	1,814	2,862	10,000	11,000	12,000
Feather River	11,528	12,838	14,148	107	229	352	10,000	10,000	10,000
Lower San Joaquin River	75,614	84,207	92,799	419	911	1,404	5,000	4,500	4,000

This analysis does not include values for the Upper San Joaquin River CPA because a study was previously completed as part of the SJRRP to recommend a minimum area of suitable juvenile rearing habitat required to meet fall- and spring-run Chinook salmon targets for the Upper San Joaquin River CPA (SJRRP 2012). The existing area of suitable rearing habitat for juvenile Chinook salmon in the Upper San Joaquin River was estimated to be 931 acres, and the total area of suitable rearing habitat across all Restoration Program reaches ranged up to a maximum of 1,327 acres.

Several refinements remain that could add to the value of this work in guiding creation of new suitable rearing habitat for juvenile salmonids. These refinements include more detailed analyses of existing channel, floodplain, and tributary suitability for inundated areas in each subreach; improved empirical data on emigrating salmon migration, growth, and survival rates; and interactions with experts in Central Valley salmon ecology, hydrology, and hydraulics, ideally in a scenario evaluation workshop setting where the methods and results of this investigation can be presented and improved iteratively with input from system experts.

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H1. ESHE Model Details

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Data from juvenile Chinook salmon released in the Yolo Bypass (Sommer et al. 2001) were used to estimate migration rate parameters and fit a Fisher (1992) age-length curve for fish migrating through a floodplain. The initial fork length of released fish (57 mm) and approximate migration distance (106 km) were used as input variables in a simulation of fish that successfully migrated (i.e., no mortality) through the Yolo Bypass from the release location at Fremont Weir to the recapture location at Chipps Island.

The simulation involves the same migration behavior as used in the Central Valley ESHE model. Small fish migrate at a slow rate until reaching a threshold size and switching to a faster migration rate. Growth rate is determined by fish size according to the Fisher age-length curve. In this simulation, values were systematically varied for the four relevant parameters (Table H1-1) to determine which parameter combination produced values for the final fork length and residence time that best matched the empirical values (91 mm and 52 days, respectively).

Table H1-1. Parameters That Were Varied in a Simulation to Find the Parameter Combination That Best Fit Empirical Data from Juvenile Chinook Salmon Migrating through the Yolo Bypass

Parameter	Values
Small fish migration rate (km/day)	0.5, 0.6, 0.7, …, 2.5
Large fish migration rate (km/day)	10, 11, 12, …, 40
Threshold fork length (mm)	70, 71, 72, …, 100
Proportionate growth rate[a]	0.005, 0.006, 0.007, …, 0.015

Note:
[a] Only the growth rate was varied for the Fisher age-length curve, not the intercept.

The simulation involved 221,991 parameter combinations (21 * 31 * 31 * 11). The percent error in final fork length and residence time was calculated separately and the values for the total percent error were summed. Percent error was calculated as follows:

$$\% \text{ Error} = (|\text{model obs} - \text{empirical obs}| / \text{empirical obs}) * 100$$

The results were sorted by total percent error and selected the parameter combination with the lowest total percent error to use in the Central Valley ESHE model (see Table H1-2) for the 10 best parameter combinations). The nine best parameter combinations all had the same total percent error. Thus, the parameter values were averaged across the top nine values. The most robust conclusion from this simulation is that the proportionate growth rate is 0.009. The top 2,192 ranked parameter combinations all have a proportionate growth rate of 0.009. The best migration rate for small fish was relatively slow (1.0 km/day). The best threshold fork length (88 mm) was close to the empirical target for final fork length (91 mm). Thus, the large fish migration rate (21.3 km/day) was a relatively unimportant parameter because so little of the migration distance was traveled at that rate.

Table H1-2. Top 10 Parameter Combinations in a Comparison of Simulated Floodplain Migration Behavior and Empirical Observations from the Yolo Bypass

Small Fish Migration Rate (km/day)	Large Fish Migration Rate (km/day)	Threshold Fork Length (mm)	Proportionate Growth Rate	Final Fork Length (mm)	Residence Time (days)	Total Percent Error (%)
0.8	10	85	0.009	91.02	52.00	0.02
1.0	10	86	0.009	91.02	52.00	0.02
1.0	19	88	0.009	91.02	52.00	0.02
1.6	13	89	0.009	91.02	52.00	0.02
1.4	18	89	0.009	91.02	52.00	0.02
1.2	23	89	0.009	91.02	52.00	0.02
1.0	28	89	0.009	91.02	52.00	0.02
0.8	33	89	0.009	91.02	52.00	0.02
0.6	38	89	0.009	91.02	52.00	0.02
1.3	40	90	0.009	91.01	51.99	0.03

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Appendix D: Analysis of Flow Effects on the Creation of and Need for Inundated Shallow Rearing Habitat on the Lower San Joaquin River and its Main Tributaries

Juvenile Chinook salmon in the Central Valley make use of periodically inundated shallow habitats (in general, "floodplains") as they rear and migrate towards San Francisco Bay and the Pacific Ocean. When these periodically inundated areas meet or exceed the threshold requirements of salmon habitat (measured in terms that include velocity, depth, cover, substrate, and temperature) they may provide access to improved bioenergetic conditions for growth (e.g., high prey densities, lower activity levels) and lower predator densities relative to in-channel habitats (Sommer et al. 2001). As a result, growth and survival of juvenile Chinook salmon are elevated on inundated floodplains and the extent of these benefits reflects habitat suitability (Sommer et al. 2001; Jeffres et al 2008); increased growth on the floodplains may lead to subsequent increases in survival in downstream habitats. Thus, the quantity and distribution of floodplain habitats are considered to be essential elements in restoration planning for Central Valley populations of Chinook salmon (e.g., SEP 2016).

Although it is possible to engineer off-channel environments to increase their availability and value as habitat, the frequency of inundation and performance of inundated habitat is intimately tied to the flow regimes in adjoining rivers. In addition, river flow regimes control other ecosystem functions that determine the overall context in which floodplain habitats exist and, as a result, the conservation value of these habitats.

We evaluated likely changes in the availability and timing of periodically inundated Chinook salmon rearing habitat in the lower San Joaquin River (downstream of the Merced River confluence) and its three main tributaries (Stanislaus, Tuolumne, and Merced Rivers) under a range of Feb-June flows referenced in the State Water Resources Control Board's 2016 Draft Revised Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the Bay Delta: San Joaquin River Flows and Southern Delta Water Quality (Draft SED). These comparisons were used to illustrate general principles regarding the relationship between flow regimes and shallow inundated acreage availability and the need for physical habitat restoration both upstream (the tributaries) and downstream (the lower mainstem) on the San Joaquin River, as well as to explore the potential trade-offs between flow regime and physical habitat creation that are alluded to in the Draft SED.

General Approach

Using a model of daily flows we developed from historical data, we generated hydrographs that represented the range of flows nominally considered by the Draft SED (30%-60% of unimpaired flow (UIF) calculated as a 7d moving average). These hydrographs were used to estimate the timing, duration, and acreage of floodplain that would be inundated in each of the tributaries and the lower San Joaquin River by applying flow-inundation relationships presented in the Draft SED. Inundated acreage was compared to estimated need for Chinook salmon rearing habitat on each river corridor that would be required to support each tributary's AFRP target population of fall-run Chinook salmon. Habitat need estimates for the tributaries and the lower San Joaquin River mainstem were derived from the California Department of Water Resources' Draft Conservation Strategy for its Central Valley Flood Protection Plan (CVFFP; CDWR 2016a) and expanded to reflect liberal assumptions regarding the relationship between inundated acreage and inundated *habitat* acreage. Differences between habitat need and acreage inundated under each flow regime were expressed in terms of flow deficits (that needed to inundate existing acreage) and acreage deficits (the area of habitat that would need to be made to inundate under a given flow regime).

The Bay Institute's San Joaquin River Simulated Daily Unimpaired Flow Model (Version 16-2)

Hydrographs were generated using a model for estimating daily unimpaired flows for the San Joaquin River. The San Joaquin River Simulated Daily Unimpaired Flow Model (TBI Flow Model) is a spreadsheet model for projecting daily flows at Vernalis and below the rim dams on the Stanislaus, Tuolumne, and Merced rivers using an unimpaired hydrograph approach (i.e., flows from the tributaries that reflect a percentage of unimpaired flows (UIF) as an x-day moving average). Input data are Full Natural Flow ("FNF"; hereafter "unimpaired flow") data from DWR (CDWR 2016b, CDWR 2016c). The TBI Flow Model allows specification of the percentage UIF from a variety of inputs to flows at Vernalis, including the Stanislaus River, Tuolumne River, Merced River, San Joaquin River above the Merced confluence, and Valley Floor flows. A multi-day averaging period (e.g., 7d) is also specified. The output is a daily flow (in cfs) at Vernalis, as well as the tributary flows.

In 2012-2013 TBI developed versions 1 through 12 of this model in order to analyze and comment on the 2012 Draft Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the Bay Delta: San Joaquin River Flows and Southern Delta Water Quality (2012 Draft SED). Documentation of Version 12 of the model was submitted with TBI et al 2013. In 2016, TBI modified the 2012 model in order to analyze and comment on the Draft SED – the current version is labeled 16-2. Documentation of changes from Version 12 to Version 16-2 is included in this Appendix D. Similar analyses should be performed in the SED using the WSE model.

Using the TBI Flow Model v. 16-2, we analyzed the influence of flow regimes described in the 2016 SED on availability of inundated rearing habitat for Chinook salmon in the San Joaquin watershed with respect to habitat objectives that are linked to attainment of the existing Water Quality Control Plan narrative salmon protection objective.

San Joaquin River and Tributaries Inundated Habitat Analysis

Methods and Data

Inundated Floodplain Habitat Acreage Needed to Support Existing Water Quality Control Plan Salmon Doubling Objective

Output from DWR's July 2016 Draft Central Valley Flood Protection Plan (CVFPP) Appendix H, Central Valley Chinook Salmon Rearing Habitat Required to Satisfy the Anadromous Fish Restoration Program Doubling Goal,[1] was the basis for the acreage of habitat needed on each tributary and in the mainstem San Joaquin River to support attainment of the existing Water Quality Control Plan salmon doubling objective for fall-run Chinook salmon. The CVFPP utilized the Emigrating Salmonid Habitat Estimation model (ESHE; SJRRP 2012), to generate estimates of the spatial extent of suitable habitat needed to support the target populations. In general, ESHE applies growth and migration rates to determine the number of salmon in a reach of river at any given time and the cumulative habitat needed to support those fish. Because ESHE uses territory size needs as the basis for its estimate, the results estimate habitat need assuming 100% suitability. Recognizing that actual inundated acreage is extremely unlikely to be 100% suitable for Chinook salmon, we converted ESHE habitat acreage estimates into the acreage that is likely to be necessary to provide equivalent habitat for fish. Estimates produced for the San Joaquin River Restoration Program (SJRRP 2010) revealed existing habitat suitability between 7-30%. Thus, the CVFPP calculation of "optimal" habitat acreage needed to support the existing Water Quality Control Plan narrative salmon protection objective was expanded to account for anticipated habitat quality; ESHE outputs were expanded to estimate the acreage needed if average Habitat Suitability Index (HSI) was 30%; slightly higher than the 27% factor used for high suitability in the CVFPP. Achieving this average level of habitat suitability is likely to require engineering of restored floodplains by grading and addition of habitat elements such as fine sediments and riparian vegetation.

For each tributary and the lower mainstem San Joaquin River, we used the ESHE results to identify the maximum daily value of expanded habitat required for the target population over the course of the rearing and migration period; this value represented the minimum needed habitat in subsequent analyses. It should be noted that the ESHE habitat need estimate for the lower San Joaquin River did not take into account juvenile fish from the San Joaquin Restoration Program Area. As a result, it likely underestimates the total habitat needed once the SJRRP has been implemented.

Estimating Flow Needed to Inundate the Minimum Habitat Required to Support Existing Water Quality Control Plan Salmon Doubling objective

Chapter 19 of the 2016 Draft SED provides tables and equations for calculating floodplain

[1] The report is available at: http://www.water.ca.gov/conservationstrategy/docs/app_h.pdf and is included as Appendix B to TBI et al 2017.

acreage that will be inundated at flows between 1,000 cfs and 5,000 cfs on tributary reaches; the upper flow limit of the flow:inundation relationship was 15,000 cfs on the mainstem. Equations were provided for the Tuolumne and Merced, and these were used to estimate the flows needed to inundate the target acreage generated by ESHE. For the Stanislaus and lower San Joaquin rivers, equations were not provided in the SED, and we developed them from the tables provided in Chapter 19 of the 2016 SED. In developing the Stanislaus River equation, we used additional data points at 7,700 cfs and 10,000 cfs derived from the inundation information provided in table F.1.6-1a in Appendix F.1 (in the HEC5Q temperature model discussion).

We applied the flow-inundation equations provided in or derived from the draft SED to all river miles downstream of the estimated midpoint of the spawning reach of each tributary (Table 1). We did not estimate inundated habitat acreage upstream of this point because most juvenile salmon would have limited access to rearing habitat created upstream of where they were born. Thus, we studied generation of rearing habitat in the “rearing reach” downstream of:

- RM 47 on the Merced River;
- RM 39 on the Tuolumne River; and,
- RM 46 on the Stanislaus River.

The flow inundation relationships for the Merced and Tuolumne (i.e., rivers with flow-inundation equations provided in the draft SED) did not cover all river miles in our estimated rearing reaches. We assumed that the inundated area per river mile as reported in the draft SED would be the same even outside the reaches used to calculate the draft SED’s flow-inundation equations. Based on this assumption, we used the flow-inundation relationships to calculate the flow needed to inundate the fraction of the total acreage need that would occur within the reach covered by the flow-inundation relationship. In other words, we scaled the inundated acreage target for each tributary by the proportion of river miles built into the flow-inundation relationship as compared to the river miles in the rearing reaches identified above.

Table 1: Flow-inundation equations used for the tributaries; X is flow, Y is acreage per RM inundated by X. Y_{10d} = represents acreage in the stretch of the tributary that must be inundated for 10 consecutive days to produce target habitat suitability; Y_{3d} = represents acreage in the stretch of the tributary that must be inundated for 3 consecutive days to produce target habitat suitability. Results are multiplied by the length (in miles) of the rearing reaches. Merced and Tuolumne equations are reorganized from those presented in the draft SED; Stanislaus equations were developed from the data in the draft SED.

River and Reach	**Final equation used**
Merced River (SED equations used)	Y_{10d} =(342.69*LN(x)-2380.9)*26/25.2 where x is the

	10d inundation flow Y_{3d} =(342.69*LN(x)-2380.9)*21/25.2 where x is the 3d inundation flow
Tuolumne River (SED equations used)	Y_{10d} =(530.68*LN(x)-3728.6)*26.5/30.5 where x is the 10d inundation flow Y_{3d} =(530.68*LN(x)-3728.6)*12.5/30.5 where x is the 3d inundation flow
Stanislaus equations (per-mile equations used)	Y_{10d} =29*(9.514*LN(x)-69.135) 29 mi times the per-mi equation, x being the 10d inundation flow Y_{3d} =17*(9.514*LN(x)-69.135) 17 mi times the per-mi equation, x being the 3d inundation flow

For the lower San Joaquin River, no flow-inundation equation was provided in the draft SED, so we developed equations for several reaches from the data provided in Chapter 19 of the 2016 SED (Table 2). The CVFFP did not provide needed acreage in each reach, therefore we calculated the flow at Vernalis that would inundate the total acreage below the Merced River confluence needed to support target populations of Chinook salmon using the "SJR from Merced River to Mossdale" equation in Table 2. This target flow in the mainstem was assumed to meet the downstream habitat need for all three tributaries. In order to calculate the portion of the target rearing acreage only available downstream of each tributary, the target Vernalis flow was then used to apportion the needed acreage downstream of the confluences with the Tuolumne and the Stanislaus by applying the applicable equations (solving for X) from Table 2.

Table 2: Flow-inundation equations and how those equations were applied to reaches on the lower San Joaquin. Y is the flow at Vernalis and X is the acreage inundated in each of the three reaches. Equations were developed from the data in the SED. To achieve target habitat suitability in the mainstem San Joaquin River corridor, inundation must occur for a minimum of 10 days.

River and Reach	Final equation used
SJR from Merced River to Mossdale	Y=-0.00005*X^2+1.7741*X+2439.9
SJR from Tuolumne River Mossdale	X=0.00002*Y^2-0.0527*Y+105.74
SJR from Stanislaus River to Mossdale	X=0.000005*Y^2-0.017*Y+72.054

ESHE maximum habitat need estimates, as expanded by HSI, were input to relevant equations to solve for the flow needed to inundate the target habitat in tributaries (table 1) and the mainstem San Joaquin (Table 2).

Habitat Suitability -- Duration of Inundation

The duration of floodplain inundation affects both habitat suitability and the number of juvenile salmon that can access this habitat. In addition to the physical characteristics of suitable habitat (e.g., velocity, depth, cover, etc.), inundation duration affects prey availability in the inundated habitat. The time needed for inundated habitat to achieve a particular level of habitat suitability (30% in this case) varies with the type of environment being inundated. In high-gradient, riparian corridors vegetated by shrubs and trees, inundation allows access to terrestrial invertebrates that enter the water column – this Chinook salmon food supply becomes available relatively quickly (i.e., within 3 days of inundation or less). Therefore, we assumed that acreage inundated in the upper upper ½ of the tributaries below the dams could reach 30% habitat suitability in 3 days. In lower-gradient habitats, where grass and sparse shrubs are the dominant vegetation in the Central Valley, habitat suitability depends largely on *in situ* generation of zooplankton, a food source that requires at least 10d to become dense enough that it can provide meaningful benefits to migrating Chinook salmon (SEP 2016 *and sources cited therein*). We assumed that 10-consecutive days of inundation would be required to create inundated floodplain habitats with 30% HSI in the lower 1/2 of the tributaries and throughout the lower San Joaquin River mainstem; therefore, the flow needed to inundate this area must persist for at least 10 days to produce habitat that met our 30% HSI assumption. This is a liberal assumption of the potential benefits arising from floodplain inundation as optimal conditions on low-gradient floodplains do not emerge until approximately 14 consecutive days of inundation (Grosholz and Gallo 2006).

To determine the maximum habitat inundated on the tributaries during the median year, we added the maximum acreage inundated for 10 consecutive days from the lower stretches (Y_{10d}) to the habitat inundated on high-gradient reaches during the highest 3-days of consecutive flow (Y_{3d}) within the 10-day peak.

Habitat Suitability -- Recurrence Frequency and Timing

Chinook salmon benefit from suitable rearing habitat throughout their migration route and, because they migrate downstream as they rear and grow, they benefit from upstream habitat earlier in the rearing period and habitats downstream provide benefits later in the rearing period (Figure D-1). This has implications for the ability of any flow regime or habitat configuration to meet the needs of a migrating cohort of juvenile Chinook salmon. Although ESHE calculates demand for habitat acreage on every day (and, potentially, for every river mile) during the fall run Chinook salmon juvenile rearing and migration period (roughly, February-June), we assumed that seasonal flow regimes (hydrographs) which resulted in inundation of the maximum necessary acreage for the appropriate period would also provide the necessary inundated acreage throughout the rearing and immigration period – this assumption may not hold if flow shaping (deviation from the 7-da averaging requirement) is employed aggressively.

Although ESHE results indicate the date(s) on which maximum habitat demand will occur, we assumed that the timing of maximum inundation would correspond to the timing of maximum habitat need (or could be made to correspond, through management of releases) as long as it occurred within certain temporal boundaries. For the tributaries, maximum habitat demand was assumed to occur between Feb 1 and May 14, whereas in the lower San Joaquin River mainstem, maximum habitat demand was assumed to occur between May 15 and June 30. Basically, we studied whether the median-year hydrograph would provide enough water to inundate available shallow habitat and left considerations regarding the timing of inundation aside. In practice, manipulation of the flow regime (flow shaping) may be needed to produce maximum habitat inundation at the time of peak habitat demand on each tributary and on the lower San Joaquin River mainstem.

We assumed that the flow needed to inundate the target habitat would need to recur in approximately half of years in order to support the existing Water Quality Control Plan narrative salmon protection objective "on average." Thus, we explored whether and for how long critical flow levels occurred during the median year. We analyzed annual hydrographs from the 1977-2016 period generated by the TBI Flow Model to identify the median year of 10-day (consecutive) habitat inundation on the tributaries. For each tributary, the median year was identified by ranking annual hydrographs according to the 10th-highest consecutive daily flow that occurred within the period when maximum habitat demand was likely to occur (see below). Calculated this way, the median year of inundation was 2010 for each tributary. 2010 was in the 33% exceedence for the mainstem San Joaquin at Vernalis; in other words it was wetter than 2/3 of the years since 1977.[2] To avoid comparison across different years, and year types, and to facilitate thinking about the effect of flow shaping within years, we present results from 2010 for the tributaries and the lower SJR mainstem. We also report, but do not graphically display, results from the median year of inundation (in terms of our 10th-highest consecutive day of flow metric) at Vernalis (WY 2000).

Results -- Analysis of Habitat Inundation in Median Years Under Different Flow Regimes

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[2] The discrepancy between the inundation metric (10th highest consecutive day of flow) on the mainstem and the tributaries likely results from (a) the timing of tributary flows (e.g., flow pulses in the tributaries that occur at different times produce a muted flow pulse in the mainstem, and (b) the effect of SJRRP flows entering the lower San Joaquin from above the Merced River (restoration flows follow a water year-type schedule and so are significantly different as water year-type changes).

The acreage inundated by 30% -60% UIF hydrographs (as estimated by the TBI Flow model using a 7d running average) were compared to the minimum habitat acreage needed to support the existing Water Quality Control Plan salmon doubling objective in each of the three main tributary rivers and the lower mainstem San Joaquin River (Figure D-5). On the tributaries, the habitat acreage needed to support target salmon populations was not attained under any of the flow levels studied (Figures D-2 through D-4). Similarly, in the median year for mainstem inundation (2000), the habitat acreage needed to support the target salmon population did not inundate under the 7-d running average hydrograph. At 60% UIF, all the inundated habitat necessary in the lower San Joaquin River may be created on existing acreage during a year like 2010 (the median inundation year for the tributaries; Figure D-6).

For hydrographs on each tributary and the lower San Joaquin River mainstem, we also tabulated the number of days of target habitat inundation that occurred, the inundated habitat acreage deficit, and the flow volume deficit (i.e., that flow needed to inundate the unmet target acreage; Tables D-1 through D-4). Finally, for hydrographs that inundated the target acreage for one or more days, we tabulated the daily volume of water in the 7d trailing average hydrograph that would be in excess of the minimum needed to inundate the target acreage and how many additional days of floodplain inundation could be attained if this “extra” water were optimally distributed over the inundation period (i.e., “shaping” to achieve maximum days of inundation; Table D-4). These values represent either the additional water that would be needed in the year depicted in order to inundate the target floodplain acreage (e.g., borrowed from some other period in order to engineer adequate floodplain inundation) and/or the floodplain acreage that would need to be restored such that it will inundate in a year with similar hydrology under the relevant % UIF hydrograph (e.g., by grading, levee removal, etc.).

These values should be regarded as liberal estimates of the inundated habitat benefits associated with each hydrograph, in the median year.

Discussion

In general, significant habitat restoration will be necessary on the tributaries and in the San Joaquin mainstem to produce the inundated floodplain habitat necessary to support the existing Water Quality Control Plan salmon doubling objective in the San Joaquin’s three main tributaries; however, the need to restore areas that will inundate and become habitat for juvenile salmon decreases substantially as flow volumes increase during February-June (Figures D-2 through D-5; Tables D-1 through D-4). Also, as the percent of unimpaired flow increases from 30% to 60%, the river stage (elevation) associated with the median year 10th highest consecutive flow increases as well; this means it is possible to inundate higher elevation surfaces under flow alternatives with higher %UIF. The ability to inundate higher elevation sites (relative to the river surface) lowers the cost of subsequent habitat creation both because more acres are potentially suitable for restoration and because the need to lower elevation of potential restoration sites (e.g., by earth moving) is reduced. Habitat improvements, such as riparian vegetation planting, may be necessary to bring existing acreage up to 30%.

"Flow shaping" is often proposed as an alternative to physical habitat restoration as a means to achieve inundated habitat needs. Our results reveal that modest "flow shaping" operations may produce beneficial habitat results that cannot be achieved by strict adherence to a multi-day averaging of inflow to rim dams (i.e., unimpaired flow). For example, flow shaping would allow full inundation of the target acreage in the lower San Joaquin in a year like 2010 (Figure D-5; Table D-4).

Less modification to the natural pattern of flow (i.e., less borrowing of flow from one time period to apply to another time period) will be necessary under flow alternatives that commit more water (greater %UIF) to river and salmon conservation. There are many benefits to minimizing the need for "flow shaping" and retaining a more natural flow pattern that would occur with a multi-day averaging of unimpaired flow. For example, flow shaping operations that require movement of significant volumes of water from one part of the hydrograph to another run the risk of producing negative habitat conditions in the period from which water is "borrowed." In many critical months, water temperatures in the tributaries will increase as flow levels decrease (SED; Chapter 19). Also, day-to-day flow variability, which provides critical migration cues for juvenile salmon (Zeug et al 2014; Sturrock and Johnson 2016 *in prep.*), will likely be reduced in periods from which water is borrowed. These risks increase as flow shaping increases in either amount or duration.

In addition, flow shaping requires reliance on runoff forecasting, which is prone to error. Conservative forecasts (e.g., 90% exceedence) may result in the tributaries of the San Joaquin receiving less water early in the winter-spring period than they would under a multi-day averaging of unimpaired flow because, by definition, these conservative forecasts underestimate unimpaired flow most of the time. One of the benefits of indexing river flow to a trailing multi-day average of unimpaired flow is that no forecasting is required. A river management approach that treats the %UIF from Feb-Jun as a water budget (or "block of water") abandons this benefit and may result in decreased efficiency and efficacy of the decision-making process (due to decreased confidence in the results); it may also result in unintentionally "shifting" flows to later in the winter-spring period, as confidence in the annual water budget increases. Finally, the efficacy of flow shaping relies on precise control and coordination of reservoir releases, in this case, from no less than three reservoirs.

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Attachment A:

Version 12 Model Documentation
(Model as used in TBI et al. comments on 2012 SED)

The Bay Institute's San Joaquin River Simulated Daily Unimpaired Flow Model (Version 16-2)

General Approach

The San Joaquin River Simulated Daily Unimpaired Flow Model is a spreadsheet model for projecting daily San Joaquin River flows at Vernalis using the proportional hydrograph (percentage of unimpaired flows (%UIF) from the tributaries and x-day averaging) approach. The input data are daily average flows. The tool allows the user to specify the desired % UIF from each tributary (Stanislaus, Tuolumne, Merced Rivers, San Joaquin above the Merced confluence, and Valley Floor flows) to the San Joaquin River above Vernalis and the output is a daily flow (in cfs) at Vernalis.

In 2012-2013 The Bay Institute (TBI) developed versions 1 through 12 of this model in order to analyze and comment on the 2012 Draft Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the Bay Delta: San Joaquin River Flows and Southern Delta Water Quality (2012 Draft SED). Documentation of Version 12 of the model was submitted to the SWRCB as part of Attachment A to our 2013 comments on the draft SED (TBI et al. 2013).

In 2016 TBI modified the 2012 model in order to analyze and comment on the 2016 Draft Revised Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the Bay Delta: San Joaquin River Flows and Southern Delta Water Quality (2016 Draft SED).

Modifications between versions 12 and 16-2 of the model include:

- New projected daily SJR Settlement flows were used from the Riverware Daily SJR Model. Valley Floor contribution to flow was set to 50% of UIF (previously 100%) in order to avoid double counting the valley floor runoff portion of modeled SJR Settlement flows upstream of the Merced River confluence.
- We updated the Valley Floor term to apply different values on the basis of quintile year types, consistent with the rest of the analysis, instead of the San Joaquin Valley Index 15-15-20-20-30 distribution.
- We updated the TBI-recommended year-round flow at Vernalis from 1,500 cfs to 2,000 cfs.
- Added a toggle for showing 7, 3, or 1 day averages on year-type graphs.
- 2012-2016 water years were added. These years were not added to the previous results summaries due to time constraints and sometimes a lack of relevance (some of the previous recommendations were superseded by new analyses).
- Averaging was set to 7 days, consistent with the 2016 SED (previously it was set to 14 days, consistent with the 2012 SED)
- Vernalis flow during Feb-Jun was set to the modeled flow or 1,000 cfs, whichever was greater, with additional flow proportions coming from each tributary consistent with the 2016 SED. Additional output columns for each tributary were added and adjusted based on the 1,000 cfs minimum flow at Vernalis.

Data & Methods

FNF ("Full Natural Flow", also known as unimpaired) data from DWR were used in version 16-2 (as in previous versions) to extend the model to water years 2012-2016. Methods used in version 16-2 were the same as in previous versions (see Attachment A).

Missing Daily Data

In our 2016 update of the model, we discovered that for certain years the daily variability in the hydrograph was muted in an unnatural way for certain years that resulted in more monthly variability than daily variability. We discovered that daily FNF data from DWR are not available during certain periods when monthly data are available Some of these periods contain averaged data and some periods contain zeroes as shown in Table 1.

Table 1: Periods in the model with missing daily data from DWR.

River	Periods Missing DWR Data	Missing Periods with zeros
Stanislaus	WY 1962-1976 (Oct 69-Nov 70 adjusted as of V.16-1)	
Tuolumne	WY 1966-Oct 1967, 11/26/68-12/31/68, Aug 1969	
Merced	WY 1962-Mar 1966	September 1962, August 1964

The monthly volumes in the model during the missing periods matched monthly volumes from DWR, but the daily pattern was clearly not representative of the expected variability and not consistent with the level of daily variability observed in the months with available DWR data. In version 16-1 we adjusted the Stanislaus River hydrograph for water year 1970 (as well as through November 1970) to match the correct monthly volumes, and we applied the daily pattern of the Tuolumne River flow within each month (% of monthly flow each day) to estimate the daily pattern on the Stanislaus. This adjustment added considerable daily variability more consistent with the months that had DWR data, and had significant effects on our floodplain inundation results, resulting in shorter periods of inundation but higher magnitudes. As of version 16-2, we have not yet adjusted the remaining periods where data are missing; we limited our floodplain inundation analysis to water years since 1977, which are unaffected by this problem.

Miscellaneous Inflows and Flood Control Operations

Earlier model versions were designed to apply a percent of unimpaired flow at the rim stations and calculate the effect of those flows at Vernalis. The 2016 SED uses compliance gages at downstream locations on each tributary. We did not update the model to reflect this approach, and any local inflows below the rim stations would result in a higher flow than at the compliance gages than is represented by reservoir releases that we did model. This means the model overestimates the flows that are necessary below the rim dams, since flow inputs below the rim stations would result in higher flows at Vernalis than would result from the percentage of unimpaired flow applied at those gages.

Because the model does not account for flood control operations, the model likely underestimates the volumes and overestimates the peak flow magnitudes resulting from each alternative in wet years —it assumes that the specified flow and nothing more is released from the rim stations. Because reservoir operations and channel capacities have not been incorporated into the model, and because local inflows above the compliance gages aren't incorporated, the modeled flows should be interpreted carefully with all of these assumptions in mind.

The newly added 1,000 cfs minimum flow at Vernalis
Vernalis flow during Feb-Jun was assumed to be 1,000 cfs whenever the modeled flow was lower, and the additional release was added to each tributary in the proportions specified in the 2016 SED:

- 24% from the Merced River
- 47% from the Tuolumne River
- 29% from the Stanislaus River

The 1,000 cfs minimum flow at Vernalis affected 116 days during the 1962-2016 Feb-Jun period. Flow this low occurred in 1977, 1987, 1991, 1992, 2001, 2012, 2014, and 2015, usually at the beginning or end of the Feb-Jun period. It is possible that years prior to 1977 were affected by the minimum flow, however we are unable to determine this with version 16-2 due to the way the FNF input data from DWR were extended to missing years in the original model.

Assumptions & Conclusions

As of version 16-2, the results summaries from previous versions were not updated. The focus of this version was to provide data for the new floodplain inundation analysis, and generate graphical representations of the proposed alternatives in the 2016 SED. See the analytical appendix to TBI et al 2013 for a more complete description of the assumptions.

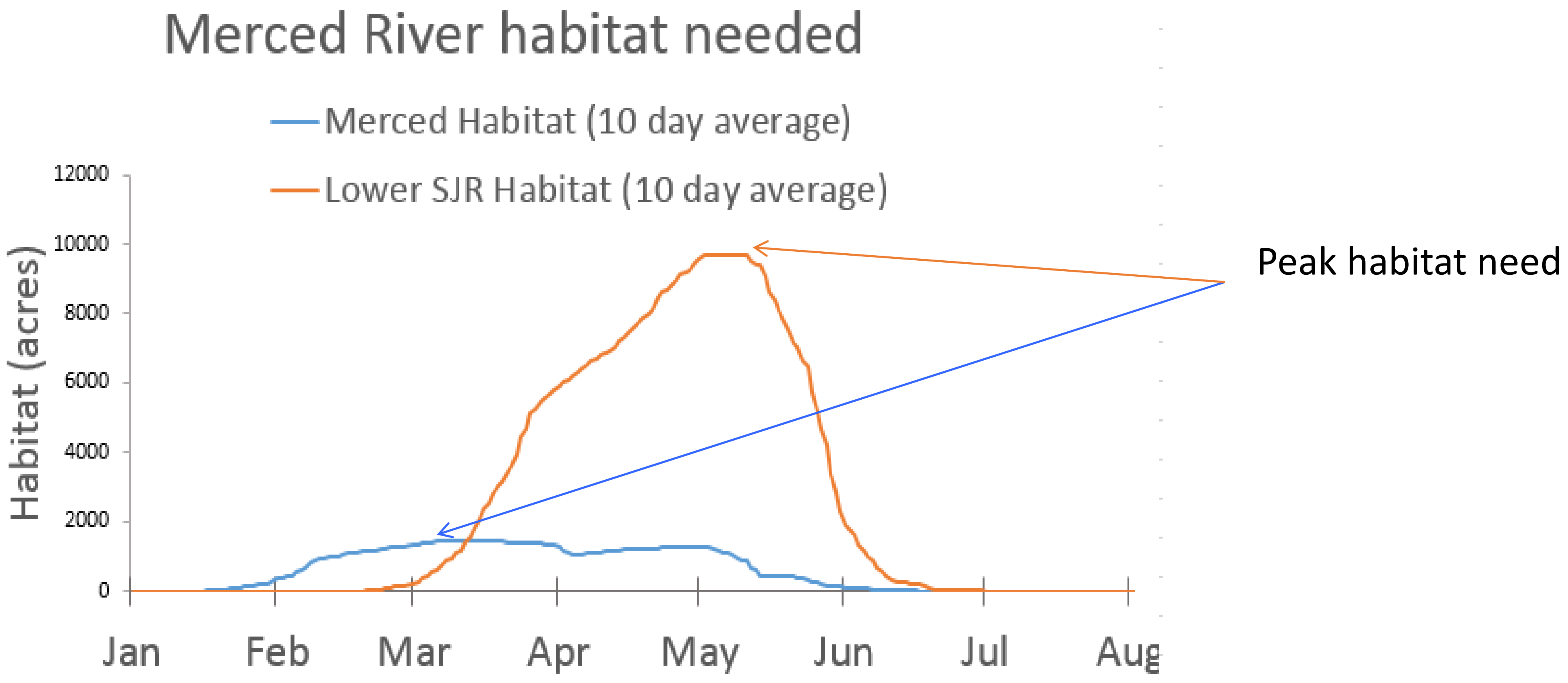

Figure D-1: Habitat acres needed each day of the migration season on the Merced River (blue line) to support target Chinook salmon populations on that tributary and the lower San Joaquin River (orange line) as estimated in the Central Valley Flood Protection Plan (CVFPP; CWR 2016a). Note that total habitat demand (the peak of each line) in the lower San Joaquin River is greater than in the Merced River and occurs later in the migration season. Source data generated by the ESHE model as produced for the Conservation Strategy of the CVFPP, available at: http://www.water.ca.gov/conservationstrategy/docs/app_h.pdf

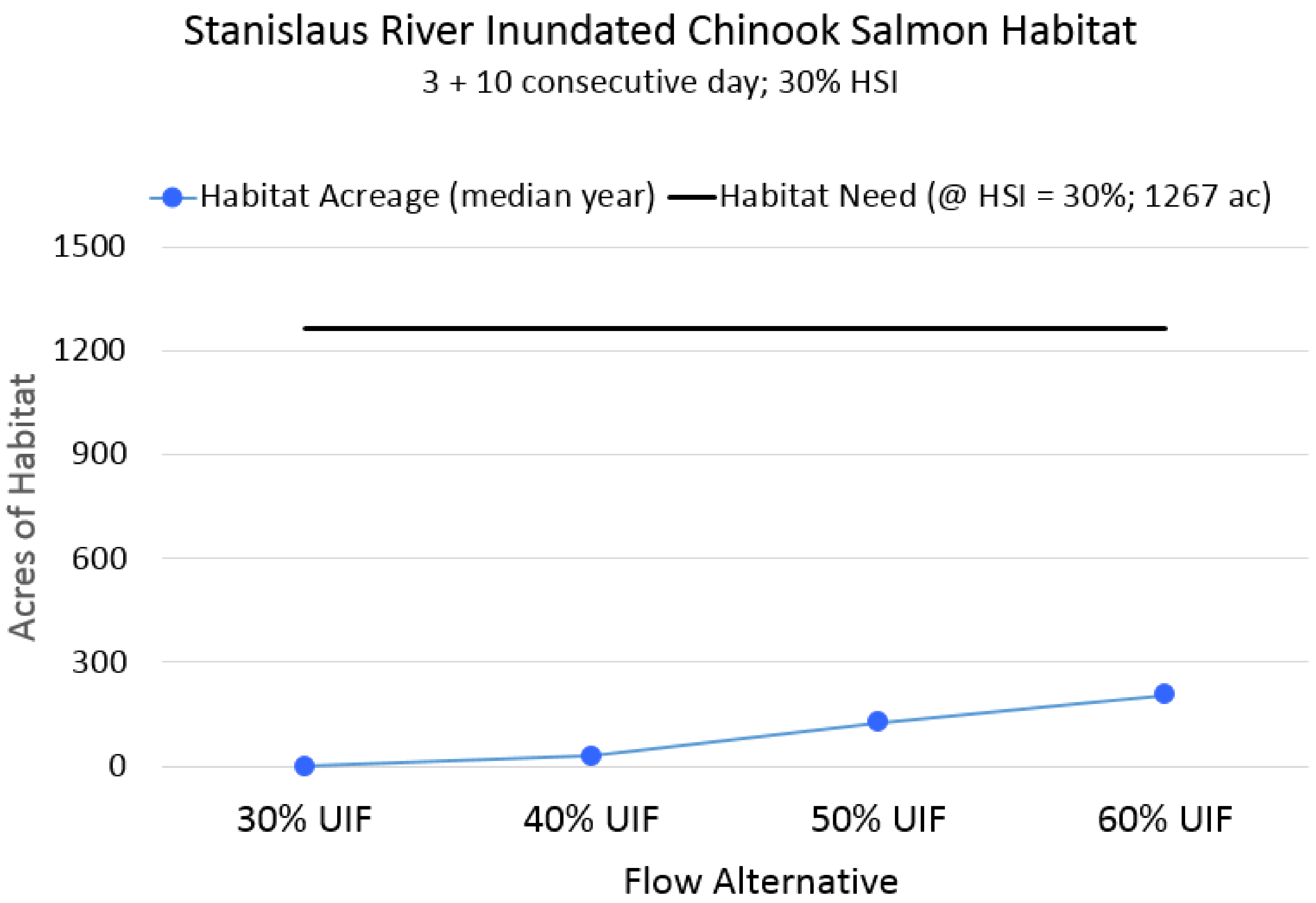

Figure D-2: Performance of different flow levels (expressed as a percentage of unimpaired flow; %UIF) in inundating Chinook salmon rearing habitat in the Stanislaus River (as per assumptions described in the text) compared to total habitat needed to support the narrative salmon protection objective for the Stanislaus River. Total habitat need was calculated by the Central Valley Flood Protection Plan (CVFPP; CDWR 2016a) and expanded to account for an assumed habitat suitability of 30%.

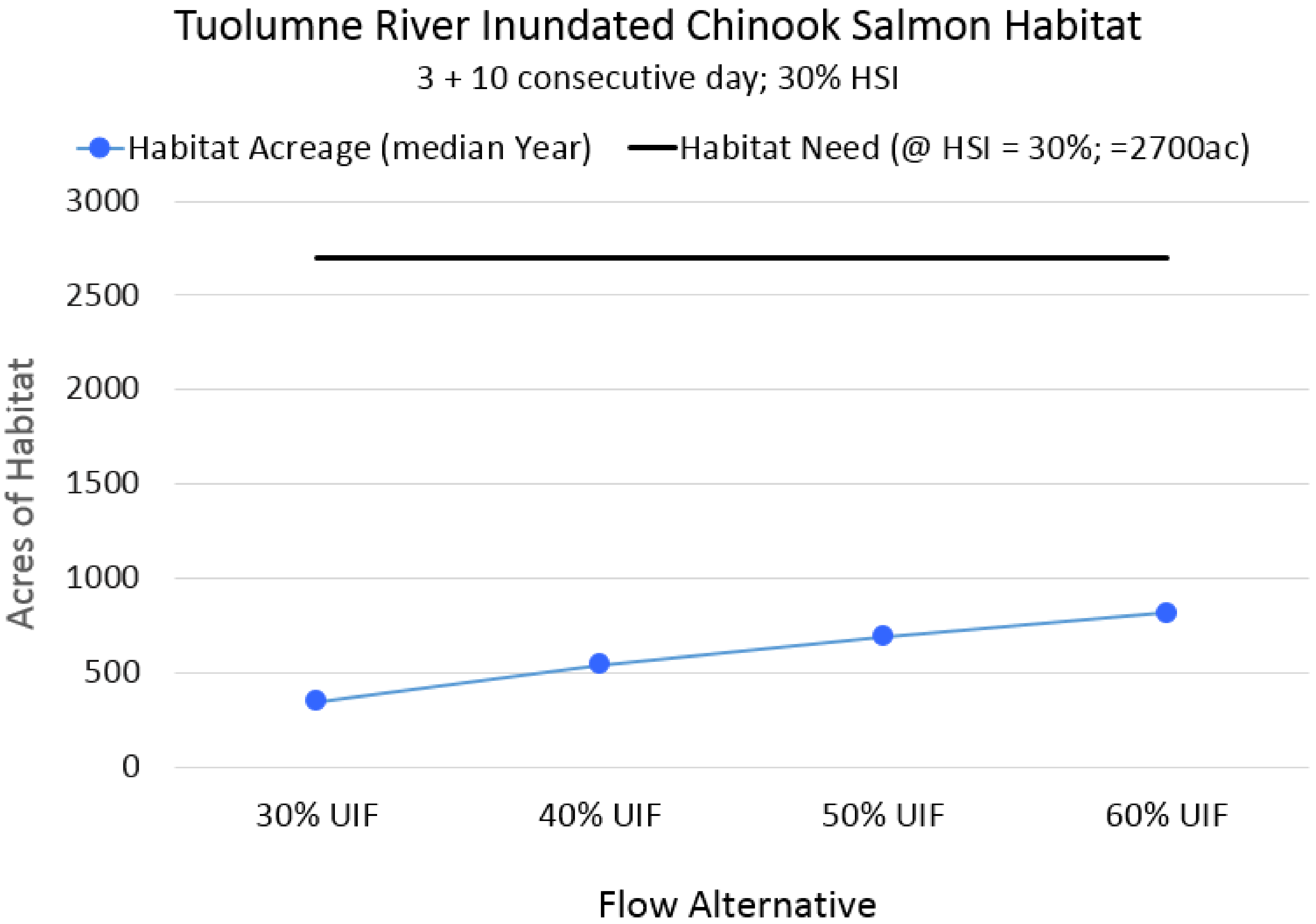

Figure D-3: Performance of different flow levels (expressed as a percentage of unimpaired flow; %UIF) in inundating Chinook salmon rearing habitat in the Stanislaus River (as per assumptions described in the text) compared to total habitat needed to support the narrative salmon protection objective for the Tuolumne River. Total habitat need was calculated by the Central Valley Flood Protection Plan (CVFPP; CDWR 2016a) and expanded to account for an assumed habitat suitability of 30%.

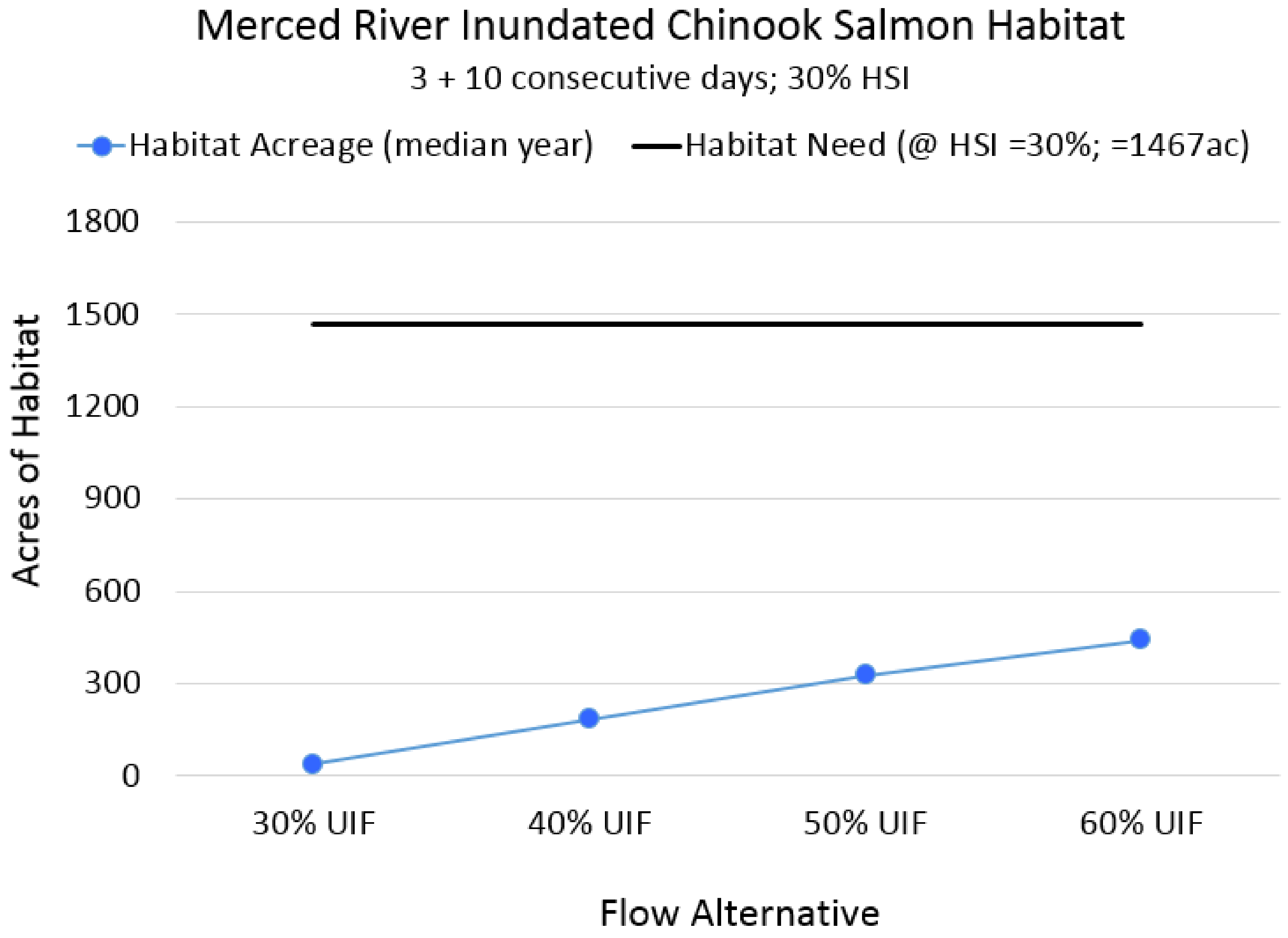

Figure D-4: Performance of different flow levels (expressed as a percentage of unimpaired flow; %UIF) in inundating Chinook salmon rearing habitat in the Stanislaus River (as per assumptions described in the text) compared to total habitat needed to support the narrative salmon protection objective for the Merced River. Total habitat need was calculated by the Central Valley Flood Protection Plan (CVFPP; CDWR 2016a) and expanded to account for an assumed habitat suitability of 30%.

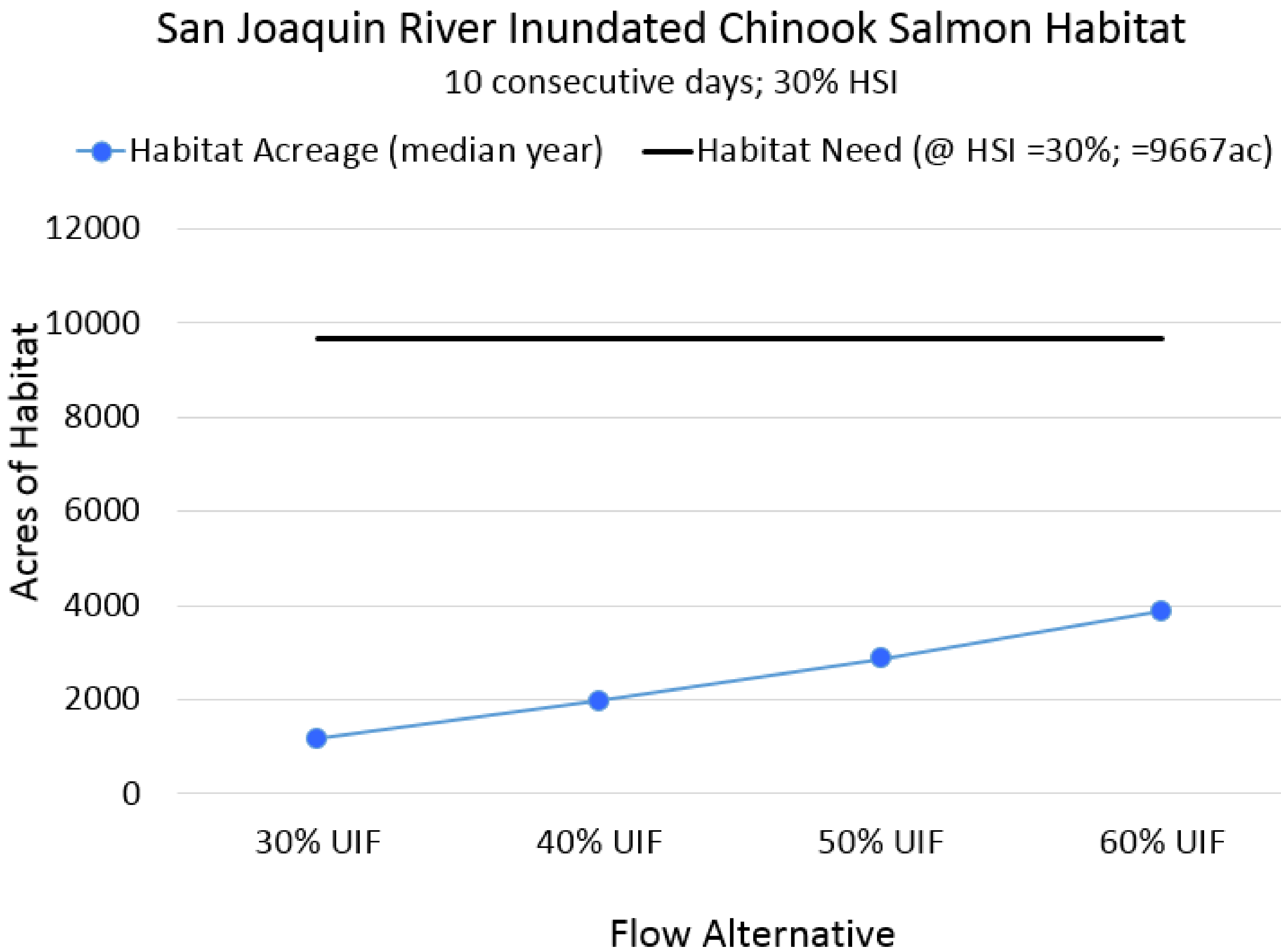

Figure D-5: Performance of different flow levels (expressed as a percentage of unimpaired flow; %UIF) in inundating Chinook salmon rearing habitat in the San Joaquin River (as per assumptions described in the text) compared to total habitat needed to support the narrative salmon protection objective for the lower San Joaquin River. Total habitat need was calculated by the Central Valley Flood Protection Plan (CVFPP; CDWR 2016a) and expanded to account for an assumed habitat suitability of 30%.

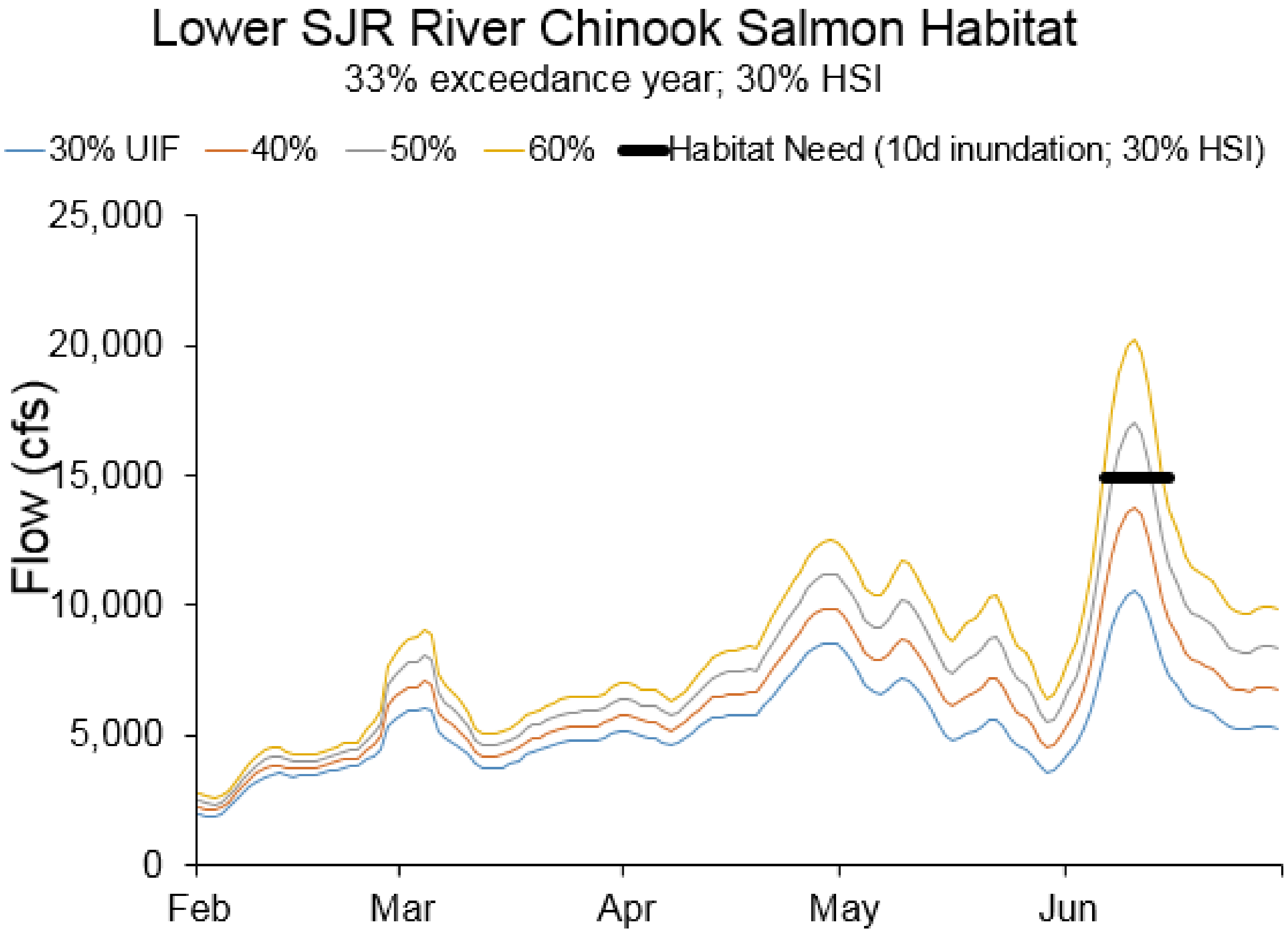

Figure D-6: Flow in the lower San Joaquin River under different hydrographs representing %UIF in 2010 (the 33% exceedence hydrograph; an Above Normal Year) calculated by the TBI Daily Flow Model (TBI 2016) as a 7d running average as compared to flow required to inundate habitat needed to support salmon doubling (horizontal black bar). The flow needed to inundate the target habitat must be sustained for at least 10 days, to achieve estimated habitat quality of 30% HSI; thus the width of the horizontal black bar represents 10 days, centered on the peak of the hydrograph. Habitat needed to support the target population was calculated for the Central Valley Flood Protection Plan (CDWR 2016a) and flow needed to inundate that habitat under current conditions was calculated using flow inundation relationships described in the text.

Table D-1: Inundated habitat acreage necessary to attain target habitat to support narrative salmon protection objective for the Stanislaus River that is not inundated (under current geometry) by different flow alternatives that are expressed as percentages of unimpaired Feb-June flow in the median year for habitat inundation (2010; *see* text).

Alternative	Acreage shortfall (@ 30% HSI)
60%	1,060
50%	1,140
40%	1,237
30%	1,267

Table D-2: Inundated habitat acreage necessary to attain target habitat to support narrative salmon protection objective for the Tuolumne River that is not inundated (under current geometry) by different flow alternatives that are expressed as percentages of unimpaired Feb-June flow in the median year for habitat inundation (2010; *see* text).

Alternative	Acreage shortfall (@ 30% HSI)
60%	1,885
50%	2,008
40%	2,160
30%	2,355

Table D-3: Inundated habitat acreage necessary to attain target habitat to support narrative salmon protection objective for the Merced River that is not inundated (under current geometry) by different flow alternatives that are expressed as percentages of unimpaired Feb-June flow in the median year for habitat inundation (2010; *see* text).

Alternative	Acreage shortfall (@ 30% HSI)
60%	1,024
50%	1,141
40%	1,283
30%	1,467

Table D-4: Inundated habitat acreage necessary to attain target habitat to support the narrative salmon protection objective in the lower San Joaquin River as inundated (under current geometry) by different flow alternatives that are expressed as percentages of unimpaired Feb-June flow in the median year for habitat inundation (2000, panel a) and in an above normal year (33% exceedence, 2010, panel b -- *see* text). Days of inundation indicates the number of consecutive days that the target acreage would inundate under a given percentage of unimpaired flow as a 7-d trailing average. Acreage shortfall without shaping reflects the amount of the target acreage that would not inundate under a 7d-trailing average hydrograph. Volume available for shaping reflects the volume of water above the flow needed to inundate the target acreage that would occur in the 10d inundation window under a 7d trailing average hydrograph. Acreage shortfall with shaping indicates the extent of the target acreage that would not inundate for 10 consecutive days, even if the volume of water available for shaping were applied optimally during the 10 day period.

a – Median inundation (2000)

Alternative	Days of Inundation	Volume needed w/o shaping	Volume available for shaping	Acreage shortfall w/o shaping	Acreage shortfall with shaping
60%	0	87,360	0	5,791	5,791
50%	0	120,501	0	6,800	6,800
40%	0	153,641	0	7,700	7,700
30%	0	186,782	0	8,491	8,491

b – Above normal inundation (2010; 33% exceedence)

Alternative	Days of Inundation	Volume needed w/o shaping	Volume available for shaping	Acreage shortfall w/o shaping	Acreage shortfall with shaping
60%	9	2,574	54,145	986	0
50%	5	17,429	14,144	3,192	194
40%	0	58,965	0	5,123	5,123
30%	0	113,820	0	6,780	6,780

Appendix A
Stanislaus Survival Model

Year	Water Year Index	Oakdale RST Expanded Passage	Caswell RST Expanded Passage	Adult Production	Ocean Harvest	Freshwater Harvest	Totatl Harvest	Grandtab Escapement (geomean=2054)	Weir Escapement (geomean=2008)	Median % females	Median fecundity	Ocean Production : Spawning Escapement (geomean=0.602)	Estimated Egg Deposition	Oakdale to Caswell (geoman=0.16)	Eggs to Oakdale RST (geomean=0.11)	Eggs to Caswell RST (geomean=0.02)	Calculated Caswell to Vernalis (geomean=0.54)	Eggs to Vernalis (geomean=0.01)
1995	Wet			2,241	1,592	31	1,623	619		0.60	5,813	0.276	2.16E+06	.	.	.	.	.
1996	Wet	245,892	70,885	365	189	8	197	168		0.60	5,813	0.460	5.86E+05	0.288	0.114	0.033	0.595	0.020
1997	Wet		98,287	14,424	8,422	279	8,702	5,588		0.60	5,813	0.387	1.95E+07	.	.	0.168	.	.
1998	Wet	954,312	1,152,154	6,145	2,841	154	2,995	3,087		0.60	5,813	0.502	1.08E+07	1.207	0.049	0.059	0.756	0.045
1999	Above	3,889,456	1,457,859	7,577	2,980	217	3,198	4,349		0.60	5,813	0.574	1.52E+07	0.375	0.361	0.135	0.621	0.084
2000	Above	2,818,845	2,060,282	17,671	8,636	425	9,061	8,498		0.60	5,813	0.481	2.96E+07	0.731	0.186	0.136	0.695	0.094
2001	Dry	1,119,203	178,557	9,503	2,120	352	2,471	7,033		0.60	5,813	0.740	2.45E+07	0.160	0.038	0.006	0.540	0.003
2002	Dry	993,796	78,505	11,527	3,351	389	3,741	7,787		0.60	5,813	0.676	2.72E+07	0.079	0.041	0.003	0.481	0.002
2003	Below	1,742,219	119,654	8,753	2,527	295	2,822	5,902	4,848	0.60	5,813	0.674	2.06E+07	0.069	0.064	0.004	0.471	0.002
2004	Dry	2,467,746	327,083	8,623	4,411	201	4,611	4,015	4,408	0.60	5,813	0.466	1.40E+07	0.133	0.120	0.016	0.524	0.008
2005	Wet	1,304,977	266,763	2,532	1,034	71	1,105	1,427	4,121	0.60	5,813	0.564	4.98E+06	0.204	0.093	0.019	0.562	0.011
2006	Wet	4,414,407	156,185	2,671	652	96	748	1,923	3,056	0.60	5,813	0.720	6.71E+06	0.035	0.887	0.031	0.423	0.013
2007	Critical	867,739	69,959	824	377	22	399	443	408	0.60	5,813	0.538	1.55E+06	0.081	0.129	0.010	0.483	0.005
2008	Critical	134,216	17,833	865				865	923	0.60	5,813	1.000	3.02E+06	0.133	0.087	0.012	0.524	0.006
2009	Below	160,541	8,704	595				595	1,303	0.60	5,813	1.000	2.08E+06	0.054	0.053	0.003	0.453	0.001
2010	Above		26,242	1,222	249		249	1,086	1,363	0.60	5,813	0.889	3.79E+06	.	.	0.013	.	.
2011	Wet		31,113	1,669				1,309	818	0.60	5,813	0.784	4.57E+06	.	.	0.008	.	.
2012	Dry		105,821	6,665				4,006	7,248	0.60	5,813	0.601	1.40E+07	.	.	0.023	.	.
2013				4,238				2,845		0.60	5,813	0.671	9.92E+06	.	.	.	.	.
2014																		
2015																		
2016																		
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Appendix A
Stanislaus Survival Model

Table 1. Calculated recruits per spawner based on consensus estimates

Reach	DOI (2011)	NMFS (2012)	Consensus Estimate	RM	Survival/RM
Eggs to Caswell	6.64%	5.64%	1.87%	46.5	91.79%
Eggs to Oakdale	-	-	10.62%	14.4	85.58%
Oakdale to Caswell	-	-	16.02%	32.1	94.46%
Caswell to Vernalis [1]	-	-	54.09%	10.5	94.32%
Vernalis to Chipps Island	5.00%	3.75%	3.75%	54.5	94.15%
Chipps Island to Adult	-	-	2.83%	-	-
Adult to Spawner	50.00%	70.00%	60.24%	-	-
Recruits per Spawner			**0.02**		

[1] *Based on average between Oakdale to Caswell and Vernalis to Chipps estimates, adjusted by river miles*

Table 2. Calculated survival required to achieve Objective A (1.26 recruits per spawner) [2]

Reach	Current	RM	Increase	Target Survival	Target Survival/RM
Eggs to Vernalis	1.01%	57.0	7.48	7.55%	95.57%
Vernalis to Chipps Island	3.75%	54.5	7.48	28.06%	97.69%
Chipps Island to Adult	2.83%	-	-	2.83%	-
Adult to Spawner	60.24%	-	-	60.24%	-
Recruits per Spawner				**1.26**	

[2] *Population growth rate of two-fold over three generations*

Table 3. Calculated survival required to achieve Objective B (2.5 recruits per spawner) [3]

Reach	Current	RM	Increase	Target Survival	Target Survival/RM
Eggs to Vernalis	1.01%	57.0	10.54	10.64%	96.15%
Vernalis to Chipps Island	3.75%	54.5	10.54	39.52%	98.31%
Chipps Island to Adult	2.83%	-	-	2.83%	-
Adult to Spawner	60.24%	-	-	60.24%	-
Recruits per Spawner				**2.50**	

[3] *Population resilience*

Table 4. Calculated survival required to achieve Objective C (10% freshwater survival) [4]

Reach	Current	RM	Increase	Target Survival	Target Survival/RM
Eggs to Vernalis	1.01%	57.0	19.81	20.00%	97.22%
Vernalis to Chipps Island [5]	3.75%	54.5	13.33	50.00%	98.74%
Chipps Island to Adult	2.83%	-	-	2.83%	-
Adult to Spawner	60.24%	-	-	60.24%	-
Recruits per Spawner				**5.95**	

[4] *Based on published values*

[5] *Capped at 50%*

Table 5. Reach-specific calculations for pre-marine entry survival

Current [6]	Proportional Survival Upstream vs. Downstream of Oakdale	Reach	River miles	Objective A	Objective B	Objective C
10.62%	0.66	Eggs to Oakdale	14.4	26.8%	30.8%	40.5%
16.02%		Oakdale to Caswell	32.1	40.4%	46.4%	61.2%
1.87%		Eggs to Caswell	46.5	10.8%	14.3%	24.8%
54.09%		Caswell to Vernalis [7]	10.5	69.8%	74.4%	80.7%
3.75%		Vernalis to Chipps Island	54.5	28.1%	39.5%	50.0%
0.04%		**Freshwater Survival**		**2.12%**	**4.20%**	**10.00%**

[6] *Estimated survival rates from Egg-to-Oakdale and Oakdale-to-Caswell were calculated annually only for those years in which sampling data are available from Oakdale RST. The product of Egg-to-Oakdale and Oakdale-to-Caswell values do not equal the current Egg-to-Caswell survival estimate because time series differ for Oakdale and Caswell data sets. Thus, only the proportional survival from "Eggs-to-Oakdale" and "Oakdale-to-Caswell" was used to estimate survival guidance for the reach above Oakdale. The Egg-Oakdale survival guidance target represents the proportional survival above and below Oakdale applied to the respective "Eggs-to-Caswell" survival objective listed here.*

[7] *Based on average of per RM survival rates for (1) Eggs to Vernalis and (2) Vernalis to Chipps Island as derived from "current" and each objective, respectively.*

Table 6. Actual survival objectives as they appear in the text. Egg-to-Oakdale survival is guidance for attaining Egg-to-Caswell Objective. This guidance target is less than implied by proportionate increase in survival before and after Oakdale, though it may be exceeded in practice.

Reach	River miles	Current	Objective A	Objective B	Objective C
Eggs to Oakdale	14.40	10.62%	25.00%	30.00%	35.00%
Oakdale to Caswell [8]	32.10	16.02%	xx	yy	zz
Eggs to Caswell	46.50	1.87%	10.24%	13.52%	24.79%
Caswell to Vernalis	10.50	54.09%	69.81%	74.47%	80.68%
Vernalis to Chipps Island	54.50	3.75%	29.64%	41.75%	50.00%
Freshwater Survival		0.038%	2.12%	4.20%	10.00%

[8] xx, yy, zz represent the survival needed to achieve overall egg-to-caswell survival objectives (e.g., "Oakdale to Caswell %" = "Egg to Caswell %" / actual "Egg to Oakdale %")

Table 6. Estimated recruits per spawner based on interactive values

Reach	Value	Units	RM	S/RM
Proportion of females	60.00	%	-	-
Fecundity	5,813	n	-	-
Eggs to Oakdale	10.62	%	14.4	85.58%
Oakdale to Caswell	16.02	%	32.1	94.45%
Caswell to Vernalis	54.09	%	10.5	94.32%
Vernalis to Chipps Island	3.75	%	54.5	94.15%
Chipps Island to Adult	2.83	%	-	-
Adult to Spawner	60.24	%	-	-
Recruits per Spawner	0.02			

<u>**Notes**</u>

Objective A: Population growth rate of two-fold over three generations (recruits per spawner of 1.26)

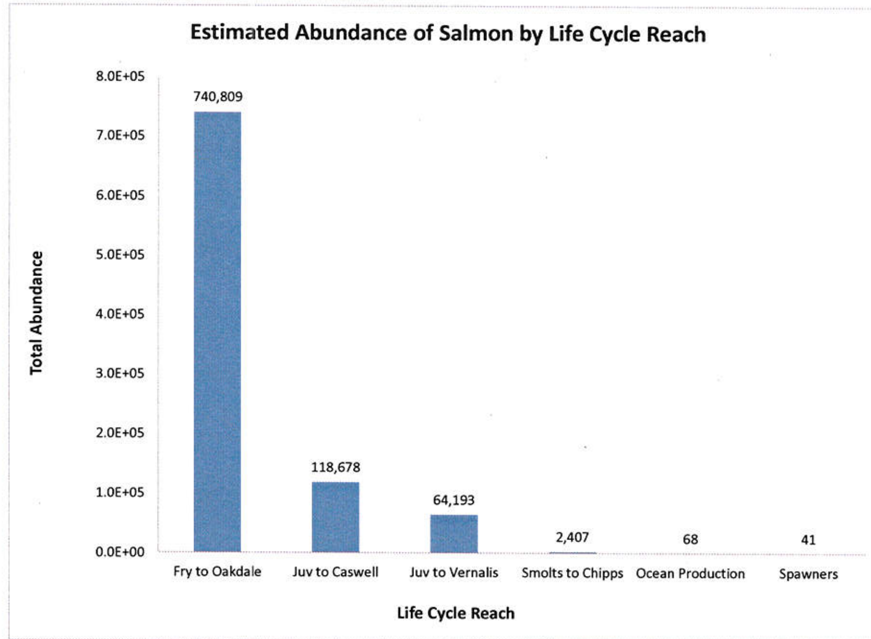
Objective B: Population resilience (recruits per spawner of 2.5)

Objective C: Sustainability (typical survival rate for Chinook salmon in freshwater = 10%) (recruits per spawner of 5.95)

Table 7. Reference performance measures based on objectives

		Objective		
Reach	Current	A	B	C
Eggs to Caswell	1.87%	10.8%	14.3%	24.8%
Eggs to Oakdale	10.62%	25.0%	30.0%	35.0%
Oakdale to Caswell	16.02%	xx	yy	zz
Caswell to Vernalis	54.09%	69.8%	74.4%	80.7%
Vernalis to Chipps Island	3.75%	28.1%	39.5%	50.0%
Chipps Island to Adult	2.83%	2.8%	2.8%	2.8%
Adult to Spawner	60.24%	60.2%	60.2%	60.2%
Recruits per Spawner	2.25	1.26	2.50	5.95

# Spawners	2,000



Appendix A
Stanislaus Survival Model

Stanislaus River Escapement data from Domenic Guidice via Stephen Louie (CDFW)

Year	% females	Eggs per female
1995	47%	5,190
1996	44%	4,545
1997	55%	5,372
1998	na	na
1999	50%	5,343
2000	63%	5,939
2001	61%	6,405
2002	60%	5,929
2003	59%	5,936
2004	60%	5,540
2005	68%	5,796
2006	71%	6,090
2007	38%	6,027
2008	62%	5,870
2009	45%	5,662
2010	45%	5,729
2011	52%	4,962
2012	65%	5,830
2013	63%	6,117
Max	71%	6,405
Average	56%	5,682
Median	60%	5,813
Min	38%	4,545

"An estimate for the number of eggs produced by the 2005 fall run was generated using a standard regression equation (158.45 * fork length cm – 6138.91 = number of eggs). This fork length-fecundity relationship was determined for 48 San Joaquin fall-run chinook salmon females ranging from 62.5 to 94.0 cm fork length (Loudermilk et al. 1990)."

Month	Year	40%, 265 MGD Total System Storage (AF)	50%, 265 MGD Total System Storage (AF)
July	1920	1,418,412	1,418,412
August	1920	1,376,340	1,376,340
September	1920	1,336,688	1,336,688
October	1920	1,306,683	1,306,683
November	1920	1,285,188	1,285,188
December	1920	1,283,915	1,283,915
January	1921	1,304,875	1,304,875
February	1921	1,295,224	1,287,159
March	1921	1,262,156	1,262,156
April	1921	1,287,396	1,287,396
May	1921	1,388,691	1,365,871
June	1921	1,483,540	1,453,165
July	1921	1,442,008	1,419,790
August	1921	1,393,089	1,378,451
September	1921	1,337,069	1,337,069
October	1921	1,301,475	1,301,475
November	1921	1,275,413	1,275,413
December	1921	1,268,958	1,268,958
January	1922	1,269,097	1,269,100
February	1922	1,238,399	1,238,399
March	1922	1,141,913	1,141,913
April	1922	1,136,314	1,124,814
May	1922	1,427,764	1,408,316
June	1922	1,580,938	1,458,362
July	1922	1,556,174	1,445,825
August	1922	1,445,432	1,404,532
September	1922	1,353,579	1,351,939
October	1922	1,317,176	1,317,176
November	1922	1,296,480	1,296,464
December	1922	1,322,320	1,322,320
January	1923	1,323,945	1,323,945
February	1923	1,314,225	1,305,904
March	1923	1,226,466	1,226,466
April	1923	1,234,504	1,234,504
May	1923	1,398,422	1,371,534
June	1923	1,439,403	1,396,163
July	1923	1,444,641	1,403,489
August	1923	1,402,589	1,362,286
September	1923	1,352,090	1,326,136
October	1923	1,322,745	1,296,841
November	1923	1,300,964	1,275,072
December	1923	1,281,357	1,255,465
January	1924	1,261,951	1,236,049
February	1924	1,243,889	1,215,990
March	1924	1,221,593	1,193,415

April	1924	1,187,335	1,151,995
May	1924	1,143,011	1,096,989
June	1924	1,105,173	1,058,452
July	1924	1,078,162	1,041,552
August	1924	1,051,586	1,024,749
September	1924	1,028,469	1,010,500
October	1924	1,010,206	999,767
November	1924	1,000,961	996,536
December	1924	993,312	994,404
January	1925	983,955	990,752
February	1925	1,061,318	1,061,204
March	1925	1,049,773	1,046,424
April	1925	1,159,080	1,140,603
May	1925	1,353,412	1,314,335
June	1925	1,427,655	1,379,286
July	1925	1,402,835	1,354,483
August	1925	1,360,221	1,311,738
September	1925	1,322,806	1,274,186
October	1925	1,292,474	1,243,762
November	1925	1,270,025	1,221,293
December	1925	1,249,906	1,201,171
January	1926	1,232,683	1,183,948
February	1926	1,247,468	1,193,507
March	1926	1,214,090	1,153,419
April	1926	1,322,500	1,241,805
May	1926	1,327,129	1,230,903
June	1926	1,275,870	1,175,458
July	1926	1,234,149	1,157,617
August	1926	1,192,906	1,139,658
September	1926	1,156,567	1,124,467
October	1926	1,127,314	1,113,096
November	1926	1,148,513	1,138,594
December	1926	1,133,597	1,131,742
January	1927	1,122,446	1,129,658
February	1927	1,191,906	1,191,480
March	1927	1,125,750	1,126,182
April	1927	1,159,733	1,154,974
May	1927	1,272,835	1,261,896
June	1927	1,436,055	1,420,787
July	1927	1,423,819	1,408,409
August	1927	1,380,551	1,364,833
September	1927	1,342,606	1,326,653
October	1927	1,314,282	1,298,118
November	1927	1,299,323	1,283,129
December	1927	1,285,602	1,269,408
January	1928	1,268,613	1,252,425
February	1928	1,261,085	1,240,653

March	1928	1,296,670	1,286,387
April	1928	1,292,767	1,283,263
May	1928	1,384,023	1,350,857
June	1928	1,329,012	1,287,669
July	1928	1,286,182	1,244,044
August	1928	1,243,974	1,199,576
September	1928	1,206,936	1,159,971
October	1928	1,176,974	1,127,173
November	1928	1,155,149	1,104,882
December	1928	1,140,708	1,090,453
January	1929	1,124,962	1,074,871
February	1929	1,109,695	1,057,575
March	1929	1,081,583	1,024,193
April	1929	1,042,296	976,701
May	1929	1,078,886	962,606
June	1929	1,075,401	949,890
July	1929	1,045,440	934,969
August	1929	1,022,590	920,401
September	1929	1,001,361	907,923
October	1929	984,276	898,292
November	1929	971,612	891,615
December	1929	960,173	885,693
January	1930	954,426	885,652
February	1930	941,128	874,029
March	1930	949,313	875,118
April	1930	958,846	875,982
May	1930	960,022	870,714
June	1930	987,671	892,406
July	1930	962,833	877,438
August	1930	938,635	862,843
September	1930	917,385	850,339
October	1930	900,342	840,741
November	1930	887,712	830,519
December	1930	876,350	823,143
January	1931	867,201	817,631
February	1931	852,509	804,623
March	1931	831,637	786,040
April	1931	794,883	745,384
May	1931	754,714	700,933
June	1931	724,619	676,459
July	1931	704,999	661,869
August	1931	685,920	647,675
September	1931	669,278	635,472
October	1931	656,012	625,965
November	1931	646,377	619,317
December	1931	704,117	671,417
January	1932	709,329	676,576

February	1932	794,804	749,593
March	1932	783,978	732,212
April	1932	828,719	763,737
May	1932	1,012,389	920,431
June	1932	1,239,780	1,102,474
July	1932	1,260,768	1,142,333
August	1932	1,222,220	1,127,747
September	1932	1,187,886	1,115,241
October	1932	1,159,545	1,105,665
November	1932	1,137,653	1,099,032
December	1932	1,117,604	1,092,819
January	1933	1,102,585	1,089,160
February	1933	1,085,436	1,084,026
March	1933	1,058,064	1,067,585
April	1933	1,029,967	1,044,628
May	1933	1,029,602	1,050,498
June	1933	1,149,109	1,170,023
July	1933	1,124,314	1,155,096
August	1933	1,100,160	1,140,542
September	1933	1,078,951	1,128,084
October	1933	1,061,869	1,118,455
November	1933	1,049,214	1,111,785
December	1933	1,047,758	1,115,049
January	1934	1,053,784	1,122,166
February	1934	1,044,994	1,110,139
March	1934	1,021,517	1,084,692
April	1934	990,809	1,048,784
May	1934	948,377	1,006,454
June	1934	912,257	974,287
July	1934	887,449	959,352
August	1934	863,312	944,800
September	1934	842,107	932,336
October	1934	825,053	922,731
November	1934	812,616	916,281
December	1934	803,467	912,650
January	1935	820,286	931,935
February	1935	802,011	912,228
March	1935	786,457	892,923
April	1935	993,287	1,074,107
May	1935	1,180,347	1,235,982
June	1935	1,386,272	1,420,734
July	1935	1,356,211	1,385,272
August	1935	1,319,216	1,341,728
September	1935	1,286,302	1,303,430
October	1935	1,259,297	1,272,736
November	1935	1,238,696	1,251,175
December	1935	1,220,361	1,232,908

January	1936	1,229,051	1,241,982
February	1936	1,264,193	1,273,062
March	1936	1,214,311	1,223,179
April	1936	1,305,101	1,312,700
May	1936	1,462,085	1,450,960
June	1936	1,457,072	1,457,072
July	1936	1,419,928	1,431,294
August	1936	1,381,390	1,386,929
September	1936	1,341,174	1,341,174
October	1936	1,306,809	1,306,809
November	1936	1,283,386	1,283,386
December	1936	1,265,890	1,265,955
January	1937	1,247,868	1,248,356
February	1937	1,258,820	1,258,820
March	1937	1,182,486	1,182,486
April	1937	1,194,400	1,194,400
May	1937	1,450,938	1,419,661
June	1937	1,456,983	1,456,983
July	1937	1,414,455	1,417,424
August	1937	1,355,514	1,371,294
September	1937	1,323,964	1,329,890
October	1937	1,295,601	1,296,243
November	1937	1,273,787	1,273,212
December	1937	1,364,108	1,363,791
January	1938	1,367,031	1,366,719
February	1938	1,353,774	1,353,462
March	1938	1,298,887	1,298,575
April	1938	1,340,994	1,340,682
May	1938	1,462,251	1,462,251
June	1938	1,456,702	1,456,702
July	1938	1,445,060	1,445,060
August	1938	1,402,980	1,402,854
September	1938	1,365,969	1,365,745
October	1938	1,336,165	1,335,881
November	1938	1,314,422	1,314,124
December	1938	1,297,408	1,297,111
January	1939	1,279,562	1,279,272
February	1939	1,262,267	1,258,876
March	1939	1,258,395	1,247,550
April	1939	1,285,413	1,259,978
May	1939	1,233,045	1,196,473
June	1939	1,183,606	1,143,268
July	1939	1,141,477	1,101,145
August	1939	1,100,297	1,059,881
September	1939	1,064,031	1,023,589
October	1939	1,034,441	993,987
November	1939	1,012,179	971,723

December	1939	992,101	951,644
January	1940	1,098,837	1,058,375
February	1940	1,193,718	1,140,326
March	1940	1,217,339	1,216,593
April	1940	1,259,040	1,258,407
May	1940	1,462,045	1,432,938
June	1940	1,456,802	1,456,802
July	1940	1,413,561	1,412,929
August	1940	1,371,093	1,369,553
September	1940	1,333,338	1,331,475
October	1940	1,299,299	1,299,299
November	1940	1,277,022	1,276,887
December	1940	1,293,611	1,293,611
January	1941	1,264,203	1,264,203
February	1941	1,256,623	1,256,623
March	1941	1,195,516	1,195,516
April	1941	1,175,875	1,175,875
May	1941	1,454,751	1,423,703
June	1941	1,451,780	1,451,780
July	1941	1,440,927	1,440,239
August	1941	1,399,672	1,397,669
September	1941	1,353,444	1,351,413
October	1941	1,321,300	1,318,588
November	1941	1,301,800	1,298,339
December	1941	1,349,660	1,346,353
January	1942	1,392,514	1,388,060
February	1942	1,393,527	1,389,394
March	1942	1,306,040	1,301,720
April	1942	1,342,093	1,326,801
May	1942	1,483,283	1,432,042
June	1942	1,569,217	1,452,035
July	1942	1,572,068	1,440,371
August	1942	1,455,697	1,398,172
September	1942	1,357,397	1,349,372
October	1942	1,318,737	1,315,040
November	1942	1,324,871	1,320,510
December	1942	1,326,884	1,321,835
January	1943	1,371,153	1,367,639
February	1943	1,371,050	1,358,627
March	1943	1,335,138	1,331,236
April	1943	1,430,508	1,414,439
May	1943	1,520,388	1,462,349
June	1943	1,531,352	1,457,953
July	1943	1,480,026	1,438,726
August	1943	1,404,489	1,397,328
September	1943	1,352,491	1,353,194
October	1943	1,320,833	1,321,534

November	1943	1,299,469	1,300,146
December	1943	1,280,775	1,281,453
January	1944	1,263,086	1,263,778
February	1944	1,260,271	1,256,833
March	1944	1,214,890	1,215,595
April	1944	1,179,947	1,180,111
May	1944	1,284,344	1,260,866
June	1944	1,276,574	1,239,285
July	1944	1,243,669	1,206,370
August	1944	1,203,330	1,165,953
September	1944	1,167,770	1,130,309
October	1944	1,138,868	1,101,341
November	1944	1,135,915	1,098,380
December	1944	1,123,972	1,086,437
January	1945	1,107,979	1,070,450
February	1945	1,233,837	1,196,260
March	1945	1,154,678	1,134,026
April	1945	1,198,656	1,166,964
May	1945	1,314,087	1,258,802
June	1945	1,456,516	1,386,661
July	1945	1,445,349	1,396,931
August	1945	1,403,853	1,355,083
September	1945	1,351,726	1,318,362
October	1945	1,337,298	1,321,608
November	1945	1,317,347	1,301,598
December	1945	1,370,029	1,360,654
January	1946	1,375,964	1,366,586
February	1946	1,357,846	1,345,347
March	1946	1,294,049	1,284,667
April	1946	1,377,677	1,357,756
May	1946	1,459,158	1,459,158
June	1946	1,453,900	1,442,771
July	1946	1,411,622	1,399,907
August	1946	1,370,286	1,357,777
September	1946	1,334,005	1,320,831
October	1946	1,304,776	1,291,148
November	1946	1,303,185	1,289,453
December	1946	1,288,573	1,274,848
January	1947	1,271,228	1,257,548
February	1947	1,257,167	1,239,356
March	1947	1,222,926	1,206,125
April	1947	1,196,591	1,169,698
May	1947	1,223,859	1,178,323
June	1947	1,166,997	1,115,265
July	1947	1,125,945	1,072,778
August	1947	1,085,826	1,027,330
September	1947	1,050,416	1,020,996

October	1947	1,022,985	994,670
November	1947	1,001,571	973,536
December	1947	982,725	954,668
January	1948	966,967	939,502
February	1948	948,642	919,797
March	1948	922,060	889,631
April	1948	910,398	866,374
May	1948	1,000,737	932,794
June	1948	1,125,376	1,034,321
July	1948	1,108,909	1,025,841
August	1948	1,082,419	1,011,329
September	1948	1,059,350	998,895
October	1948	1,041,076	989,296
November	1948	1,028,113	982,648
December	1948	1,017,450	977,457
January	1949	1,007,003	972,505
February	1949	995,916	963,865
March	1949	1,009,708	965,714
April	1949	1,078,061	1,019,164
May	1949	1,172,471	1,095,992
June	1949	1,170,717	1,090,497
July	1949	1,127,911	1,034,727
August	1949	1,084,954	996,204
September	1949	1,046,559	961,908
October	1949	1,015,106	933,516
November	1949	992,448	911,583
December	1949	972,791	891,879
January	1950	975,110	893,945
February	1950	976,066	888,419
March	1950	948,579	854,386
April	1950	1,023,864	912,672
May	1950	1,155,778	1,018,896
June	1950	1,188,682	1,036,443
July	1950	1,144,476	1,017,418
August	1950	1,117,581	1,002,887
September	1950	1,084,009	990,439
October	1950	1,059,524	984,010
November	1950	1,374,403	1,384,625
December	1950	1,396,873	1,398,167
January	1951	1,397,581	1,398,583
February	1951	1,390,056	1,385,367
March	1951	1,316,406	1,320,335
April	1951	1,356,487	1,361,204
May	1951	1,434,443	1,437,667
June	1951	1,418,905	1,429,938
July	1951	1,376,504	1,386,828
August	1951	1,334,880	1,344,514

September	1951	1,298,320	1,307,299
October	1951	1,268,814	1,277,116
November	1951	1,247,345	1,254,982
December	1951	1,282,598	1,289,295
January	1952	1,195,326	1,203,114
February	1952	1,113,047	1,119,824
March	1952	1,045,969	1,052,062
April	1952	1,139,759	1,145,531
May	1952	1,456,038	1,459,458
June	1952	1,463,245	1,456,627
July	1952	1,490,895	1,445,680
August	1952	1,422,657	1,405,424
September	1952	1,371,650	1,369,238
October	1952	1,338,126	1,337,742
November	1952	1,315,518	1,315,134
December	1952	1,316,618	1,316,236
January	1953	1,349,260	1,348,878
February	1953	1,332,078	1,328,440
March	1953	1,257,113	1,256,731
April	1953	1,295,608	1,295,361
May	1953	1,283,584	1,270,051
June	1953	1,392,385	1,357,479
July	1953	1,402,866	1,368,035
August	1953	1,361,703	1,326,916
September	1953	1,325,542	1,290,775
October	1953	1,296,318	1,261,557
November	1953	1,275,469	1,240,711
December	1953	1,256,472	1,221,715
January	1954	1,249,373	1,214,611
February	1954	1,240,372	1,200,324
March	1954	1,241,073	1,213,602
April	1954	1,311,909	1,276,730
May	1954	1,408,875	1,350,567
June	1954	1,362,802	1,295,036
July	1954	1,320,803	1,253,125
August	1954	1,279,746	1,212,055
September	1954	1,243,650	1,175,901
October	1954	1,214,404	1,146,588
November	1954	1,192,969	1,125,139
December	1954	1,182,182	1,114,353
January	1955	1,178,132	1,110,305
February	1955	1,158,252	1,087,268
March	1955	1,127,573	1,052,296
April	1955	1,093,094	1,010,370
May	1955	1,135,509	1,033,861
June	1955	1,157,060	1,040,584
July	1955	1,130,266	1,023,902

August	1955	1,103,840	1,006,616
September	1955	1,080,829	991,588
October	1955	1,062,586	980,027
November	1955	1,049,676	972,992
December	1955	1,399,202	1,401,044
January	1956	1,370,366	1,372,208
February	1956	1,285,076	1,286,881
March	1956	1,226,947	1,226,947
April	1956	1,267,949	1,256,530
May	1956	1,462,756	1,440,673
June	1956	1,555,800	1,461,173
July	1956	1,555,375	1,449,499
August	1956	1,456,595	1,407,477
September	1956	1,371,263	1,370,528
October	1956	1,338,114	1,340,688
November	1956	1,316,032	1,318,568
December	1956	1,296,332	1,298,867
January	1957	1,278,091	1,280,643
February	1957	1,291,002	1,286,804
March	1957	1,253,513	1,255,557
April	1957	1,237,707	1,239,511
May	1957	1,310,805	1,292,845
June	1957	1,411,100	1,372,102
July	1957	1,372,846	1,333,681
August	1957	1,331,750	1,292,318
September	1957	1,295,655	1,255,993
October	1957	1,266,400	1,226,579
November	1957	1,244,934	1,205,072
December	1957	1,232,764	1,192,904
January	1958	1,226,550	1,186,705
February	1958	1,265,195	1,215,919
March	1958	1,203,230	1,184,885
April	1958	1,214,904	1,197,903
May	1958	1,509,311	1,461,628
June	1958	1,588,309	1,452,779
July	1958	1,571,956	1,441,933
August	1958	1,470,854	1,400,616
September	1958	1,374,330	1,364,306
October	1958	1,335,433	1,335,051
November	1958	1,311,664	1,311,664
December	1958	1,290,576	1,290,576
January	1959	1,295,381	1,295,381
February	1959	1,313,421	1,313,421
March	1959	1,281,673	1,273,309
April	1959	1,270,364	1,250,265
May	1959	1,235,891	1,203,681
June	1959	1,177,464	1,137,981

July	1959	1,136,442	1,096,766
August	1959	1,096,440	1,056,421
September	1959	1,076,669	1,036,449
October	1959	1,047,948	1,007,561
November	1959	1,026,400	985,971
December	1959	1,007,070	966,643
January	1960	989,576	949,172
February	1960	1,003,034	956,480
March	1960	987,313	933,043
April	1960	985,676	919,081
May	1960	979,934	897,700
June	1960	937,776	847,583
July	1960	912,357	832,670
August	1960	887,430	818,947
September	1960	865,542	806,554
October	1960	848,051	797,000
November	1960	835,757	790,823
December	1960	825,994	786,571
January	1961	815,915	782,069
February	1961	801,164	770,197
March	1961	781,103	752,297
April	1961	759,405	726,237
May	1961	714,295	677,108
June	1961	669,214	634,623
July	1961	649,764	620,214
August	1961	630,853	606,204
September	1961	614,286	594,127
October	1961	601,059	584,690
November	1961	591,441	578,065
December	1961	583,041	572,406
January	1962	574,907	567,088
February	1962	684,580	658,461
March	1962	681,298	648,404
April	1962	833,546	780,606
May	1962	911,595	843,138
June	1962	1,062,991	977,027
July	1962	1,053,043	978,614
August	1962	1,026,827	964,065
September	1962	1,003,862	951,600
October	1962	985,864	942,201
November	1962	973,032	935,671
December	1962	964,843	932,538
January	1963	1,047,827	1,007,110
February	1963	1,187,624	1,130,774
March	1963	1,187,600	1,124,597
April	1963	1,217,405	1,149,001
May	1963	1,411,355	1,314,997

June	1963	1,451,124	1,459,070
July	1963	1,439,483	1,449,006
August	1963	1,396,569	1,405,609
September	1963	1,346,576	1,358,906
October	1963	1,313,850	1,327,518
November	1963	1,318,917	1,333,679
December	1963	1,300,082	1,316,108
January	1964	1,291,641	1,308,930
February	1964	1,271,985	1,287,780
March	1964	1,244,728	1,257,853
April	1964	1,211,871	1,216,762
May	1964	1,224,271	1,213,242
June	1964	1,185,547	1,163,627
July	1964	1,157,693	1,144,490
August	1964	1,129,738	1,124,467
September	1964	1,105,318	1,108,035
October	1964	1,086,031	1,095,843
November	1964	1,074,469	1,090,265
December	1964	1,381,800	1,392,060
January	1965	1,394,933	1,395,599
February	1965	1,311,011	1,311,011
March	1965	1,224,422	1,227,800
April	1965	1,241,925	1,241,925
May	1965	1,362,392	1,345,043
June	1965	1,458,370	1,461,197
July	1965	1,446,635	1,449,440
August	1965	1,412,635	1,415,239
September	1965	1,375,621	1,378,064
October	1965	1,345,619	1,347,952
November	1965	1,355,506	1,358,259
December	1965	1,350,367	1,353,119
January	1966	1,336,263	1,339,023
February	1966	1,319,464	1,322,147
March	1966	1,261,985	1,264,671
April	1966	1,303,821	1,290,709
May	1966	1,322,871	1,291,388
June	1966	1,270,758	1,234,835
July	1966	1,228,370	1,192,400
August	1966	1,186,965	1,150,837
September	1966	1,150,470	1,114,186
October	1966	1,120,677	1,084,273
November	1966	1,115,243	1,078,820
December	1966	1,219,114	1,182,691
January	1967	1,265,025	1,227,644
February	1967	1,222,628	1,201,994
March	1967	1,198,751	1,213,089
April	1967	1,134,202	1,147,410

May	1967	1,372,876	1,382,920
June	1967	1,479,512	1,449,814
July	1967	1,568,217	1,438,163
August	1967	1,472,879	1,397,187
September	1967	1,381,008	1,360,382
October	1967	1,342,894	1,330,539
November	1967	1,320,797	1,308,427
December	1967	1,301,957	1,289,588
January	1968	1,297,012	1,284,652
February	1968	1,314,788	1,286,863
March	1968	1,293,276	1,253,075
April	1968	1,276,333	1,225,153
May	1968	1,252,310	1,186,322
June	1968	1,199,236	1,126,171
July	1968	1,158,232	1,084,725
August	1968	1,118,263	1,044,265
September	1968	1,082,982	1,008,433
October	1968	1,054,261	979,087
November	1968	1,040,965	965,152
December	1968	1,033,095	956,595
January	1969	1,254,170	1,256,264
February	1969	1,173,088	1,175,400
March	1969	1,109,513	1,111,201
April	1969	1,195,958	1,198,414
May	1969	1,535,152	1,487,987
June	1969	1,627,207	1,572,111
July	1969	1,588,826	1,575,156
August	1969	1,469,972	1,468,162
September	1969	1,372,302	1,369,863
October	1969	1,341,156	1,338,038
November	1969	1,319,731	1,315,947
December	1969	1,328,210	1,323,634
January	1970	1,372,838	1,371,488
February	1970	1,362,190	1,360,528
March	1970	1,307,193	1,307,700
April	1970	1,269,753	1,262,638
May	1970	1,352,216	1,322,963
June	1970	1,404,603	1,357,471
July	1970	1,366,919	1,320,028
August	1970	1,325,902	1,279,253
September	1970	1,289,855	1,243,377
October	1970	1,260,646	1,214,271
November	1970	1,264,931	1,218,584
December	1970	1,284,040	1,237,565
January	1971	1,295,240	1,252,884
February	1971	1,269,762	1,222,524
March	1971	1,213,346	1,174,928

April	1971	1,194,298	1,161,588
May	1971	1,230,452	1,179,658
June	1971	1,342,057	1,269,901
July	1971	1,312,182	1,240,366
August	1971	1,271,417	1,199,924
September	1971	1,235,556	1,164,288
October	1971	1,206,494	1,135,362
November	1971	1,186,964	1,115,869
December	1971	1,177,906	1,106,808
January	1972	1,160,878	1,089,769
February	1972	1,136,910	1,061,739
March	1972	1,124,976	1,040,398
April	1972	1,090,053	996,887
May	1972	1,104,500	993,470
June	1972	1,077,761	955,902
July	1972	1,051,531	940,291
August	1972	1,025,776	924,841
September	1972	1,003,339	911,645
October	1972	985,514	901,573
November	1972	981,242	902,425
December	1972	987,834	911,561
January	1973	1,040,912	957,821
February	1973	1,075,545	983,787
March	1973	1,070,399	968,006
April	1973	1,096,251	1,004,876
May	1973	1,378,984	1,260,320
June	1973	1,457,506	1,363,721
July	1973	1,414,408	1,320,777
August	1973	1,372,154	1,278,558
September	1973	1,333,877	1,241,386
October	1973	1,299,333	1,211,502
November	1973	1,341,404	1,278,213
December	1973	1,369,623	1,317,881
January	1974	1,394,769	1,347,766
February	1974	1,373,497	1,323,039
March	1974	1,328,834	1,281,811
April	1974	1,319,748	1,272,648
May	1974	1,462,349	1,440,500
June	1974	1,457,048	1,457,048
July	1974	1,437,013	1,436,572
August	1974	1,395,737	1,394,714
September	1974	1,344,804	1,344,804
October	1974	1,308,918	1,308,918
November	1974	1,283,947	1,283,947
December	1974	1,266,819	1,266,825
January	1975	1,252,111	1,252,154
February	1975	1,293,284	1,285,889

March	1975	1,229,866	1,229,866
April	1975	1,156,602	1,156,602
May	1975	1,373,338	1,343,001
June	1975	1,457,121	1,457,121
July	1975	1,442,380	1,442,380
August	1975	1,394,767	1,394,767
September	1975	1,340,405	1,340,405
October	1975	1,322,977	1,322,607
November	1975	1,301,622	1,301,159
December	1975	1,282,539	1,282,083
January	1976	1,263,621	1,263,215
February	1976	1,245,910	1,244,307
March	1976	1,219,879	1,214,525
April	1976	1,185,257	1,174,553
May	1976	1,134,187	1,112,300
June	1976	1,091,792	1,067,393
July	1976	1,064,969	1,049,738
August	1976	1,038,733	1,032,278
September	1976	1,015,936	1,017,620
October	1976	997,942	1,006,692
November	1976	985,080	999,707
December	1976	973,611	993,759
January	1977	963,128	989,039
February	1977	952,810	983,460
March	1977	940,094	975,346
April	1977	916,270	951,245
May	1977	881,658	914,975
June	1977	841,904	878,455
July	1977	821,058	863,603
August	1977	799,753	849,153
September	1977	780,706	836,799
October	1977	732,499	827,227
November	1977	722,883	820,599
December	1977	741,952	842,255
January	1978	834,350	927,596
February	1978	873,985	956,873
March	1978	991,350	1,057,081
April	1978	1,102,287	1,149,615
May	1978	1,348,583	1,366,095
June	1978	1,457,800	1,461,352
July	1978	1,446,087	1,449,612
August	1978	1,403,711	1,406,458
September	1978	1,380,148	1,382,404
October	1978	1,350,005	1,351,871
November	1978	1,327,781	1,329,553
December	1978	1,307,947	1,309,723
January	1979	1,343,190	1,344,842

February	1979	1,349,817	1,351,471
March	1979	1,295,512	1,297,421
April	1979	1,301,273	1,303,279
May	1979	1,461,920	1,461,920
June	1979	1,457,201	1,457,201
July	1979	1,414,456	1,413,656
August	1979	1,372,076	1,370,138
September	1979	1,331,534	1,331,534
October	1979	1,302,309	1,301,707
November	1979	1,280,400	1,279,658
December	1979	1,270,044	1,269,311
January	1980	1,354,703	1,354,459
February	1980	1,375,777	1,375,533
March	1980	1,303,011	1,302,767
April	1980	1,358,507	1,343,278
May	1980	1,487,113	1,462,123
June	1980	1,553,964	1,457,849
July	1980	1,576,948	1,446,876
August	1980	1,474,550	1,405,551
September	1980	1,375,621	1,369,224
October	1980	1,333,715	1,333,715
November	1980	1,310,068	1,310,068
December	1980	1,291,085	1,291,088
January	1981	1,297,152	1,297,152
February	1981	1,277,955	1,274,702
March	1981	1,220,264	1,220,264
April	1981	1,235,365	1,211,643
May	1981	1,238,026	1,197,303
June	1981	1,191,302	1,142,783
July	1981	1,150,296	1,101,726
August	1981	1,110,340	1,061,607
September	1981	1,075,049	1,026,145
October	1981	1,046,324	997,309
November	1981	1,099,796	1,050,771
December	1981	1,209,438	1,160,413
January	1982	1,263,179	1,217,479
February	1982	1,262,028	1,269,752
March	1982	1,209,154	1,215,921
April	1982	1,320,221	1,312,146
May	1982	1,531,063	1,462,344
June	1982	1,606,237	1,481,883
July	1982	1,571,696	1,521,609
August	1982	1,477,037	1,450,008
September	1982	1,410,508	1,410,500
October	1982	1,365,657	1,365,657
November	1982	1,374,388	1,374,388
December	1982	1,378,973	1,378,973

January	1983	1,314,557	1,314,557
February	1983	1,249,349	1,249,349
March	1983	1,216,036	1,216,036
April	1983	1,157,937	1,157,937
May	1983	1,407,181	1,407,181
June	1983	1,446,573	1,446,573
July	1983	1,566,081	1,561,799
August	1983	1,471,729	1,471,720
September	1983	1,400,441	1,400,441
October	1983	1,368,064	1,368,064
November	1983	1,370,742	1,370,742
December	1983	1,393,325	1,393,325
January	1984	1,353,782	1,353,782
February	1984	1,262,862	1,262,862
March	1984	1,221,266	1,221,266
April	1984	1,230,611	1,220,597
May	1984	1,438,272	1,400,623
June	1984	1,451,225	1,442,882
July	1984	1,416,175	1,407,821
August	1984	1,374,897	1,366,523
September	1984	1,338,663	1,330,267
October	1984	1,309,434	1,301,025
November	1984	1,296,734	1,288,322
December	1984	1,279,937	1,271,526
January	1985	1,261,657	1,253,246
February	1985	1,249,519	1,237,536
March	1985	1,184,095	1,180,798
April	1985	1,236,327	1,217,409
May	1985	1,253,415	1,216,914
June	1985	1,195,521	1,152,164
July	1985	1,154,423	1,111,217
August	1985	1,114,317	1,071,237
September	1985	1,078,962	1,035,959
October	1985	1,050,196	1,007,238
November	1985	1,031,619	988,676
December	1985	1,029,273	986,328
January	1986	1,029,772	986,820
February	1986	1,311,393	1,311,393
March	1986	1,323,469	1,323,469
April	1986	1,385,979	1,385,979
May	1986	1,497,420	1,462,325
June	1986	1,551,750	1,457,365
July	1986	1,503,321	1,445,129
August	1986	1,408,435	1,403,674
September	1986	1,354,177	1,354,177
October	1986	1,324,902	1,324,807
November	1986	1,301,715	1,301,715

December	1986	1,280,656	1,280,656
January	1987	1,262,059	1,262,080
February	1987	1,256,254	1,255,330
March	1987	1,230,485	1,224,416
April	1987	1,197,845	1,181,690
May	1987	1,156,503	1,129,767
June	1987	1,109,036	1,078,850
July	1987	1,082,262	1,061,757
August	1987	1,055,984	1,044,744
September	1987	1,033,123	1,030,345
October	1987	1,015,005	1,019,498
November	1987	1,002,124	1,012,562
December	1987	992,140	1,008,003
January	1988	984,366	1,005,581
February	1988	966,554	989,316
March	1988	938,440	961,747
April	1988	908,483	927,372
May	1988	870,787	885,280
June	1988	830,508	848,018
July	1988	810,744	833,167
August	1988	791,463	818,641
September	1988	774,636	806,152
October	1988	761,265	796,471
November	1988	751,638	789,817
December	1988	743,465	784,379
January	1989	735,448	779,225
February	1989	719,484	762,325
March	1989	798,051	828,551
April	1989	865,149	880,687
May	1989	881,321	882,395
June	1989	863,162	857,183
July	1989	843,383	842,322
August	1989	824,050	827,584
September	1989	807,042	814,701
October	1989	804,203	815,521
November	1989	795,122	809,375
December	1989	786,810	803,802
January	1990	780,109	799,961
February	1990	767,630	787,375
March	1990	746,656	761,770
April	1990	736,383	740,690
May	1990	698,388	695,293
June	1990	665,172	660,543
July	1990	645,744	646,057
August	1990	626,769	631,900
September	1990	610,552	619,609
October	1990	597,386	609,716

November	1990	587,825	603,137
December	1990	579,390	597,435
January	1991	571,073	591,959
February	1991	563,321	586,025
March	1991	592,930	604,241
April	1991	583,892	586,373
May	1991	609,789	597,768
June	1991	651,823	629,039
July	1991	634,059	616,273
August	1991	615,228	602,207
September	1991	598,761	589,978
October	1991	586,480	581,342
November	1991	576,884	574,726
December	1991	568,900	569,472
January	1992	561,481	564,277
February	1992	575,990	566,378
March	1992	559,170	544,610
April	1992	554,796	529,176
May	1992	521,301	488,969
June	1992	497,122	466,880
July	1992	479,474	454,215
August	1992	461,249	440,782
September	1992	445,186	429,009
October	1992	432,185	419,707
November	1992	422,574	413,078
December	1992	416,983	410,061
January	1993	583,884	570,363
February	1993	604,265	580,541
March	1993	714,773	674,049
April	1993	795,624	737,741
May	1993	1,061,649	973,427
June	1993	1,261,116	1,150,728
July	1993	1,297,704	1,188,442
August	1993	1,254,362	1,146,723
September	1993	1,216,056	1,109,767
October	1993	1,184,925	1,079,649
November	1993	1,162,397	1,057,406
December	1993	1,143,661	1,038,651
January	1994	1,124,905	1,019,770
February	1994	1,117,608	1,009,700
March	1994	1,083,955	970,589
April	1994	1,050,210	927,324
May	1994	1,014,068	878,690
June	1994	972,422	818,118
July	1994	947,665	802,332
August	1994	923,584	787,892
September	1994	902,434	775,512

October	1994	885,366	765,913
November	1994	886,536	773,092
December	1994	875,941	768,032
January	1995	1,123,203	1,002,723
February	1995	1,107,803	977,761
March	1995	1,204,250	1,217,856
April	1995	1,250,728	1,261,168
May	1995	1,398,103	1,406,837
June	1995	1,458,686	1,462,021
July	1995	1,447,639	1,450,948
August	1995	1,432,488	1,435,773
September	1995	1,391,233	1,394,499
October	1995	1,356,693	1,359,946
November	1995	1,332,278	1,335,528
December	1995	1,336,484	1,339,733
January	1996	1,365,169	1,368,418
February	1996	1,398,949	1,395,648
March	1996	1,365,294	1,361,903
April	1996	1,435,691	1,429,584
May	1996	1,567,790	1,534,705
June	1996	1,588,192	1,535,798
July	1996	1,527,138	1,474,972
August	1996	1,413,644	1,399,193
September	1996	1,343,808	1,343,808
October	1996	1,309,898	1,309,898
November	1996	1,336,401	1,336,401
December	1996	1,362,121	1,362,121
January	1997	1,399,202	1,399,202
February	1997	1,319,626	1,319,626
March	1997	1,302,698	1,302,698
April	1997	1,346,174	1,331,860
May	1997	1,465,614	1,458,855
June	1997	1,464,180	1,454,318
July	1997	1,422,148	1,412,280
August	1997	1,380,268	1,370,385
September	1997	1,343,482	1,333,588
October	1997	1,310,975	1,310,799
November	1997	1,289,851	1,289,664
December	1997	1,274,644	1,274,457
January	1998	1,325,023	1,324,722
February	1998	1,313,818	1,313,517
March	1998	1,284,378	1,284,077
April	1998	1,299,714	1,299,450
May	1998	1,371,995	1,371,765
June	1998	1,591,036	1,548,242
July	1998	1,614,419	1,614,419
August	1998	1,476,942	1,476,942

September	1998	1,388,744	1,388,744
October	1998	1,353,660	1,353,660
November	1998	1,337,532	1,337,532
December	1998	1,321,902	1,321,902
January	1999	1,335,701	1,335,701
February	1999	1,330,779	1,330,779
March	1999	1,258,633	1,258,633
April	1999	1,265,333	1,263,166
May	1999	1,462,315	1,435,422
June	1999	1,489,049	1,457,466
July	1999	1,445,963	1,426,962
August	1999	1,397,521	1,385,168
September	1999	1,343,534	1,343,534
October	1999	1,309,163	1,309,163
November	1999	1,287,122	1,287,114
December	1999	1,267,388	1,267,380
January	2000	1,273,003	1,273,003
February	2000	1,282,651	1,282,651
March	2000	1,241,311	1,241,311
April	2000	1,316,514	1,296,367
May	2000	1,485,260	1,437,325
June	2000	1,498,506	1,446,549
July	2000	1,432,500	1,403,684
August	2000	1,383,379	1,361,660
September	2000	1,328,102	1,324,806
October	2000	1,293,421	1,293,421
November	2000	1,271,318	1,271,298
December	2000	1,251,645	1,251,626
January	2001	1,234,363	1,234,355
February	2001	1,228,643	1,225,534
March	2001	1,238,295	1,237,486
April	2001	1,238,584	1,226,016
May	2001	1,308,254	1,274,595
June	2001	1,262,470	1,226,003
July	2001	1,220,742	1,184,311
August	2001	1,179,989	1,143,567
September	2001	1,144,128	1,107,696
October	2001	1,115,017	1,078,568
November	2001	1,097,733	1,061,282
December	2001	1,112,798	1,076,346
January	2002	1,111,078	1,074,627
February	2002	1,084,219	1,043,670
March	2002	1,066,763	1,018,923
April	2002	1,120,596	1,057,210
May	2002	1,169,398	1,086,960
June	2002	1,142,764	1,049,175
July	2002	1,101,808	1,032,796

August	2002	1,061,776	1,016,503
September	2002	1,026,396	1,002,605
October	2002	997,522	991,986
November	2002	1,008,006	1,017,087
December	2002	1,025,900	1,028,175
January	2003	1,012,611	1,017,781
February	2003	986,911	1,000,342
March	2003	967,523	988,931
April	2003	973,292	996,519
May	2003	1,148,585	1,162,587
June	2003	1,228,372	1,244,320
July	2003	1,188,597	1,204,089
August	2003	1,151,098	1,166,062
September	2003	1,115,999	1,130,549
October	2003	1,087,553	1,101,775
November	2003	1,066,795	1,080,933
December	2003	1,061,990	1,076,133
January	2004	1,054,022	1,068,188
February	2004	1,064,992	1,073,544
March	2004	1,116,701	1,111,916
April	2004	1,146,642	1,127,810
May	2004	1,140,536	1,105,216
June	2004	1,083,252	1,040,203
July	2004	1,041,586	997,075
August	2004	1,000,585	968,883
September	2004	964,095	934,590
October	2004	937,248	908,996
November	2004	915,538	887,568
December	2004	919,146	891,167
January	2005	1,043,768	1,015,793
February	2005	1,083,275	1,045,650
March	2005	1,143,712	1,132,841
April	2005	1,184,358	1,180,203
May	2005	1,462,277	1,462,277
June	2005	1,457,439	1,457,439
July	2005	1,446,518	1,445,830
August	2005	1,404,918	1,402,697
September	2005	1,350,126	1,348,096
October	2005	1,316,227	1,313,516
November	2005	1,294,707	1,291,207
December	2005	1,337,888	1,333,891
January	2006	1,362,992	1,358,260
February	2006	1,365,159	1,360,210
March	2006	1,328,772	1,322,703
April	2006	1,393,025	1,373,014
May	2006	1,612,193	1,462,349
June	2006	1,626,559	1,456,722

July	2006	1,575,715	1,445,816
August	2006	1,453,769	1,403,909
September	2006	1,352,188	1,347,335
October	2006	1,311,061	1,311,220
November	2006	1,289,754	1,289,888
December	2006	1,272,116	1,272,253
January	2007	1,254,194	1,254,342
February	2007	1,257,612	1,252,880
March	2007	1,240,502	1,224,128
April	2007	1,220,153	1,194,500
May	2007	1,177,247	1,139,018
June	2007	1,130,246	1,088,827
July	2007	1,103,348	1,071,840
August	2007	1,077,014	1,055,089
September	2007	1,054,111	1,040,897
October	2007	1,036,017	1,030,228
November	2007	1,023,323	1,023,512
December	2007	1,012,197	1,017,890
January	2008	1,033,519	1,031,012
February	2008	1,032,585	1,024,637
March	2008	1,006,645	998,096
April	2008	993,805	979,486
May	2008	1,033,957	1,008,756
June	2008	1,000,809	973,872
July	2008	975,070	958,149
August	2008	949,797	942,563
September	2008	927,639	929,176
October	2008	909,931	918,917
November	2008	905,143	919,743
December	2008	894,323	912,538
January	2009	920,572	942,855
February	2009	933,770	941,449
March	2009	979,499	974,206
April	2009	1,008,606	993,229
May	2009	1,207,759	1,170,418
June	2009	1,186,010	1,145,748
July	2009	1,144,795	1,104,396
August	2009	1,103,913	1,063,220
September	2009	1,067,747	1,026,750
October	2009	1,057,289	1,016,106
November	2009	1,035,195	993,954
December	2009	1,016,494	975,254
January	2010	1,033,651	992,417
February	2010	1,029,051	982,343
March	2010	1,012,584	957,612
April	2010	1,037,901	971,182
May	2010	1,095,825	1,009,262

June	2010	1,374,984	1,256,284
July	2010	1,369,846	1,251,227
August	2010	1,327,590	1,208,663
September	2010	1,290,418	1,171,093
October	2010	1,324,619	1,205,079
November	2010	1,304,136	1,184,574
December	2010	1,363,443	1,353,337
January	2011	1,341,005	1,330,895
February	2011	1,273,996	1,263,881
March	2011	1,249,125	1,238,872
April	2011	1,304,092	1,295,091
May	2011	1,453,762	1,430,870
June	2011	1,614,218	1,457,593
July	2011	1,616,817	1,446,817
August	2011	1,482,315	1,406,697
September	2011	1,391,409	1,370,523

Month	Year	40%, 223 MGD Total System Storage (AF)	50%, 223 MGD Total System Storage (AF)
July	1920	1,423,711	1,423,711
August	1920	1,386,764	1,386,764
September	1920	1,351,754	1,351,754
October	1920	1,325,720	1,325,720
November	1920	1,307,420	1,307,420
December	1920	1,309,116	1,309,116
January	1921	1,329,212	1,329,212
February	1921	1,320,514	1,312,449
March	1921	1,283,045	1,283,045
April	1921	1,306,620	1,306,620
May	1921	1,412,290	1,389,469
June	1921	1,497,623	1,453,050
July	1921	1,445,956	1,424,985
August	1921	1,402,155	1,388,777
September	1921	1,350,774	1,350,774
October	1921	1,319,148	1,319,148
November	1921	1,296,277	1,296,277
December	1921	1,292,788	1,292,788
January	1922	1,296,014	1,296,017
February	1922	1,265,417	1,265,417
March	1922	1,166,514	1,166,514
April	1922	1,156,580	1,145,080
May	1922	1,448,564	1,432,944
June	1922	1,595,941	1,493,420
July	1922	1,575,790	1,473,712
August	1922	1,465,896	1,415,887
September	1922	1,371,469	1,366,458
October	1922	1,335,659	1,335,659
November	1922	1,318,156	1,318,145
December	1922	1,345,816	1,345,816
January	1923	1,347,781	1,347,781
February	1923	1,338,846	1,330,984
March	1923	1,244,915	1,244,915
April	1923	1,251,831	1,251,831
May	1923	1,420,114	1,393,226
June	1923	1,455,591	1,422,489
July	1923	1,448,483	1,434,966
August	1923	1,411,550	1,398,725
September	1923	1,365,688	1,365,688
October	1923	1,340,318	1,340,294
November	1923	1,321,733	1,321,702
December	1923	1,305,096	1,305,065
January	1924	1,288,779	1,288,752
February	1924	1,273,579	1,271,567
March	1924	1,254,518	1,252,216

April	1924	1,222,753	1,213,255
May	1924	1,182,091	1,161,804
June	1924	1,148,920	1,127,789
July	1924	1,124,979	1,110,260
August	1924	1,101,391	1,092,829
September	1924	1,081,018	1,078,074
October	1924	1,065,113	1,066,954
November	1924	1,057,786	1,063,481
December	1924	1,051,926	1,061,177
January	1925	1,044,413	1,057,352
February	1925	1,123,038	1,127,623
March	1925	1,113,392	1,113,107
April	1925	1,201,408	1,207,379
May	1925	1,397,900	1,380,873
June	1925	1,446,600	1,445,259
July	1925	1,427,069	1,425,392
August	1925	1,389,597	1,387,435
September	1925	1,351,895	1,354,295
October	1925	1,325,575	1,327,679
November	1925	1,306,328	1,308,355
December	1925	1,289,174	1,291,203
January	1926	1,275,026	1,277,089
February	1926	1,292,258	1,288,947
March	1926	1,262,029	1,252,073
April	1926	1,374,145	1,344,014
May	1926	1,382,850	1,336,436
June	1926	1,336,199	1,284,841
July	1926	1,298,742	1,246,373
August	1926	1,261,784	1,206,668
September	1926	1,229,524	1,171,433
October	1926	1,203,746	1,143,070
November	1926	1,227,536	1,166,715
December	1926	1,215,024	1,154,211
January	1927	1,206,485	1,145,708
February	1927	1,270,299	1,218,664
March	1927	1,197,267	1,149,183
April	1927	1,223,290	1,180,813
May	1927	1,340,072	1,273,672
June	1927	1,456,994	1,415,753
July	1927	1,449,906	1,408,651
August	1927	1,412,580	1,369,417
September	1927	1,364,117	1,334,997
October	1927	1,336,530	1,309,742
November	1927	1,325,447	1,298,391
December	1927	1,315,379	1,288,338
January	1928	1,302,149	1,275,196
February	1928	1,298,100	1,266,919

March	1928	1,336,650	1,316,826
April	1928	1,331,036	1,311,212
May	1928	1,427,323	1,383,675
June	1928	1,377,620	1,325,035
July	1928	1,340,043	1,283,726
August	1928	1,302,974	1,227,550
September	1928	1,270,627	1,198,552
October	1928	1,244,752	1,174,839
November	1928	1,226,149	1,156,801
December	1928	1,214,674	1,145,282
January	1929	1,202,002	1,132,313
February	1929	1,189,589	1,117,756
March	1929	1,164,713	1,088,118
April	1929	1,128,343	1,044,962
May	1929	1,168,991	1,067,923
June	1929	1,170,727	1,059,938
July	1929	1,146,661	1,044,687
August	1929	1,122,964	1,029,805
September	1929	1,102,509	1,017,056
October	1929	1,086,541	1,007,175
November	1929	1,075,449	1,000,293
December	1929	1,065,823	994,197
January	1930	1,062,088	993,962
February	1930	1,050,546	982,161
March	1930	1,060,462	985,245
April	1930	1,072,201	986,109
May	1930	1,075,374	980,218
June	1930	1,104,432	1,000,604
July	1930	1,080,697	983,287
August	1930	1,057,011	964,969
September	1930	1,036,338	949,456
October	1930	1,020,210	937,947
November	1930	1,009,135	928,864
December	1930	999,588	921,507
January	1931	992,474	916,181
February	1931	979,545	903,225
March	1931	960,370	884,466
April	1931	925,280	843,339
May	1931	887,726	798,888
June	1931	860,283	774,313
July	1931	838,470	759,215
August	1931	816,999	744,263
September	1931	798,096	732,038
October	1931	783,033	722,203
November	1931	772,192	715,328
December	1931	829,180	768,917
January	1932	835,199	774,304

February	1932	921,029	847,450
March	1932	908,866	830,134
April	1932	951,903	861,889
May	1932	1,132,140	1,019,887
June	1932	1,355,229	1,221,462
July	1932	1,377,694	1,244,402
August	1932	1,339,895	1,206,740
September	1932	1,306,826	1,173,543
October	1932	1,280,262	1,146,560
November	1932	1,260,972	1,127,114
December	1932	1,243,937	1,110,087
January	1933	1,232,311	1,098,523
February	1933	1,218,102	1,084,328
March	1933	1,193,574	1,055,534
April	1933	1,166,960	1,020,452
May	1933	1,167,749	1,008,428
June	1933	1,288,382	1,107,418
July	1933	1,248,058	1,089,018
August	1933	1,203,252	1,070,296
September	1933	1,345,160	1,054,725
October	1933	1,315,157	1,042,820
November	1933	1,295,612	1,035,397
December	1933	1,288,496	1,038,779
January	1934	1,288,765	1,047,459
February	1934	1,274,575	1,035,485
March	1934	1,244,461	1,009,604
April	1934	1,206,035	972,331
May	1934	1,149,438	929,314
June	1934	1,111,267	896,571
July	1934	1,089,671	880,903
August	1934	1,068,647	865,420
September	1934	1,050,275	852,087
October	1934	1,035,628	841,855
November	1934	1,025,115	835,141
December	1934	1,017,754	831,347
January	1935	1,036,625	851,560
February	1935	1,020,123	831,888
March	1935	1,006,196	812,518
April	1935	1,184,234	993,957
May	1935	1,370,933	1,157,331
June	1935	1,458,228	1,342,979
July	1935	1,427,251	1,314,776
August	1935	1,388,619	1,279,029
September	1935	1,354,903	1,247,738
October	1935	1,327,871	1,222,785
November	1935	1,308,495	1,204,877
December	1935	1,291,929	1,189,547

January	1936	1,302,848	1,201,561
February	1936	1,314,760	1,274,083
March	1936	1,263,375	1,222,176
April	1936	1,346,324	1,311,845
May	1936	1,461,356	1,454,903
June	1936	1,456,016	1,456,900
July	1936	1,436,378	1,437,073
August	1936	1,398,367	1,398,755
September	1936	1,355,174	1,356,044
October	1936	1,324,772	1,325,641
November	1936	1,304,541	1,305,408
December	1936	1,290,056	1,290,927
January	1937	1,275,418	1,276,308
February	1937	1,286,740	1,287,134
March	1937	1,207,831	1,209,977
April	1937	1,212,053	1,213,863
May	1937	1,462,349	1,442,966
June	1937	1,458,963	1,458,963
July	1937	1,427,056	1,425,719
August	1937	1,389,952	1,386,952
September	1937	1,356,410	1,353,113
October	1937	1,325,853	1,324,073
November	1937	1,307,327	1,304,724
December	1937	1,378,056	1,376,319
January	1938	1,380,845	1,381,276
February	1938	1,368,280	1,367,599
March	1938	1,313,393	1,313,393
April	1938	1,355,892	1,355,892
May	1938	1,462,349	1,462,349
June	1938	1,541,045	1,457,398
July	1938	1,576,922	1,451,051
August	1938	1,481,663	1,414,189
September	1938	1,393,097	1,381,896
October	1938	1,368,100	1,356,108
November	1938	1,350,252	1,337,571
December	1938	1,336,891	1,323,523
January	1939	1,322,802	1,308,753
February	1939	1,312,787	1,291,212
March	1939	1,329,104	1,283,140
April	1939	1,372,147	1,299,134
May	1939	1,324,802	1,240,441
June	1939	1,280,646	1,191,983
July	1939	1,244,394	1,155,230
August	1939	1,209,000	1,119,220
September	1939	1,178,028	1,087,628
October	1939	1,153,077	1,062,017
November	1939	1,134,673	1,042,955

December	1939	1,118,242	1,025,836
January	1940	1,228,763	1,135,656
February	1940	1,273,408	1,218,069
March	1940	1,250,504	1,236,472
April	1940	1,296,094	1,273,709
May	1940	1,476,729	1,452,724
June	1940	1,488,882	1,456,701
July	1940	1,446,210	1,418,568
August	1940	1,400,543	1,380,965
September	1940	1,351,507	1,348,075
October	1940	1,322,112	1,318,195
November	1940	1,303,768	1,299,067
December	1940	1,323,644	1,318,451
January	1941	1,297,622	1,292,621
February	1941	1,286,298	1,281,415
March	1941	1,222,743	1,218,758
April	1941	1,198,827	1,195,309
May	1941	1,462,349	1,447,629
June	1941	1,526,176	1,451,559
July	1941	1,521,876	1,446,008
August	1941	1,420,983	1,409,596
September	1941	1,369,369	1,368,258
October	1941	1,341,181	1,340,071
November	1941	1,324,898	1,323,728
December	1941	1,374,003	1,373,007
January	1942	1,398,435	1,398,435
February	1942	1,399,202	1,399,202
March	1942	1,313,977	1,313,977
April	1942	1,348,109	1,336,609
May	1942	1,488,200	1,446,261
June	1942	1,577,014	1,454,289
July	1942	1,578,615	1,448,597
August	1942	1,467,330	1,412,410
September	1942	1,373,653	1,368,648
October	1942	1,338,952	1,338,952
November	1942	1,348,277	1,348,277
December	1942	1,353,258	1,353,258
January	1943	1,397,902	1,397,902
February	1943	1,398,053	1,390,595
March	1943	1,361,919	1,361,919
April	1943	1,453,192	1,453,192
May	1943	1,533,774	1,509,054
June	1943	1,547,360	1,505,101
July	1943	1,500,643	1,458,567
August	1943	1,414,260	1,414,260
September	1943	1,366,898	1,366,898
October	1943	1,339,204	1,339,204

November	1943	1,321,034	1,321,028
December	1943	1,305,308	1,305,303
January	1944	1,290,706	1,290,704
February	1944	1,290,755	1,286,616
March	1944	1,246,709	1,246,709
April	1944	1,207,286	1,207,286
May	1944	1,316,045	1,292,478
June	1944	1,312,885	1,275,602
July	1944	1,285,090	1,247,940
August	1944	1,249,675	1,212,633
September	1944	1,218,614	1,181,641
October	1944	1,193,593	1,156,660
November	1944	1,193,808	1,156,888
December	1944	1,184,827	1,147,906
January	1945	1,171,906	1,134,983
February	1945	1,273,763	1,261,526
March	1945	1,189,662	1,178,772
April	1945	1,225,213	1,214,638
May	1945	1,344,540	1,310,418
June	1945	1,457,683	1,442,955
July	1945	1,450,571	1,450,571
August	1945	1,414,265	1,413,964
September	1945	1,366,691	1,366,691
October	1945	1,356,227	1,356,227
November	1945	1,339,474	1,339,441
December	1945	1,391,663	1,391,663
January	1946	1,393,248	1,393,248
February	1946	1,377,443	1,374,323
March	1946	1,310,115	1,310,115
April	1946	1,396,568	1,386,431
May	1946	1,503,941	1,459,762
June	1946	1,490,943	1,448,328
July	1946	1,446,105	1,411,154
August	1946	1,403,663	1,374,675
September	1946	1,355,446	1,342,819
October	1946	1,330,205	1,317,417
November	1946	1,331,807	1,318,983
December	1946	1,320,164	1,307,342
January	1947	1,305,904	1,293,099
February	1947	1,294,709	1,277,765
March	1947	1,254,140	1,244,537
April	1947	1,231,836	1,212,239
May	1947	1,262,435	1,224,550
June	1947	1,210,179	1,166,499
July	1947	1,174,250	1,130,394
August	1947	1,139,103	1,094,909
September	1947	1,108,245	1,063,767

October	1947	1,084,731	1,040,092
November	1947	1,066,494	1,021,819
December	1947	1,050,617	1,005,944
January	1948	1,037,950	993,293
February	1948	1,022,485	976,489
March	1948	999,128	949,339
April	1948	990,938	929,739
May	1948	1,085,622	1,002,041
June	1948	1,214,666	1,108,989
July	1948	1,200,934	1,102,213
August	1948	1,177,151	1,085,272
September	1948	1,156,624	1,070,903
October	1948	1,140,589	1,059,998
November	1948	1,129,506	1,052,855
December	1948	1,120,635	1,047,538
January	1949	1,112,053	1,042,554
February	1949	1,102,684	1,034,414
March	1949	1,118,074	1,035,626
April	1949	1,187,981	1,089,401
May	1949	1,284,781	1,167,477
June	1949	1,285,478	1,162,042
July	1949	1,247,665	1,124,968
August	1949	1,210,334	1,088,171
September	1949	1,177,615	1,055,590
October	1949	1,151,147	1,029,000
November	1949	1,131,865	1,009,706
December	1949	1,115,165	993,004
January	1950	1,120,549	998,371
February	1950	1,124,327	995,731
March	1950	1,100,024	964,859
April	1950	1,178,619	1,026,511
May	1950	1,314,278	1,138,153
June	1950	1,351,700	1,159,371
July	1950	1,314,750	1,120,280
August	1950	1,276,315	1,090,020
September	1950	1,242,727	1,061,028
October	1950	1,219,157	1,040,471
November	1950	1,378,839	1,378,863
December	1950	1,397,362	1,397,362
January	1951	1,398,583	1,398,583
February	1951	1,391,827	1,385,369
March	1951	1,320,178	1,320,178
April	1951	1,362,981	1,352,928
May	1951	1,445,625	1,416,204
June	1951	1,434,928	1,392,166
July	1951	1,398,016	1,355,127
August	1951	1,361,771	1,318,645

September	1951	1,330,069	1,286,724
October	1951	1,304,680	1,261,171
November	1951	1,286,437	1,242,893
December	1951	1,314,922	1,281,838
January	1952	1,225,447	1,255,681
February	1952	1,139,737	1,168,241
March	1952	1,068,900	1,095,217
April	1952	1,158,357	1,182,319
May	1952	1,471,514	1,462,010
June	1952	1,559,296	1,456,822
July	1952	1,579,961	1,449,937
August	1952	1,481,673	1,414,735
September	1952	1,390,289	1,383,138
October	1952	1,355,715	1,355,715
November	1952	1,336,298	1,336,298
December	1952	1,340,367	1,340,369
January	1953	1,371,443	1,371,443
February	1953	1,361,021	1,353,349
March	1953	1,277,339	1,277,339
April	1953	1,317,777	1,316,472
May	1953	1,310,007	1,295,259
June	1953	1,423,414	1,387,257
July	1953	1,439,022	1,402,889
August	1953	1,402,799	1,366,635
September	1953	1,360,562	1,334,946
October	1953	1,329,575	1,309,577
November	1953	1,311,173	1,291,890
December	1953	1,295,143	1,275,862
January	1954	1,291,134	1,271,863
February	1954	1,284,995	1,260,446
March	1954	1,272,042	1,272,042
April	1954	1,339,294	1,338,020
May	1954	1,440,568	1,416,001
June	1954	1,399,105	1,364,848
July	1954	1,362,228	1,327,711
August	1954	1,326,113	1,291,182
September	1954	1,294,531	1,259,235
October	1954	1,269,176	1,233,615
November	1954	1,250,911	1,215,287
December	1954	1,243,087	1,207,467
January	1955	1,242,111	1,206,513
February	1955	1,225,075	1,186,319
March	1955	1,188,937	1,154,530
April	1955	1,157,981	1,116,021
May	1955	1,204,630	1,143,484
June	1955	1,230,575	1,154,156
July	1955	1,195,404	1,136,061

August	1955	1,160,874	1,117,265
September	1955	1,130,545	1,101,024
October	1955	1,106,161	1,088,642
November	1955	1,088,400	1,081,257
December	1955	1,396,401	1,399,549
January	1956	1,367,564	1,371,095
February	1956	1,282,273	1,285,694
March	1956	1,221,658	1,226,947
April	1956	1,265,573	1,256,530
May	1956	1,458,354	1,440,687
June	1956	1,547,544	1,461,196
July	1956	1,552,457	1,452,632
August	1956	1,458,823	1,415,765
September	1956	1,382,186	1,383,484
October	1956	1,356,445	1,357,633
November	1956	1,337,550	1,338,709
December	1956	1,320,816	1,321,977
January	1957	1,305,661	1,306,837
February	1957	1,321,089	1,315,856
March	1957	1,284,404	1,285,877
April	1957	1,267,954	1,269,351
May	1957	1,345,411	1,327,065
June	1957	1,450,283	1,410,929
July	1957	1,417,114	1,377,635
August	1957	1,380,909	1,341,217
September	1957	1,349,286	1,309,416
October	1957	1,323,899	1,283,901
November	1957	1,305,595	1,265,565
December	1957	1,296,391	1,256,364
January	1958	1,293,273	1,253,255
February	1958	1,330,814	1,281,636
March	1958	1,241,138	1,228,371
April	1958	1,249,856	1,237,861
May	1958	1,529,246	1,462,218
June	1958	1,611,073	1,454,423
July	1958	1,578,932	1,448,865
August	1958	1,482,883	1,412,740
September	1958	1,390,980	1,381,130
October	1958	1,356,041	1,355,887
November	1958	1,335,463	1,335,463
December	1958	1,317,342	1,317,342
January	1959	1,325,235	1,325,235
February	1959	1,346,138	1,346,138
March	1959	1,314,859	1,309,261
April	1959	1,309,230	1,289,772
May	1959	1,278,899	1,247,362
June	1959	1,225,088	1,186,298

July	1959	1,189,182	1,150,223
August	1959	1,154,114	1,114,828
September	1959	1,138,849	1,099,376
October	1959	1,114,014	1,074,375
November	1959	1,095,639	1,055,957
December	1959	1,079,270	1,039,592
January	1960	1,064,867	1,025,210
February	1960	1,081,167	1,035,361
March	1960	1,068,643	1,015,114
April	1960	1,070,466	1,004,591
May	1960	1,068,064	986,480
June	1960	1,030,246	940,482
July	1960	1,007,470	924,188
August	1960	985,105	906,965
September	1960	965,660	888,000
October	1960	950,332	878,177
November	1960	939,905	871,788
December	1960	931,935	867,369
January	1961	923,740	862,827
February	1961	910,720	850,850
March	1961	892,527	832,564
April	1961	872,763	805,962
May	1961	829,891	756,833
June	1961	787,567	713,968
July	1961	766,107	699,016
August	1961	745,225	684,453
September	1961	726,911	671,850
October	1961	712,246	662,018
November	1961	701,526	655,150
December	1961	692,130	649,299
January	1962	683,092	643,826
February	1962	792,344	735,733
March	1962	788,631	725,696
April	1962	939,638	858,030
May	1962	1,015,262	919,774
June	1962	1,164,437	1,051,838
July	1962	1,144,053	1,033,067
August	1962	1,107,565	994,406
September	1962	1,075,357	967,230
October	1962	1,049,470	944,399
November	1962	1,030,410	927,081
December	1962	1,016,573	914,463
January	1963	1,099,883	998,210
February	1963	1,242,278	1,123,367
March	1963	1,238,736	1,115,311
April	1963	1,244,978	1,141,987
May	1963	1,431,183	1,301,662

June	1963	1,449,982	1,435,587
July	1963	1,443,646	1,445,764
August	1963	1,405,673	1,409,229
September	1963	1,360,473	1,365,495
October	1963	1,331,698	1,338,095
November	1963	1,339,935	1,347,616
December	1963	1,324,069	1,332,999
January	1964	1,318,723	1,328,831
February	1964	1,301,927	1,310,515
March	1964	1,277,888	1,283,908
April	1964	1,247,737	1,247,062
May	1964	1,263,882	1,248,399
June	1964	1,229,595	1,203,938
July	1964	1,192,322	1,167,654
August	1964	1,155,133	1,131,064
September	1964	1,122,382	1,098,632
October	1964	1,096,010	1,072,829
November	1964	1,078,942	1,056,415
December	1964	1,371,681	1,373,115
January	1965	1,394,127	1,394,933
February	1965	1,310,907	1,311,011
March	1965	1,224,102	1,224,543
April	1965	1,241,644	1,241,925
May	1965	1,354,738	1,332,487
June	1965	1,457,916	1,457,720
July	1965	1,450,935	1,451,289
August	1965	1,422,665	1,422,120
September	1965	1,390,893	1,389,514
October	1965	1,364,423	1,363,207
November	1965	1,375,719	1,374,398
December	1965	1,374,286	1,372,278
January	1966	1,363,951	1,361,265
February	1966	1,350,130	1,346,815
March	1966	1,292,672	1,291,529
April	1966	1,337,753	1,320,796
May	1966	1,360,665	1,325,330
June	1966	1,313,746	1,273,289
July	1966	1,277,030	1,235,800
August	1966	1,241,095	1,198,937
September	1966	1,209,654	1,166,611
October	1966	1,184,354	1,140,466
November	1966	1,182,736	1,138,158
December	1966	1,290,265	1,244,998
January	1967	1,319,933	1,286,917
February	1967	1,279,317	1,246,281
March	1967	1,249,568	1,220,044
April	1967	1,175,019	1,149,608

May	1967	1,406,423	1,385,148
June	1967	1,493,277	1,449,952
July	1967	1,574,118	1,443,599
August	1967	1,483,306	1,407,733
September	1967	1,396,712	1,375,542
October	1967	1,363,236	1,349,647
November	1967	1,344,993	1,330,722
December	1967	1,329,809	1,314,851
January	1968	1,328,630	1,312,994
February	1968	1,352,518	1,318,060
March	1968	1,329,286	1,287,506
April	1968	1,320,598	1,263,222
May	1968	1,301,703	1,228,382
June	1968	1,253,792	1,172,753
July	1968	1,217,764	1,136,304
August	1968	1,182,578	1,100,652
September	1968	1,151,689	1,069,234
October	1968	1,126,785	1,043,715
November	1968	1,116,641	1,032,934
December	1968	1,111,744	1,027,346
January	1969	1,247,846	1,261,983
February	1969	1,165,569	1,179,124
March	1969	1,102,267	1,116,863
April	1969	1,185,017	1,200,185
May	1969	1,531,899	1,490,941
June	1969	1,627,832	1,578,413
July	1969	1,594,126	1,581,510
August	1969	1,479,769	1,479,610
September	1969	1,386,734	1,385,936
October	1969	1,359,555	1,358,068
November	1969	1,341,320	1,339,167
December	1969	1,349,947	1,348,503
January	1970	1,374,318	1,372,187
February	1970	1,366,036	1,363,286
March	1970	1,309,513	1,309,887
April	1970	1,271,362	1,266,639
May	1970	1,358,230	1,330,752
June	1970	1,415,318	1,369,957
July	1970	1,382,867	1,337,730
August	1970	1,346,901	1,301,994
September	1970	1,315,441	1,270,702
October	1970	1,290,171	1,245,531
November	1970	1,297,639	1,253,026
December	1970	1,319,612	1,274,877
January	1971	1,331,563	1,292,036
February	1971	1,308,936	1,264,526
March	1971	1,251,833	1,212,080

April	1971	1,225,490	1,190,588
May	1971	1,265,981	1,213,081
June	1971	1,382,146	1,307,891
July	1971	1,357,355	1,283,448
August	1971	1,321,486	1,247,914
September	1971	1,290,106	1,216,767
October	1971	1,264,915	1,191,715
November	1971	1,248,551	1,175,389
December	1971	1,242,462	1,169,299
January	1972	1,228,534	1,155,350
February	1972	1,207,442	1,130,193
March	1972	1,198,737	1,112,078
April	1972	1,167,306	1,072,620
May	1972	1,185,350	1,073,107
June	1972	1,162,899	1,039,860
July	1972	1,139,241	1,023,376
August	1972	1,115,935	1,007,049
September	1972	1,095,846	993,172
October	1972	1,080,126	982,595
November	1972	1,077,703	983,151
December	1972	1,086,090	992,641
January	1973	1,137,970	1,038,930
February	1973	1,150,272	1,066,424
March	1973	1,059,379	1,049,084
April	1973	1,082,493	1,085,854
May	1973	1,367,877	1,341,037
June	1973	1,457,501	1,444,134
July	1973	1,419,713	1,406,051
August	1973	1,382,584	1,368,548
September	1973	1,348,910	1,335,753
October	1973	1,318,326	1,309,679
November	1973	1,363,584	1,366,974
December	1973	1,389,950	1,389,863
January	1974	1,397,276	1,397,216
February	1974	1,378,622	1,375,126
March	1974	1,330,540	1,330,481
April	1974	1,319,748	1,319,748
May	1974	1,462,349	1,462,349
June	1974	1,457,646	1,457,646
July	1974	1,442,928	1,442,609
August	1974	1,406,792	1,406,054
September	1974	1,359,211	1,359,211
October	1974	1,327,290	1,327,290
November	1974	1,305,510	1,305,510
December	1974	1,291,343	1,291,347
January	1975	1,279,700	1,279,730
February	1975	1,323,704	1,316,293

March	1975	1,250,389	1,250,389
April	1975	1,173,645	1,173,645
May	1975	1,394,653	1,364,400
June	1975	1,482,206	1,458,180
July	1975	1,447,495	1,447,495
August	1975	1,404,992	1,404,992
September	1975	1,355,265	1,355,265
October	1975	1,341,825	1,341,570
November	1975	1,323,667	1,323,349
December	1975	1,307,553	1,307,239
January	1976	1,291,714	1,291,435
February	1976	1,276,859	1,275,379
March	1976	1,254,061	1,248,858
April	1976	1,222,966	1,212,496
May	1976	1,175,742	1,154,314
June	1976	1,137,977	1,114,345
July	1976	1,114,187	1,096,828
August	1976	1,090,902	1,079,653
September	1976	1,070,822	1,065,168
October	1976	1,055,169	1,054,281
November	1976	1,044,218	1,047,173
December	1976	1,034,537	1,041,049
January	1977	1,025,909	1,036,097
February	1977	1,017,319	1,030,825
March	1977	1,006,530	1,022,720
April	1977	985,123	998,613
May	1977	953,609	965,203
June	1977	916,645	928,189
July	1977	894,239	912,320
August	1977	872,292	896,676
September	1977	853,172	883,269
October	1977	837,995	872,926
November	1977	827,138	865,940
December	1977	845,216	887,478
January	1978	938,251	973,782
February	1978	978,053	1,003,140
March	1978	1,095,414	1,103,384
April	1978	1,175,764	1,195,997
May	1978	1,386,252	1,412,287
June	1978	1,458,451	1,461,352
July	1978	1,450,796	1,452,723
August	1978	1,414,011	1,415,662
September	1978	1,395,369	1,396,838
October	1978	1,369,382	1,370,722
November	1978	1,350,391	1,351,698
December	1978	1,333,518	1,334,828
January	1979	1,358,804	1,359,697

February	1979	1,367,905	1,368,797
March	1979	1,311,272	1,312,128
April	1979	1,316,942	1,317,798
May	1979	1,475,720	1,461,920
June	1979	1,478,018	1,458,260
July	1979	1,440,776	1,420,865
August	1979	1,401,551	1,383,661
September	1979	1,347,611	1,347,611
October	1979	1,322,552	1,322,379
November	1979	1,303,883	1,303,668
December	1979	1,296,483	1,296,270
January	1980	1,378,124	1,378,124
February	1980	1,391,351	1,391,351
March	1980	1,319,326	1,319,326
April	1980	1,372,831	1,367,397
May	1980	1,496,028	1,465,788
June	1980	1,565,747	1,508,700
July	1980	1,581,134	1,569,482
August	1980	1,483,838	1,483,813
September	1980	1,389,548	1,389,548
October	1980	1,351,611	1,351,611
November	1980	1,331,154	1,331,154
December	1980	1,315,138	1,315,138
January	1981	1,324,286	1,324,286
February	1981	1,307,950	1,304,692
March	1981	1,253,501	1,253,501
April	1981	1,276,186	1,263,629
May	1981	1,283,162	1,253,719
June	1981	1,240,954	1,203,849
July	1981	1,204,952	1,168,050
August	1981	1,169,809	1,133,105
September	1981	1,138,933	1,102,371
October	1981	1,114,036	1,077,560
November	1981	1,170,665	1,134,213
December	1981	1,283,279	1,246,824
January	1982	1,321,653	1,300,773
February	1982	1,314,285	1,293,393
March	1982	1,259,907	1,239,015
April	1982	1,362,411	1,344,023
May	1982	1,554,133	1,510,348
June	1982	1,608,721	1,559,725
July	1982	1,579,049	1,576,750
August	1982	1,485,997	1,485,991
September	1982	1,417,366	1,417,366
October	1982	1,368,865	1,368,865
November	1982	1,376,182	1,376,182
December	1982	1,383,734	1,383,734

January	1983	1,314,585	1,314,585
February	1983	1,249,349	1,249,349
March	1983	1,216,036	1,216,036
April	1983	1,157,937	1,157,937
May	1983	1,407,181	1,407,181
June	1983	1,446,712	1,446,712
July	1983	1,571,517	1,571,431
August	1983	1,482,270	1,482,270
September	1983	1,413,610	1,413,610
October	1983	1,371,884	1,371,884
November	1983	1,373,147	1,373,147
December	1983	1,393,499	1,393,499
January	1984	1,356,437	1,356,437
February	1984	1,268,356	1,268,356
March	1984	1,227,034	1,227,034
April	1984	1,236,055	1,229,396
May	1984	1,448,002	1,413,697
June	1984	1,453,192	1,452,992
July	1984	1,423,434	1,423,174
August	1984	1,387,266	1,386,935
September	1984	1,355,672	1,355,285
October	1984	1,330,407	1,329,984
November	1984	1,320,895	1,320,464
December	1984	1,307,057	1,306,626
January	1985	1,291,838	1,291,411
February	1985	1,282,529	1,278,534
March	1985	1,217,046	1,216,507
April	1985	1,272,777	1,256,617
May	1985	1,293,418	1,259,671
June	1985	1,240,054	1,199,431
July	1985	1,203,985	1,163,485
August	1985	1,168,730	1,128,328
September	1985	1,137,813	1,097,473
October	1985	1,112,889	1,072,584
November	1985	1,097,469	1,057,177
December	1985	1,098,091	1,057,798
January	1986	1,101,671	1,061,370
February	1986	1,311,598	1,311,598
March	1986	1,323,674	1,323,674
April	1986	1,399,983	1,386,183
May	1986	1,524,279	1,462,333
June	1986	1,581,187	1,457,972
July	1986	1,537,307	1,451,024
August	1986	1,434,225	1,414,750
September	1986	1,368,592	1,368,592
October	1986	1,343,284	1,343,229
November	1986	1,323,286	1,323,286

December	1986	1,305,194	1,305,194
January	1987	1,289,684	1,289,701
February	1987	1,286,743	1,285,813
March	1987	1,264,218	1,258,149
April	1987	1,235,191	1,219,047
May	1987	1,197,896	1,171,197
June	1987	1,155,044	1,124,930
July	1987	1,131,273	1,107,431
August	1987	1,107,912	1,090,055
September	1987	1,087,743	1,075,353
October	1987	1,071,952	1,064,241
November	1987	1,060,978	1,057,094
December	1987	1,052,783	1,052,404
January	1988	1,046,873	1,049,998
February	1988	1,030,785	1,034,212
March	1988	1,004,577	1,006,421
April	1988	977,464	972,231
May	1988	942,635	929,970
June	1988	904,970	892,563
July	1988	883,053	877,154
August	1988	861,568	862,020
September	1988	842,751	848,990
October	1988	827,769	838,903
November	1988	816,973	831,985
December	1988	807,809	826,377
January	1989	798,792	821,021
February	1989	781,885	804,345
March	1989	859,331	870,721
April	1989	925,652	922,262
May	1989	940,063	923,802
June	1989	919,937	898,374
July	1989	897,869	882,918
August	1989	876,125	867,666
September	1989	857,149	854,556
October	1989	852,738	855,055
November	1989	842,496	848,691
December	1989	833,195	842,945
January	1990	825,489	838,907
February	1990	812,066	826,142
March	1990	789,974	800,415
April	1990	778,451	779,293
May	1990	738,914	733,796
June	1990	704,048	699,006
July	1990	685,549	684,102
August	1990	667,513	669,564
September	1990	651,807	657,041
October	1990	639,344	647,271

November	1990	630,363	640,453
December	1990	622,489	634,581
January	1991	614,785	628,928
February	1991	607,592	623,635
March	1991	637,703	642,232
April	1991	628,177	624,317
May	1991	653,912	635,699
June	1991	696,812	666,606
July	1991	679,943	653,396
August	1991	661,924	638,931
September	1991	646,217	626,444
October	1991	634,620	617,560
November	1991	625,613	610,718
December	1991	618,193	605,299
January	1992	611,390	600,509
February	1992	625,945	604,209
March	1992	609,737	582,528
April	1992	605,705	567,012
May	1992	572,175	526,772
June	1992	548,573	504,327
July	1992	531,600	491,246
August	1992	514,219	477,417
September	1992	498,918	465,336
October	1992	486,615	455,747
November	1992	477,586	448,883
December	1992	472,551	445,672
January	1993	638,672	607,019
February	1993	659,736	617,263
March	1993	770,290	710,940
April	1993	851,257	774,654
May	1993	1,118,124	1,010,359
June	1993	1,318,827	1,187,671
July	1993	1,361,311	1,230,775
August	1993	1,324,481	1,194,524
September	1993	1,292,165	1,162,583
October	1993	1,266,157	1,136,787
November	1993	1,247,152	1,117,843
December	1993	1,231,363	1,102,050
January	1994	1,215,553	1,086,211
February	1994	1,211,078	1,078,989
March	1994	1,180,798	1,043,155
April	1994	1,150,370	1,003,018
May	1994	1,119,199	958,221
June	1994	1,068,136	902,045
July	1994	1,044,493	886,349
August	1994	1,021,061	870,860
September	1994	1,000,741	857,538

October	1994	984,786	847,266
November	1994	987,590	854,134
December	1994	978,805	848,892
January	1995	1,223,455	1,084,128
February	1995	1,181,942	1,059,224
March	1995	1,211,459	1,234,126
April	1995	1,257,197	1,275,763
May	1995	1,410,112	1,419,628
June	1995	1,463,250	1,462,021
July	1995	1,592,660	1,584,110
August	1995	1,489,500	1,491,001
September	1995	1,407,745	1,409,260
October	1995	1,372,156	1,373,415
November	1995	1,350,931	1,352,189
December	1995	1,358,105	1,359,362
January	1996	1,388,720	1,389,977
February	1996	1,394,716	1,394,716
March	1996	1,363,237	1,363,237
April	1996	1,431,809	1,431,809
May	1996	1,567,920	1,539,156
June	1996	1,590,759	1,542,671
July	1996	1,534,996	1,487,117
August	1996	1,426,600	1,409,278
September	1996	1,358,523	1,358,523
October	1996	1,328,572	1,328,572
November	1996	1,358,263	1,358,263
December	1996	1,382,257	1,382,257
January	1997	1,396,300	1,396,300
February	1997	1,319,544	1,319,544
March	1997	1,302,996	1,302,996
April	1997	1,349,853	1,335,539
May	1997	1,469,350	1,458,855
June	1997	1,470,802	1,455,377
July	1997	1,434,027	1,418,630
August	1997	1,397,223	1,381,847
September	1997	1,361,023	1,349,681
October	1997	1,329,791	1,329,791
November	1997	1,311,858	1,311,847
December	1997	1,299,617	1,299,607
January	1998	1,349,044	1,349,044
February	1998	1,329,291	1,329,291
March	1998	1,304,054	1,304,054
April	1998	1,320,902	1,320,902
May	1998	1,391,521	1,391,521
June	1998	1,603,808	1,561,128
July	1998	1,621,047	1,621,047
August	1998	1,488,670	1,488,670

September	1998	1,405,095	1,405,095
October	1998	1,372,253	1,372,253
November	1998	1,359,314	1,359,314
December	1998	1,346,652	1,346,652
January	1999	1,361,782	1,361,782
February	1999	1,360,023	1,360,023
March	1999	1,285,876	1,285,876
April	1999	1,292,394	1,291,870
May	1999	1,473,660	1,462,349
June	1999	1,507,129	1,458,097
July	1999	1,451,890	1,432,911
August	1999	1,408,554	1,396,247
September	1999	1,359,194	1,359,194
October	1999	1,328,782	1,328,782
November	1999	1,309,934	1,309,926
December	1999	1,293,159	1,293,152
January	2000	1,301,840	1,301,840
February	2000	1,311,324	1,311,324
March	2000	1,261,103	1,261,103
April	2000	1,332,826	1,319,026
May	2000	1,502,783	1,461,763
June	2000	1,511,303	1,458,396
July	2000	1,438,850	1,420,805
August	2000	1,394,837	1,383,880
September	2000	1,344,191	1,344,191
October	2000	1,313,470	1,313,470
November	2000	1,294,560	1,294,547
December	2000	1,277,855	1,277,842
January	2001	1,263,657	1,263,651
February	2001	1,260,797	1,257,690
March	2001	1,270,143	1,269,273
April	2001	1,274,194	1,261,572
May	2001	1,347,691	1,313,988
June	2001	1,306,574	1,270,067
July	2001	1,270,039	1,233,542
August	2001	1,234,300	1,197,765
September	2001	1,202,997	1,166,413
October	2001	1,177,803	1,141,175
November	2001	1,163,702	1,127,066
December	2001	1,181,737	1,145,100
January	2002	1,183,112	1,146,479
February	2002	1,159,142	1,118,411
March	2002	1,144,913	1,096,886
April	2002	1,201,920	1,138,332
May	2002	1,254,904	1,172,208
June	2002	1,232,584	1,138,659
July	2002	1,196,355	1,102,814

August	2002	1,160,870	1,067,641
September	2002	1,129,729	1,036,714
October	2002	1,104,577	1,011,679
November	2002	1,118,186	1,025,329
December	2002	1,136,471	1,043,610
January	2003	1,126,230	1,033,350
February	2003	1,103,387	1,007,138
March	2003	1,087,172	984,544
April	2003	1,096,057	982,256
May	2003	1,274,498	1,134,113
June	2003	1,358,476	1,199,319
July	2003	1,323,249	1,182,112
August	2003	1,290,144	1,166,361
September	2003	1,259,180	1,151,080
October	2003	1,234,387	1,139,461
November	2003	1,216,737	1,131,555
December	2003	1,214,905	1,134,396
January	2004	1,210,063	1,136,061
February	2004	1,223,920	1,137,188
March	2004	1,258,621	1,187,535
April	2004	1,291,990	1,216,072
May	2004	1,290,056	1,211,492
June	2004	1,236,781	1,166,237
July	2004	1,199,410	1,128,048
August	2004	1,162,655	1,088,447
September	2004	1,130,383	1,052,874
October	2004	1,107,217	1,028,676
November	2004	1,088,604	1,009,944
December	2004	1,095,182	1,016,521
January	2005	1,178,493	1,144,249
February	2005	1,141,139	1,156,749
March	2005	1,131,896	1,147,298
April	2005	1,169,280	1,183,487
May	2005	1,462,246	1,462,246
June	2005	1,457,546	1,457,546
July	2005	1,450,687	1,450,687
August	2005	1,414,367	1,413,724
September	2005	1,364,050	1,364,050
October	2005	1,334,117	1,334,117
November	2005	1,315,819	1,315,720
December	2005	1,362,004	1,362,004
January	2006	1,382,833	1,382,833
February	2006	1,379,395	1,379,395
March	2006	1,341,081	1,341,081
April	2006	1,403,265	1,389,465
May	2006	1,618,549	1,462,349
June	2006	1,627,526	1,492,536

July	2006	1,580,739	1,475,312
August	2006	1,463,904	1,413,883
September	2006	1,366,957	1,361,944
October	2006	1,329,794	1,329,794
November	2006	1,311,677	1,311,666
December	2006	1,297,008	1,296,998
January	2007	1,282,172	1,282,167
February	2007	1,288,451	1,283,564
March	2007	1,275,821	1,258,055
April	2007	1,259,156	1,231,981
May	2007	1,220,157	1,180,307
June	2007	1,177,800	1,134,828
July	2007	1,142,813	1,117,467
August	2007	1,108,635	1,100,354
September	2007	1,078,595	1,085,865
October	2007	1,054,473	1,074,933
November	2007	1,036,966	1,068,014
December	2007	1,021,434	1,062,233
January	2008	1,038,213	1,076,028
February	2008	1,041,038	1,069,670
March	2008	1,010,552	1,042,913
April	2008	992,555	1,023,407
May	2008	1,026,804	1,052,599
June	2008	986,591	1,017,196
July	2008	964,086	983,369
August	2008	941,949	950,224
September	2008	922,640	920,901
October	2008	907,346	897,143
November	2008	904,486	887,541
December	2008	895,452	872,317
January	2009	923,536	893,982
February	2009	936,770	897,429
March	2009	981,706	934,673
April	2009	1,012,946	944,992
May	2009	1,214,636	1,109,124
June	2009	1,195,688	1,069,117
July	2009	1,161,336	1,052,822
August	2009	1,127,037	1,035,962
September	2009	1,096,854	1,021,555
October	2009	1,091,711	1,029,715
November	2009	1,074,084	1,022,684
December	2009	1,059,593	1,017,931
January	2010	1,081,001	1,038,805
February	2010	1,080,404	1,035,858
March	2010	1,068,439	1,020,044
April	2010	1,099,201	1,038,520
May	2010	1,162,646	1,094,859

June	2010	1,447,599	1,363,316
July	2010	1,447,261	1,363,100
August	2010	1,406,507	1,325,345
September	2010	1,354,759	1,292,317
October	2010	1,371,204	1,330,212
November	2010	1,353,878	1,312,857
December	2010	1,377,652	1,375,336
January	2011	1,354,597	1,352,280
February	2011	1,290,479	1,288,172
March	2011	1,262,100	1,259,803
April	2011	1,316,130	1,313,833
May	2011	1,466,148	1,454,072
June	2011	1,622,976	1,457,303
July	2011	1,621,142	1,494,446
August	2011	1,488,881	1,438,752
September	2011	1,401,945	1,396,928

Month	Year	40%, 175 MGD Total System Storage (AF)	50%, 175 MGD Total System Storage (AF)
July	1920	1,429,724	1,429,724
August	1920	1,398,600	1,398,600
September	1920	1,368,907	1,368,907
October	1920	1,347,395	1,347,395
November	1920	1,332,720	1,332,720
December	1920	1,337,597	1,337,597
January	1921	1,354,811	1,354,811
February	1921	1,345,359	1,337,294
March	1921	1,307,814	1,307,814
April	1921	1,331,465	1,331,465
May	1921	1,441,138	1,418,317
June	1921	1,515,679	1,470,790
July	1921	1,448,877	1,447,256
August	1921	1,409,278	1,409,278
September	1921	1,363,220	1,363,220
October	1921	1,336,116	1,336,116
November	1921	1,316,872	1,316,872
December	1921	1,316,724	1,316,724
January	1922	1,323,419	1,323,422
February	1922	1,290,260	1,290,260
March	1922	1,192,239	1,192,239
April	1922	1,177,944	1,172,211
May	1922	1,470,470	1,453,895
June	1922	1,612,195	1,533,218
July	1922	1,581,610	1,516,008
August	1922	1,472,719	1,422,699
September	1922	1,383,606	1,378,594
October	1922	1,352,319	1,352,319
November	1922	1,338,441	1,338,435
December	1922	1,365,447	1,365,447
January	1923	1,367,421	1,367,421
February	1923	1,359,945	1,359,945
March	1923	1,264,915	1,264,915
April	1923	1,270,233	1,270,233
May	1923	1,442,757	1,415,868
June	1923	1,461,350	1,450,399
July	1923	1,449,971	1,449,971
August	1923	1,418,860	1,418,860
September	1923	1,378,322	1,378,322
October	1923	1,357,485	1,357,461
November	1923	1,342,529	1,342,499
December	1923	1,329,231	1,329,201
January	1924	1,316,385	1,316,359
February	1924	1,304,405	1,302,394
March	1924	1,289,014	1,286,713

April	1924	1,262,324	1,252,827
May	1924	1,227,233	1,206,947
June	1924	1,199,290	1,178,158
July	1924	1,174,416	1,157,630
August	1924	1,149,932	1,137,328
September	1924	1,128,793	1,119,981
October	1924	1,112,268	1,106,687
November	1924	1,104,468	1,101,508
December	1924	1,098,191	1,097,653
January	1925	1,090,269	1,092,247
February	1925	1,168,951	1,161,051
March	1925	1,158,858	1,144,999
April	1925	1,218,388	1,225,097
May	1925	1,414,859	1,397,452
June	1925	1,445,867	1,447,664
July	1925	1,432,431	1,433,893
August	1925	1,400,875	1,401,874
September	1925	1,362,633	1,364,403
October	1925	1,340,904	1,342,412
November	1925	1,325,302	1,326,742
December	1925	1,311,485	1,312,928
January	1926	1,300,796	1,302,270
February	1926	1,316,202	1,312,269
March	1926	1,289,642	1,279,056
April	1926	1,405,633	1,375,391
May	1926	1,419,563	1,373,459
June	1926	1,378,205	1,327,227
July	1926	1,346,716	1,295,062
August	1926	1,315,634	1,262,672
September	1926	1,288,730	1,234,352
October	1926	1,267,504	1,211,957
November	1926	1,294,918	1,239,196
December	1926	1,285,741	1,230,025
January	1927	1,280,686	1,224,992
February	1927	1,320,381	1,287,758
March	1927	1,248,320	1,215,697
April	1927	1,264,855	1,236,437
May	1927	1,385,555	1,333,286
June	1927	1,458,951	1,458,951
July	1927	1,451,201	1,451,201
August	1927	1,420,084	1,418,744
September	1927	1,376,558	1,376,558
October	1927	1,353,492	1,353,492
November	1927	1,346,084	1,345,939
December	1927	1,339,353	1,339,218
January	1928	1,329,575	1,329,504
February	1928	1,328,741	1,324,446

March	1928	1,366,246	1,364,768
April	1928	1,359,005	1,357,526
May	1928	1,459,478	1,434,409
June	1928	1,415,117	1,381,546
July	1928	1,383,535	1,348,708
August	1928	1,352,339	1,315,256
September	1928	1,325,345	1,285,975
October	1928	1,304,013	1,262,466
November	1928	1,289,042	1,247,098
December	1928	1,280,905	1,238,985
January	1929	1,271,718	1,230,002
February	1929	1,262,535	1,218,797
March	1929	1,241,325	1,192,232
April	1929	1,209,360	1,152,304
May	1929	1,255,342	1,177,720
June	1929	1,261,715	1,171,650
July	1929	1,230,056	1,148,968
August	1929	1,198,045	1,126,185
September	1929	1,169,754	1,106,853
October	1929	1,147,373	1,092,275
November	1929	1,132,102	1,082,908
December	1929	1,119,085	1,075,301
January	1930	1,112,102	1,073,776
February	1930	1,097,327	1,060,568
March	1930	1,103,387	1,064,996
April	1930	1,110,748	1,064,497
May	1930	1,108,564	1,056,509
June	1930	1,131,976	1,074,013
July	1930	1,107,224	1,054,049
August	1930	1,082,803	1,034,299
September	1930	1,061,678	1,017,304
October	1930	1,045,211	1,004,273
November	1930	1,033,722	995,452
December	1930	1,023,756	987,891
January	1931	1,016,200	982,700
February	1931	1,002,871	969,348
March	1931	983,276	948,966
April	1931	947,717	908,293
May	1931	909,478	863,123
June	1931	881,235	836,493
July	1931	858,492	818,513
August	1931	836,150	800,934
September	1931	816,534	785,585
October	1931	800,892	773,466
November	1931	789,589	764,859
December	1931	846,526	821,459
January	1932	852,115	826,858

February	1932	938,864	900,022
March	1932	926,414	881,186
April	1932	968,955	913,368
May	1932	1,149,123	1,070,256
June	1932	1,371,535	1,269,327
July	1932	1,399,920	1,298,255
August	1932	1,367,813	1,266,712
September	1932	1,339,946	1,239,282
October	1932	1,317,817	1,217,407
November	1932	1,302,135	1,201,783
December	1932	1,288,440	1,188,084
January	1933	1,280,295	1,179,907
February	1933	1,269,313	1,168,909
March	1933	1,187,045	1,143,814
April	1933	1,165,062	1,113,507
May	1933	1,171,476	1,107,269
June	1933	1,297,682	1,212,274
July	1933	1,264,228	1,180,941
August	1933	1,228,601	1,150,124
September	1933	1,197,118	1,123,272
October	1933	1,161,044	1,101,714
November	1933	1,145,928	1,086,149
December	1933	1,142,190	1,082,404
January	1934	1,146,282	1,086,343
February	1934	1,135,385	1,070,753
March	1934	1,109,057	1,036,834
April	1934	1,075,298	993,909
May	1934	1,028,016	940,495
June	1934	986,897	896,027
July	1934	960,916	877,548
August	1934	925,260	859,411
September	1934	895,988	843,636
October	1934	879,672	831,328
November	1934	868,484	822,922
December	1934	860,720	817,576
January	1935	879,077	838,392
February	1935	862,149	818,166
March	1935	847,908	798,713
April	1935	1,054,217	980,931
May	1935	1,241,517	1,144,425
June	1935	1,446,724	1,327,736
July	1935	1,423,736	1,305,802
August	1935	1,392,921	1,276,226
September	1935	1,366,282	1,250,519
October	1935	1,345,428	1,230,251
November	1935	1,331,035	1,216,012
December	1935	1,319,054	1,204,019

January	1936	1,334,598	1,219,487
February	1936	1,346,008	1,282,931
March	1936	1,294,101	1,231,024
April	1936	1,375,493	1,319,394
May	1936	1,461,784	1,461,784
June	1936	1,457,684	1,457,684
July	1936	1,444,261	1,444,110
August	1936	1,411,920	1,411,920
September	1936	1,367,048	1,367,048
October	1936	1,341,168	1,341,168
November	1936	1,324,563	1,324,563
December	1936	1,313,415	1,313,418
January	1937	1,302,227	1,302,248
February	1937	1,315,691	1,315,691
March	1937	1,235,529	1,235,529
April	1937	1,236,512	1,236,512
May	1937	1,462,349	1,462,349
June	1937	1,458,815	1,458,815
July	1937	1,432,489	1,432,059
August	1937	1,400,880	1,399,838
September	1937	1,366,629	1,366,629
October	1937	1,339,907	1,339,907
November	1937	1,324,404	1,324,313
December	1937	1,380,667	1,380,667
January	1938	1,384,077	1,384,077
February	1938	1,368,280	1,368,280
March	1938	1,313,393	1,313,393
April	1938	1,355,892	1,355,892
May	1938	1,482,051	1,462,051
June	1938	1,605,770	1,456,955
July	1938	1,580,453	1,449,679
August	1938	1,487,620	1,418,805
September	1938	1,404,369	1,391,951
October	1938	1,373,089	1,370,731
November	1938	1,358,866	1,355,828
December	1938	1,348,844	1,345,119
January	1939	1,338,222	1,333,813
February	1939	1,331,414	1,319,486
March	1939	1,331,649	1,315,081
April	1939	1,379,573	1,335,135
May	1939	1,337,554	1,281,421
June	1939	1,298,698	1,238,253
July	1939	1,268,355	1,208,118
August	1939	1,238,683	1,178,619
September	1939	1,212,954	1,153,019
October	1939	1,192,474	1,132,619
November	1939	1,177,683	1,117,850

December	1939	1,164,587	1,104,751
January	1940	1,278,575	1,218,726
February	1940	1,305,909	1,278,173
March	1940	1,279,374	1,254,587
April	1940	1,322,334	1,290,002
May	1940	1,493,220	1,462,144
June	1940	1,507,930	1,457,556
July	1940	1,450,879	1,426,471
August	1940	1,411,038	1,395,827
September	1940	1,367,320	1,367,320
October	1940	1,342,448	1,342,448
November	1940	1,327,734	1,327,684
December	1940	1,351,023	1,351,023
January	1941	1,322,184	1,322,184
February	1941	1,309,804	1,309,804
March	1941	1,247,146	1,247,146
April	1941	1,220,292	1,220,292
May	1941	1,473,190	1,462,349
June	1941	1,542,292	1,453,460
July	1941	1,541,406	1,448,866
August	1941	1,446,256	1,418,561
September	1941	1,382,246	1,382,246
October	1941	1,358,578	1,358,578
November	1941	1,345,922	1,345,899
December	1941	1,382,423	1,382,423
January	1942	1,399,202	1,399,202
February	1942	1,399,202	1,399,202
March	1942	1,315,644	1,315,644
April	1942	1,348,109	1,348,109
May	1942	1,490,576	1,467,004
June	1942	1,582,453	1,529,109
July	1942	1,578,468	1,541,864
August	1942	1,473,000	1,445,354
September	1942	1,384,648	1,379,643
October	1942	1,354,469	1,354,469
November	1942	1,367,419	1,367,419
December	1942	1,375,707	1,375,707
January	1943	1,397,978	1,397,978
February	1943	1,398,129	1,398,129
March	1943	1,361,995	1,361,995
April	1943	1,452,961	1,452,961
May	1943	1,535,963	1,511,243
June	1943	1,552,155	1,509,896
July	1943	1,508,572	1,466,496
August	1943	1,419,565	1,419,565
September	1943	1,377,526	1,377,526
October	1943	1,354,356	1,354,356

November	1943	1,339,815	1,339,809
December	1943	1,327,427	1,327,421
January	1944	1,316,299	1,316,297
February	1944	1,319,567	1,315,428
March	1944	1,269,559	1,269,559
April	1944	1,230,127	1,230,127
May	1944	1,343,124	1,319,558
June	1944	1,345,215	1,307,931
July	1944	1,323,220	1,286,067
August	1944	1,293,432	1,256,389
September	1944	1,267,551	1,230,575
October	1944	1,246,971	1,210,033
November	1944	1,250,792	1,213,867
December	1944	1,245,148	1,208,223
January	1945	1,235,711	1,198,773
February	1945	1,319,982	1,303,516
March	1945	1,230,019	1,213,553
April	1945	1,266,755	1,245,789
May	1945	1,391,516	1,347,030
June	1945	1,480,352	1,457,280
July	1945	1,450,475	1,450,475
August	1945	1,420,002	1,419,830
September	1945	1,377,749	1,377,749
October	1945	1,371,812	1,371,812
November	1945	1,358,682	1,358,655
December	1945	1,393,200	1,393,200
January	1946	1,393,248	1,393,248
February	1946	1,380,536	1,377,415
March	1946	1,310,133	1,310,133
April	1946	1,398,408	1,390,129
May	1946	1,507,924	1,459,058
June	1946	1,497,525	1,453,063
July	1946	1,447,466	1,421,980
August	1946	1,410,857	1,391,446
September	1946	1,367,962	1,365,005
October	1946	1,347,250	1,344,186
November	1946	1,352,481	1,349,392
December	1946	1,344,175	1,341,088
January	1947	1,333,387	1,330,311
February	1947	1,325,411	1,318,200
March	1947	1,285,170	1,282,685
April	1947	1,266,901	1,254,447
May	1947	1,302,808	1,272,099
June	1947	1,255,736	1,219,253
July	1947	1,225,562	1,188,951
August	1947	1,195,983	1,159,092
September	1947	1,170,261	1,133,110

October	1947	1,151,152	1,113,855
November	1947	1,136,510	1,099,182
December	1947	1,123,976	1,086,650
January	1948	1,114,796	1,077,487
February	1948	1,102,552	1,063,903
March	1948	1,082,821	1,040,379
April	1948	1,078,576	1,024,702
May	1948	1,177,039	1,100,710
June	1948	1,311,050	1,212,576
July	1948	1,291,668	1,202,402
August	1948	1,262,396	1,182,169
September	1948	1,236,976	1,164,896
October	1948	1,216,882	1,151,637
November	1948	1,202,645	1,142,739
December	1948	1,190,922	1,135,874
January	1949	1,179,411	1,129,373
February	1949	1,167,312	1,119,910
March	1949	1,172,291	1,126,313
April	1949	1,238,673	1,179,991
May	1949	1,331,002	1,256,650
June	1949	1,326,981	1,248,355
July	1949	1,295,018	1,216,840
August	1949	1,263,368	1,185,643
September	1949	1,235,911	1,158,458
October	1949	1,213,980	1,136,639
November	1949	1,198,332	1,121,022
December	1949	1,184,966	1,107,656
January	1950	1,193,822	1,116,492
February	1950	1,200,821	1,117,072
March	1950	1,165,352	1,089,821
April	1950	1,239,542	1,155,143
May	1950	1,380,684	1,272,204
June	1950	1,423,290	1,298,589
July	1950	1,392,197	1,267,512
August	1950	1,359,902	1,233,704
September	1950	1,332,133	1,204,394
October	1950	1,313,486	1,184,799
November	1950	1,385,060	1,385,045
December	1950	1,399,202	1,399,202
January	1951	1,399,202	1,399,202
February	1951	1,392,445	1,385,985
March	1951	1,320,335	1,320,335
April	1951	1,363,695	1,356,435
May	1951	1,451,368	1,424,788
June	1951	1,446,063	1,406,207
July	1951	1,415,174	1,375,308
August	1951	1,384,792	1,344,850

September	1951	1,358,446	1,318,430
October	1951	1,337,608	1,297,537
November	1951	1,322,996	1,282,915
December	1951	1,347,099	1,323,190
January	1952	1,252,965	1,229,044
February	1952	1,166,317	1,144,209
March	1952	1,091,200	1,072,655
April	1952	1,176,529	1,161,237
May	1952	1,483,205	1,459,779
June	1952	1,574,018	1,457,841
July	1952	1,581,313	1,481,253
August	1952	1,487,765	1,437,732
September	1952	1,401,706	1,396,690
October	1952	1,371,657	1,371,657
November	1952	1,355,865	1,355,865
December	1952	1,361,912	1,361,913
January	1953	1,391,275	1,391,275
February	1953	1,384,064	1,376,390
March	1953	1,296,224	1,296,224
April	1953	1,338,597	1,335,451
May	1953	1,336,118	1,319,609
June	1953	1,454,772	1,416,963
July	1953	1,450,116	1,438,566
August	1953	1,414,746	1,408,142
September	1953	1,371,409	1,371,409
October	1953	1,344,949	1,344,949
November	1953	1,330,177	1,330,177
December	1953	1,317,487	1,317,487
January	1954	1,316,952	1,316,956
February	1954	1,314,033	1,308,763
March	1954	1,300,940	1,300,940
April	1954	1,367,423	1,367,423
May	1954	1,462,144	1,449,781
June	1954	1,425,978	1,404,040
July	1954	1,394,997	1,373,030
August	1954	1,364,617	1,342,571
September	1954	1,338,291	1,316,176
October	1954	1,317,424	1,295,261
November	1954	1,302,780	1,280,605
December	1954	1,298,291	1,276,118
January	1955	1,300,791	1,278,620
February	1955	1,286,980	1,261,647
March	1955	1,248,037	1,228,210
April	1955	1,202,742	1,184,382
May	1955	1,253,578	1,216,195
June	1955	1,284,670	1,232,266
July	1955	1,254,241	1,201,941

August	1955	1,224,357	1,172,076
September	1955	1,198,375	1,146,082
October	1955	1,177,671	1,125,364
November	1955	1,162,879	1,110,572
December	1955	1,395,267	1,395,267
January	1956	1,366,430	1,366,430
February	1956	1,281,137	1,281,137
March	1956	1,223,009	1,223,009
April	1956	1,264,383	1,262,716
May	1956	1,459,517	1,437,440
June	1956	1,551,971	1,493,387
July	1956	1,559,601	1,501,272
August	1956	1,472,454	1,434,945
September	1956	1,397,748	1,395,601
October	1956	1,372,823	1,372,823
November	1956	1,358,223	1,358,216
December	1956	1,345,515	1,345,509
January	1957	1,334,517	1,334,514
February	1957	1,360,306	1,347,372
March	1957	1,304,994	1,304,994
April	1957	1,287,739	1,287,739
May	1957	1,370,862	1,351,226
June	1957	1,454,115	1,441,165
July	1957	1,426,924	1,413,950
August	1957	1,396,520	1,383,506
September	1957	1,364,131	1,357,147
October	1957	1,340,110	1,336,240
November	1957	1,325,436	1,321,553
December	1957	1,319,574	1,315,691
January	1958	1,319,928	1,316,051
February	1958	1,353,990	1,343,899
March	1958	1,264,077	1,260,901
April	1958	1,270,786	1,267,611
May	1958	1,542,198	1,462,349
June	1958	1,625,326	1,498,271
July	1958	1,578,915	1,500,547
August	1958	1,487,287	1,437,256
September	1958	1,400,708	1,395,690
October	1958	1,370,290	1,370,290
November	1958	1,353,337	1,353,337
December	1958	1,338,556	1,338,556
January	1959	1,349,921	1,349,921
February	1959	1,373,858	1,373,858
March	1959	1,342,364	1,340,618
April	1959	1,342,674	1,325,213
May	1959	1,317,469	1,288,060
June	1959	1,268,837	1,232,347

July	1959	1,238,690	1,202,336
August	1959	1,209,194	1,172,951
September	1959	1,199,067	1,162,910
October	1959	1,178,637	1,142,528
November	1959	1,163,858	1,127,761
December	1959	1,150,825	1,114,727
January	1960	1,139,900	1,103,796
February	1960	1,159,420	1,117,161
March	1960	1,150,533	1,100,581
April	1960	1,156,262	1,094,055
May	1960	1,159,017	1,081,301
June	1960	1,126,054	1,040,276
July	1960	1,101,828	1,020,883
August	1960	1,077,992	1,001,749
September	1960	1,057,345	985,279
October	1960	1,041,124	972,538
November	1960	1,030,152	964,248
December	1960	1,021,770	958,285
January	1961	1,013,186	952,194
February	1961	999,778	938,722
March	1961	981,092	918,891
April	1961	960,728	891,845
May	1961	917,065	840,973
June	1961	874,059	795,573
July	1961	851,696	777,694
August	1961	829,865	760,300
September	1961	810,685	745,176
October	1961	795,346	733,236
November	1961	784,144	724,689
December	1961	774,333	717,297
January	1962	764,906	710,350
February	1962	873,852	807,102
March	1962	870,295	797,632
April	1962	1,020,611	929,703
May	1962	1,095,922	990,410
June	1962	1,244,294	1,120,034
July	1962	1,229,830	1,106,126
August	1962	1,199,332	1,076,068
September	1962	1,172,701	1,049,686
October	1962	1,151,576	1,028,662
November	1962	1,136,210	1,013,325
December	1962	1,125,709	1,002,822
January	1963	1,209,710	1,085,727
February	1963	1,349,555	1,209,585
March	1963	1,349,466	1,203,717
April	1963	1,307,492	1,228,189
May	1963	1,462,349	1,391,557

June	1963	1,450,778	1,450,778
July	1963	1,446,455	1,446,455
August	1963	1,415,016	1,413,942
September	1963	1,374,412	1,374,412
October	1963	1,350,161	1,350,161
November	1963	1,362,105	1,361,999
December	1963	1,349,571	1,349,473
January	1964	1,347,660	1,347,614
February	1964	1,334,072	1,331,351
March	1964	1,313,747	1,307,075
April	1964	1,288,103	1,272,566
May	1964	1,310,040	1,277,593
June	1964	1,281,369	1,237,221
July	1964	1,250,731	1,206,631
August	1964	1,220,612	1,176,674
September	1964	1,194,443	1,150,666
October	1964	1,173,631	1,129,971
November	1964	1,160,363	1,116,729
December	1964	1,378,319	1,378,319
January	1965	1,394,933	1,394,933
February	1965	1,311,011	1,311,011
March	1965	1,224,062	1,224,062
April	1965	1,241,925	1,241,925
May	1965	1,360,543	1,337,336
June	1965	1,457,696	1,457,696
July	1965	1,451,021	1,451,021
August	1965	1,428,847	1,428,728
September	1965	1,398,624	1,398,624
October	1965	1,373,535	1,373,535
November	1965	1,377,450	1,377,450
December	1965	1,378,795	1,378,795
January	1966	1,371,905	1,371,911
February	1966	1,360,866	1,360,866
March	1966	1,307,081	1,307,081
April	1966	1,375,452	1,341,696
May	1966	1,404,042	1,352,032
June	1966	1,362,456	1,306,169
July	1966	1,331,753	1,275,679
August	1966	1,301,717	1,245,827
September	1966	1,275,665	1,219,900
October	1966	1,254,946	1,199,252
November	1966	1,256,963	1,201,290
December	1966	1,332,270	1,312,156
January	1967	1,354,585	1,336,063
February	1967	1,313,988	1,295,456
March	1967	1,284,239	1,265,708
April	1967	1,206,115	1,189,202

May	1967	1,453,292	1,418,310
June	1967	1,602,520	1,494,675
July	1967	1,615,590	1,575,677
August	1967	1,485,067	1,484,982
September	1967	1,403,705	1,403,705
October	1967	1,372,950	1,372,950
November	1967	1,358,333	1,358,333
December	1967	1,346,486	1,346,486
January	1968	1,348,773	1,348,773
February	1968	1,380,372	1,373,443
March	1968	1,352,825	1,348,958
April	1968	1,347,516	1,335,175
May	1968	1,332,855	1,305,681
June	1968	1,290,163	1,255,831
July	1968	1,259,932	1,225,784
August	1968	1,230,368	1,196,400
September	1968	1,204,651	1,170,811
October	1968	1,184,173	1,150,412
November	1968	1,177,633	1,143,894
December	1968	1,176,079	1,142,338
January	1969	1,290,464	1,275,322
February	1969	1,204,386	1,189,237
March	1969	1,137,845	1,123,786
April	1969	1,216,542	1,203,474
May	1969	1,549,822	1,495,358
June	1969	1,627,073	1,585,172
July	1969	1,596,526	1,580,507
August	1969	1,485,162	1,485,127
September	1969	1,397,444	1,397,444
October	1969	1,372,995	1,372,995
November	1969	1,358,385	1,358,385
December	1969	1,356,130	1,356,130
January	1970	1,382,053	1,382,053
February	1970	1,375,843	1,375,843
March	1970	1,316,742	1,316,742
April	1970	1,275,393	1,274,351
May	1970	1,366,393	1,344,144
June	1970	1,428,810	1,389,317
July	1970	1,402,262	1,362,967
August	1970	1,372,017	1,332,920
September	1970	1,345,808	1,306,855
October	1970	1,325,014	1,286,146
November	1970	1,336,097	1,297,251
December	1970	1,356,685	1,317,838
January	1971	1,366,800	1,332,002
February	1971	1,347,394	1,307,720
March	1971	1,287,286	1,252,473

April	1971	1,260,491	1,226,108
May	1971	1,304,988	1,252,600
June	1971	1,426,349	1,352,594
July	1971	1,407,298	1,333,885
August	1971	1,376,986	1,303,907
September	1971	1,350,736	1,277,891
October	1971	1,329,951	1,257,244
November	1971	1,317,183	1,244,514
December	1971	1,314,433	1,241,763
January	1972	1,304,000	1,231,301
February	1972	1,286,149	1,209,382
March	1972	1,281,100	1,194,930
April	1972	1,253,628	1,159,429
May	1972	1,276,824	1,165,096
June	1972	1,259,317	1,136,718
July	1972	1,234,350	1,116,776
August	1972	1,209,750	1,097,092
September	1972	1,188,606	1,080,276
October	1972	1,172,089	1,067,322
November	1972	1,169,149	1,067,085
December	1972	1,177,123	1,077,317
January	1973	1,229,716	1,126,062
February	1973	1,189,253	1,152,651
March	1973	1,095,117	1,059,379
April	1973	1,114,164	1,082,493
May	1973	1,398,403	1,336,555
June	1973	1,459,334	1,437,268
July	1973	1,427,621	1,405,386
August	1973	1,396,413	1,373,937
September	1973	1,367,339	1,346,651
October	1973	1,341,278	1,325,227
November	1973	1,378,570	1,379,664
December	1973	1,390,580	1,390,580
January	1974	1,397,280	1,397,280
February	1974	1,381,822	1,378,383
March	1974	1,333,016	1,333,016
April	1974	1,319,748	1,319,748
May	1974	1,471,442	1,461,830
June	1974	1,516,982	1,456,984
July	1974	1,470,918	1,446,667
August	1974	1,416,616	1,416,101
September	1974	1,370,016	1,370,016
October	1974	1,342,617	1,342,617
November	1974	1,324,465	1,324,465
December	1974	1,313,630	1,313,634
January	1975	1,305,444	1,305,468
February	1975	1,351,714	1,344,297

March	1975	1,274,022	1,274,022
April	1975	1,210,192	1,196,392
May	1975	1,424,790	1,392,325
June	1975	1,531,018	1,458,033
July	1975	1,491,578	1,447,653
August	1975	1,410,981	1,410,981
September	1975	1,366,582	1,366,582
October	1975	1,357,691	1,357,509
November	1975	1,343,167	1,342,939
December	1975	1,330,390	1,330,166
January	1976	1,318,015	1,317,816
February	1976	1,306,372	1,304,968
March	1976	1,287,232	1,282,123
April	1976	1,260,120	1,249,755
May	1976	1,218,186	1,196,831
June	1976	1,185,642	1,161,952
July	1976	1,160,892	1,141,008
August	1976	1,136,660	1,120,366
September	1976	1,115,770	1,102,843
October	1976	1,099,468	1,089,491
November	1976	1,088,042	1,080,606
December	1976	1,077,944	1,072,939
January	1977	1,068,906	1,066,464
February	1977	1,059,926	1,059,735
March	1977	1,048,672	1,049,826
April	1977	1,026,398	1,025,492
May	1977	993,551	990,539
June	1977	955,723	950,284
July	1977	932,294	929,157
August	1977	909,342	918,795
September	1977	889,369	903,661
October	1977	873,524	891,719
November	1977	862,182	883,176
December	1977	879,844	903,260
January	1978	971,641	992,848
February	1978	1,011,626	1,022,420
March	1978	1,128,972	1,122,622
April	1978	1,175,426	1,201,618
May	1978	1,386,180	1,407,792
June	1978	1,459,852	1,458,679
July	1978	1,451,539	1,451,327
August	1978	1,420,574	1,419,713
September	1978	1,407,227	1,405,955
October	1978	1,373,877	1,373,668
November	1978	1,358,513	1,358,228
December	1978	1,344,978	1,344,700
January	1979	1,371,385	1,371,177

February	1979	1,383,695	1,383,488
March	1979	1,323,202	1,323,556
April	1979	1,329,317	1,328,664
May	1979	1,475,633	1,461,920
June	1979	1,480,542	1,459,033
July	1979	1,449,301	1,427,378
August	1979	1,410,526	1,395,668
September	1979	1,361,911	1,362,898
October	1979	1,341,379	1,342,021
November	1979	1,326,339	1,326,897
December	1979	1,322,275	1,322,837
January	1980	1,384,527	1,385,507
February	1980	1,391,351	1,391,351
March	1980	1,320,533	1,320,533
April	1980	1,373,168	1,359,368
May	1980	1,498,879	1,462,134
June	1980	1,571,198	1,458,771
July	1980	1,581,292	1,493,521
August	1980	1,487,702	1,437,664
September	1980	1,398,740	1,393,719
October	1980	1,365,328	1,365,328
November	1980	1,348,498	1,348,498
December	1980	1,335,824	1,335,824
January	1981	1,348,440	1,348,440
February	1981	1,335,311	1,332,054
March	1981	1,274,042	1,274,042
April	1981	1,302,204	1,272,725
May	1981	1,313,616	1,267,287
June	1981	1,276,615	1,222,673
July	1981	1,246,396	1,192,718
August	1981	1,216,859	1,163,429
September	1981	1,191,144	1,137,888
October	1981	1,170,668	1,117,519
November	1981	1,230,900	1,177,779
December	1981	1,325,497	1,293,451
January	1982	1,355,434	1,335,070
February	1982	1,347,470	1,327,096
March	1982	1,293,092	1,272,718
April	1982	1,392,892	1,373,666
May	1982	1,555,430	1,527,766
June	1982	1,609,740	1,580,156
July	1982	1,583,547	1,578,759
August	1982	1,487,151	1,487,140
September	1982	1,418,309	1,418,309
October	1982	1,369,578	1,369,578
November	1982	1,377,759	1,377,759
December	1982	1,385,625	1,385,625

January	1983	1,314,043	1,314,043
February	1983	1,247,215	1,247,215
March	1983	1,216,036	1,216,036
April	1983	1,157,937	1,157,937
May	1983	1,407,181	1,407,181
June	1983	1,448,406	1,448,406
July	1983	1,575,218	1,575,144
August	1983	1,488,169	1,488,095
September	1983	1,415,968	1,415,968
October	1983	1,373,055	1,373,055
November	1983	1,377,024	1,377,024
December	1983	1,394,267	1,394,267
January	1984	1,356,437	1,356,437
February	1984	1,271,561	1,271,561
March	1984	1,226,283	1,226,283
April	1984	1,238,000	1,232,790
May	1984	1,450,495	1,422,206
June	1984	1,460,014	1,452,386
July	1984	1,436,211	1,428,568
August	1984	1,405,813	1,398,142
September	1984	1,366,958	1,366,958
October	1984	1,346,222	1,346,187
November	1984	1,340,338	1,340,295
December	1984	1,329,834	1,329,792
January	1985	1,318,076	1,318,038
February	1985	1,311,979	1,308,374
March	1985	1,244,581	1,244,581
April	1985	1,303,804	1,288,183
May	1985	1,329,659	1,296,450
June	1985	1,281,510	1,241,422
July	1985	1,251,247	1,211,273
August	1985	1,221,617	1,181,731
September	1985	1,195,871	1,156,045
October	1985	1,175,373	1,135,583
November	1985	1,163,553	1,123,775
December	1985	1,167,516	1,127,737
January	1986	1,174,579	1,134,794
February	1986	1,311,948	1,311,402
March	1986	1,325,360	1,324,813
April	1986	1,401,670	1,387,323
May	1986	1,527,374	1,461,736
June	1986	1,586,884	1,457,231
July	1986	1,546,135	1,450,593
August	1986	1,448,847	1,420,234
September	1986	1,379,319	1,379,319
October	1986	1,358,537	1,358,521
November	1986	1,342,167	1,342,167

December	1986	1,327,415	1,327,415
January	1987	1,315,375	1,315,387
February	1987	1,315,648	1,314,712
March	1987	1,296,776	1,290,707
April	1987	1,271,299	1,255,175
May	1987	1,239,316	1,212,683
June	1987	1,201,758	1,171,769
July	1987	1,177,139	1,151,465
August	1987	1,152,956	1,131,442
September	1987	1,132,069	1,114,324
October	1987	1,115,689	1,101,156
November	1987	1,104,257	1,092,336
December	1987	1,095,645	1,086,149
January	1988	1,089,324	1,082,157
February	1988	1,072,849	1,065,049
March	1988	1,046,198	1,035,566
April	1988	1,018,535	1,001,304
May	1988	982,751	958,352
June	1988	944,224	918,784
July	1988	921,267	900,382
August	1988	898,749	882,357
September	1988	879,059	866,719
October	1988	863,397	854,457
November	1988	852,114	845,831
December	1988	842,534	838,673
January	1989	833,102	831,741
February	1989	815,803	813,603
March	1989	892,797	878,505
April	1989	958,272	930,621
May	1989	971,390	931,509
June	1989	950,445	904,040
July	1989	927,374	885,776
August	1989	904,655	867,835
September	1989	884,865	852,269
October	1989	879,812	850,710
November	1989	869,090	842,671
December	1989	859,374	835,372
January	1990	851,252	829,732
February	1990	837,439	815,481
March	1990	814,894	788,869
April	1990	801,930	767,591
May	1990	761,832	721,669
June	1990	726,302	684,890
July	1990	707,090	672,246
August	1990	688,374	659,900
September	1990	672,042	649,356
October	1990	659,054	640,567

November	1990	649,678	632,933
December	1990	641,424	625,309
January	1991	633,340	618,225
February	1991	625,798	611,796
March	1991	655,593	629,573
April	1991	646,615	610,587
May	1991	672,333	621,980
June	1991	714,612	653,354
July	1991	697,035	641,379
August	1991	678,323	629,098
September	1991	661,987	617,913
October	1991	649,870	609,755
November	1991	640,466	602,108
December	1991	632,666	594,825
January	1992	625,481	588,338
February	1992	640,034	591,487
March	1992	623,396	569,275
April	1992	618,580	553,189
May	1992	585,043	512,965
June	1992	560,812	490,915
July	1992	543,035	479,051
August	1992	524,897	467,411
September	1992	508,927	456,643
October	1992	496,092	447,793
November	1992	486,666	440,123
December	1992	481,250	434,545
January	1993	647,613	594,001
February	1993	668,893	605,847
March	1993	779,445	699,523
April	1993	860,407	761,621
May	1993	1,127,017	997,415
June	1993	1,327,084	1,174,857
July	1993	1,375,526	1,224,115
August	1993	1,344,467	1,193,888
September	1993	1,317,432	1,167,438
October	1993	1,295,923	1,146,275
November	1993	1,280,540	1,130,985
December	1993	1,268,091	1,118,529
January	1994	1,255,756	1,106,148
February	1994	1,254,500	1,102,140
March	1994	1,227,884	1,069,982
April	1994	1,201,944	1,034,026
May	1994	1,176,243	994,770
June	1994	1,130,328	943,802
July	1994	1,105,634	925,082
August	1994	1,081,199	906,692
September	1994	1,060,067	890,767

October	1994	1,043,477	878,324
November	1994	1,045,802	883,485
December	1994	1,036,600	876,692
January	1995	1,255,829	1,116,709
February	1995	1,193,975	1,091,887
March	1995	1,221,548	1,238,095
April	1995	1,265,698	1,278,360
May	1995	1,418,102	1,421,891
June	1995	1,499,675	1,462,298
July	1995	1,622,362	1,594,238
August	1995	1,506,203	1,491,345
September	1995	1,414,009	1,414,905
October	1995	1,373,306	1,372,389
November	1995	1,355,708	1,354,793
December	1995	1,366,219	1,365,305
January	1996	1,393,223	1,393,223
February	1996	1,395,648	1,395,648
March	1996	1,363,237	1,363,237
April	1996	1,432,136	1,432,136
May	1996	1,570,292	1,541,527
June	1996	1,596,654	1,548,566
July	1996	1,543,391	1,495,511
August	1996	1,440,788	1,416,315
September	1996	1,370,880	1,370,880
October	1996	1,345,451	1,345,451
November	1996	1,378,770	1,378,770
December	1996	1,399,202	1,399,202
January	1997	1,399,202	1,399,202
February	1997	1,322,148	1,322,148
March	1997	1,304,196	1,304,196
April	1997	1,355,371	1,341,058
May	1997	1,474,955	1,458,855
June	1997	1,478,998	1,455,229
July	1997	1,447,832	1,424,479
August	1997	1,416,519	1,393,506
September	1997	1,372,335	1,366,648
October	1997	1,345,625	1,345,625
November	1997	1,331,320	1,331,310
December	1997	1,322,419	1,322,410
January	1998	1,369,846	1,369,846
February	1998	1,357,450	1,357,450
March	1998	1,328,431	1,328,431
April	1998	1,341,713	1,341,713
May	1998	1,412,321	1,412,321
June	1998	1,605,681	1,574,573
July	1998	1,620,883	1,620,883
August	1998	1,489,275	1,489,275

September	1998	1,411,025	1,411,025
October	1998	1,372,713	1,372,713
November	1998	1,363,401	1,363,401
December	1998	1,354,077	1,354,077
January	1999	1,372,060	1,372,060
February	1999	1,372,219	1,372,219
March	1999	1,296,020	1,296,020
April	1999	1,302,535	1,302,535
May	1999	1,481,376	1,462,152
June	1999	1,517,430	1,467,343
July	1999	1,453,329	1,448,099
August	1999	1,413,123	1,413,123
September	1999	1,369,093	1,369,093
October	1999	1,343,208	1,343,208
November	1999	1,327,987	1,327,980
December	1999	1,314,545	1,314,539
January	2000	1,326,682	1,326,682
February	2000	1,338,760	1,338,760
March	2000	1,284,082	1,284,082
April	2000	1,351,770	1,337,970
May	2000	1,515,163	1,469,337
June	2000	1,526,253	1,464,503
July	2000	1,444,716	1,432,929
August	2000	1,406,528	1,401,836
September	2000	1,361,199	1,361,199
October	2000	1,334,998	1,334,998
November	2000	1,319,718	1,319,708
December	2000	1,306,350	1,306,341
January	2001	1,295,623	1,295,619
February	2001	1,295,980	1,292,874
March	2001	1,307,619	1,306,758
April	2001	1,315,718	1,303,110
May	2001	1,394,404	1,360,732
June	2001	1,358,490	1,322,040
July	2001	1,327,730	1,291,333
August	2001	1,297,590	1,261,209
September	2001	1,271,440	1,235,064
October	2001	1,250,668	1,214,287
November	2001	1,240,167	1,203,787
December	2001	1,261,542	1,225,162
January	2002	1,266,420	1,230,029
February	2002	1,245,688	1,205,204
March	2002	1,215,635	1,187,336
April	2002	1,277,088	1,233,207
May	2002	1,334,952	1,271,865
June	2002	1,317,675	1,243,217
July	2002	1,287,009	1,212,704

August	2002	1,256,922	1,182,643
September	2002	1,230,806	1,156,492
October	2002	1,210,001	1,135,641
November	2002	1,227,192	1,152,834
December	2002	1,245,620	1,171,262
January	2003	1,236,051	1,161,687
February	2003	1,216,450	1,138,706
March	2003	1,203,703	1,119,548
April	2003	1,215,901	1,120,471
May	2003	1,398,793	1,276,565
June	2003	1,455,804	1,346,444
July	2003	1,425,197	1,316,763
August	2003	1,396,657	1,288,877
September	2003	1,365,951	1,262,767
October	2003	1,339,421	1,242,151
November	2003	1,324,745	1,228,038
December	2003	1,325,693	1,229,549
January	2004	1,323,864	1,228,212
February	2004	1,333,632	1,237,353
March	2004	1,339,183	1,271,430
April	2004	1,376,218	1,294,509
May	2004	1,378,393	1,279,921
June	2004	1,329,439	1,224,037
July	2004	1,298,327	1,191,449
August	2004	1,267,643	1,157,698
September	2004	1,241,016	1,127,981
October	2004	1,222,834	1,108,251
November	2004	1,208,451	1,093,072
December	2004	1,219,052	1,102,988
January	2005	1,289,576	1,198,431
February	2005	1,236,796	1,225,283
March	2005	1,212,718	1,231,979
April	2005	1,237,981	1,253,828
May	2005	1,462,230	1,462,349
June	2005	1,458,049	1,459,342
July	2005	1,451,491	1,451,823
August	2005	1,420,998	1,420,823
September	2005	1,376,007	1,376,335
October	2005	1,350,599	1,350,926
November	2005	1,335,943	1,336,178
December	2005	1,377,561	1,377,887
January	2006	1,387,340	1,387,340
February	2006	1,386,850	1,386,850
March	2006	1,343,228	1,343,228
April	2006	1,403,265	1,389,465
May	2006	1,618,549	1,473,000
June	2006	1,628,299	1,545,112

July	2006	1,581,818	1,530,811
August	2006	1,470,802	1,429,548
September	2006	1,379,180	1,374,167
October	2006	1,346,540	1,346,540
November	2006	1,332,052	1,332,048
December	2006	1,320,721	1,320,717
January	2007	1,309,361	1,309,359
February	2007	1,318,859	1,313,974
March	2007	1,311,631	1,292,128
April	2007	1,298,559	1,269,655
May	2007	1,265,008	1,223,447
June	2007	1,227,908	1,183,253
July	2007	1,197,826	1,162,978
August	2007	1,168,462	1,143,061
September	2007	1,142,881	1,126,029
October	2007	1,122,512	1,112,972
November	2007	1,107,997	1,104,362
December	2007	1,095,242	1,097,031
January	2008	1,114,943	1,116,348
February	2008	1,115,224	1,109,995
March	2008	1,087,764	1,081,529
April	2008	1,073,074	1,061,845
May	2008	1,111,313	1,089,411
June	2008	1,075,366	1,051,343
July	2008	1,046,278	1,021,669
August	2008	1,017,801	992,559
September	2008	992,845	966,967
October	2008	972,781	946,234
November	2008	966,144	938,941
December	2008	953,698	925,807
January	2009	978,371	949,790
February	2009	989,902	955,905
March	2009	1,036,121	991,464
April	2009	1,062,901	1,004,401
May	2009	1,259,415	1,171,935
June	2009	1,234,954	1,135,567
July	2009	1,205,306	1,106,397
August	2009	1,175,557	1,077,099
September	2009	1,149,641	1,051,491
October	2009	1,148,125	1,050,171
November	2009	1,133,450	1,035,546
December	2009	1,121,736	1,023,830
January	2010	1,146,145	1,048,210
February	2010	1,148,211	1,044,798
March	2010	1,139,251	1,027,620
April	2010	1,171,600	1,046,290
May	2010	1,239,081	1,094,249

June	2010	1,457,288	1,351,759
July	2010	1,449,886	1,358,291
August	2010	1,412,408	1,327,072
September	2010	1,366,650	1,300,042
October	2010	1,373,321	1,343,141
November	2010	1,360,301	1,330,068
December	2010	1,381,129	1,381,129
January	2011	1,363,797	1,363,797
February	2011	1,297,517	1,297,517
March	2011	1,267,942	1,267,942
April	2011	1,335,693	1,321,893
May	2011	1,489,441	1,461,685
June	2011	1,627,727	1,457,727
July	2011	1,621,319	1,515,232
August	2011	1,489,875	1,446,694
September	2011	1,408,925	1,403,908

The values in this spreadsheet are from model runs used to create the tables included in the file "Annual rationing comparison tables with notes 6Feb2017.pdf"

The total system storage values in this spreadsheet represent the simulated storage volume in Hetch Hetchy, Cherry, Eleanor, Calaveras, San Antonio, Crystal Springs, San Andreas and Pilarcitos reservoirs, plus the balance of the SFPUC Water Bank Account in New Don Pedro Reservoir.

The values in the tab "265" are from model simulations that assume a system demand of 265 MGD. This pattern holds for the other tabs.

The level of assumed contribution to Tuolumne River flow per SWRCB SED alternative is indicated in the column heading for each set of system storage data. For example, "40%, 265 MGD" indicates a 40% unimpaired flow requirement and a system demand of 265 MGD. See the notes attached to the annual rationing comparison tables for more information on how the SED alternatives were evaluated.

The storage values represent simulated system storage at the end of the timestep.