Chapter 19

# Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30

## 19.1 General Introduction

The State Water Resources Control Board (State Water Board) is in the process of reviewing the San Joaquin River (SJR) flow objectives for the protection of fish and wildlife beneficial uses, water quality objectives for the protection of southern delta agricultural beneficial uses, and the program of implementation for those objectives contained in the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (2006 Bay-Delta Plan). The project area, which includes the Stanislaus, Tuolumne, and Merced Rivers and the Lower SJR (LSJR) between the confluence of the Merced River and Vernalis, is the focus of the following benefits analysis.

This chapter presents biologically important and measurable benefits of providing higher and more variable flow during the February 1 through June 30 time period. Specifically, the benefits of improved temperature and floodplain habitat relative to Central Valley fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley steelhead (*Oncorhynchus mykiss*) during February through June are quantified and compared between Baseline flows, and 20%, 30%, 40%, 50%, and 60% unimpaired flows[1] on the lower Stanislaus, Tuolumne, Merced, and LSJ Rivers. However, modifying flows in this time period may have unanticipated temperature benefits or impacts during other time periods. For example, modifying flow requirements in the spring season could alter reservoir levels in the fall and result in changes to river temperatures. Therefore, potential temperature effects were analyzed during all months of the year on these rivers. By evaluating the full range of unimpaired flows (20-60%), and evaluating effects during all months of the year, this chapter includes the range of unimpaired flows that could occur under the LSJR alternatives described in Chapter 3, *Alternatives Description*, because adaptive implementation could be applied to each of the alternatives.

In addition to evaluating temperature and floodplain benefits of the project, a life-history population simulation model for fall-run Chinook salmon originating from the SJR and its upper three east-side salmon bearing tributaries (Stanislaus, Tuolumne, and Merced Rivers) was used to provide insight into population level changes that could be expected under a variety of unimpaired flow scenarios. The model used is called SalSim and was developed by the California Department of Fish and Wildlife (CDFW), AD Consultants, and a variety of other modeling and fisheries experts (CDFW 2013a; CDFW 2014). The State Water Board used the model to compare effects of unimpaired and baseline flow scenarios on salmon by evaluating potential changes in annual salmon production.

---

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

The results of the temperature, floodplain, and SalSim analysis presented in this chapter indicate that as the percentage of unimpaired flow is increased during the February through June time period, the flow related benefits to salmon and steelhead also increase. Improving flows that mimic the natural hydrographic conditions including related temperature and floodplain regimes to which native fish species are adapted, are expected to provide many juvenile salmonids with additional space, time, and food resources which are necessary for required growth, development, and survival. Extending spatial, temporal, and nutritional opportunities available to juvenile fall-run Chinook salmon and steelhead in the Stanislaus, Tuolumne, and Merced Rivers is expected to improve abundance, productivity, diversity, and spatial structure of the SJR Basin and Central Valley populations, and should also provide substantial benefits to other native fish in the SJR Watershed. Improving and maintaining these important population attributes should help buffer SJR Basin and Central Valley fall-run Chinook salmon populations from catastrophic events and conditions in the future.

Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*, documents the scientific basis and technical resources that were used in the recirculated substitute environmental document (SED) to analyze project effects in accordance with CEQA requirements. The purpose of this chapter is to supplement the information contained in Appendix C by quantitatively evaluating the benefits of this project in terms of potentially available cold water and floodplain habitats, and associated population implications to native salmonids.

The information contained in this chapter is intended to assist the State Water Board in its water quality control planning process and decision making as part of that process. The water quality control planning process has requirements separate and apart from CEQA and the information contained in this chapter is not a requirement of CEQA. One of the purposes of CEQA is to inform governmental decision makers and the public about the potential, significant environmental effects of proposed activities (State CEQA Guidelines, § 15002(a)(1)). Significant effects on the environment are defined as a substantial adverse change in physical conditions which exist in the area affected by the proposed project (i.e., significant impacts) (State CEQA Guidelines, § 15002(g)). To satisfy CEQA requirements, impacts on various resources are evaluated and significance determinations are made in Chapters 5 through 16 and Appendix B, *State Water Board's Environmental Checklist*, of this SED.

### 19.1.1 Problem Statement

Scientific evidence indicates that reductions in flows and alterations to the flow regime in the SJR Basin, resulting from water development over the past several decades, have negatively impacted fish and wildlife beneficial uses. As outlined in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*, water development in the SJR Basin has resulted in: reduced annual flows, fewer peak flows, reduced and shifted spring and early summer flows, reduced frequency of peak flows from winter rainfall events, shifted fall and winter flows, and a general decline in hydrologic variability over multiple spatial and temporal scales. Currently, there is relatively little unregulated runoff from the SJR Basin with dams regulating at least 90% of the inflow (Cain et al. 2010). Dams and diversions in the SJR Basin have caused a substantial overall reduction of flows, compared to unimpaired hydrographic conditions, with a median reduction in annual flows at Vernalis of 54% and median reduction of spring flows of 74%, 83%, and 81% during April, May, and June, respectively.

The SJR Basin once supported large spring-run and fall-run (and possibly late fall-run) Chinook salmon populations; however, the basin now only supports fall-run Chinook salmon populations, and these populations are facing a high risk of extinction (see Mesick 2009, 2010a, 2010b). The Stanislaus, Tuolumne, and Merced Rivers (individually or combined) have had larger reductions in the natural production of adult fall-run Chinook salmon than any of the other tributaries (or combination of three tributaries) to the Sacramento or San Joaquin Rivers when comparing the 1967-1991 and 1992-2011 time periods (Figure 19-1).

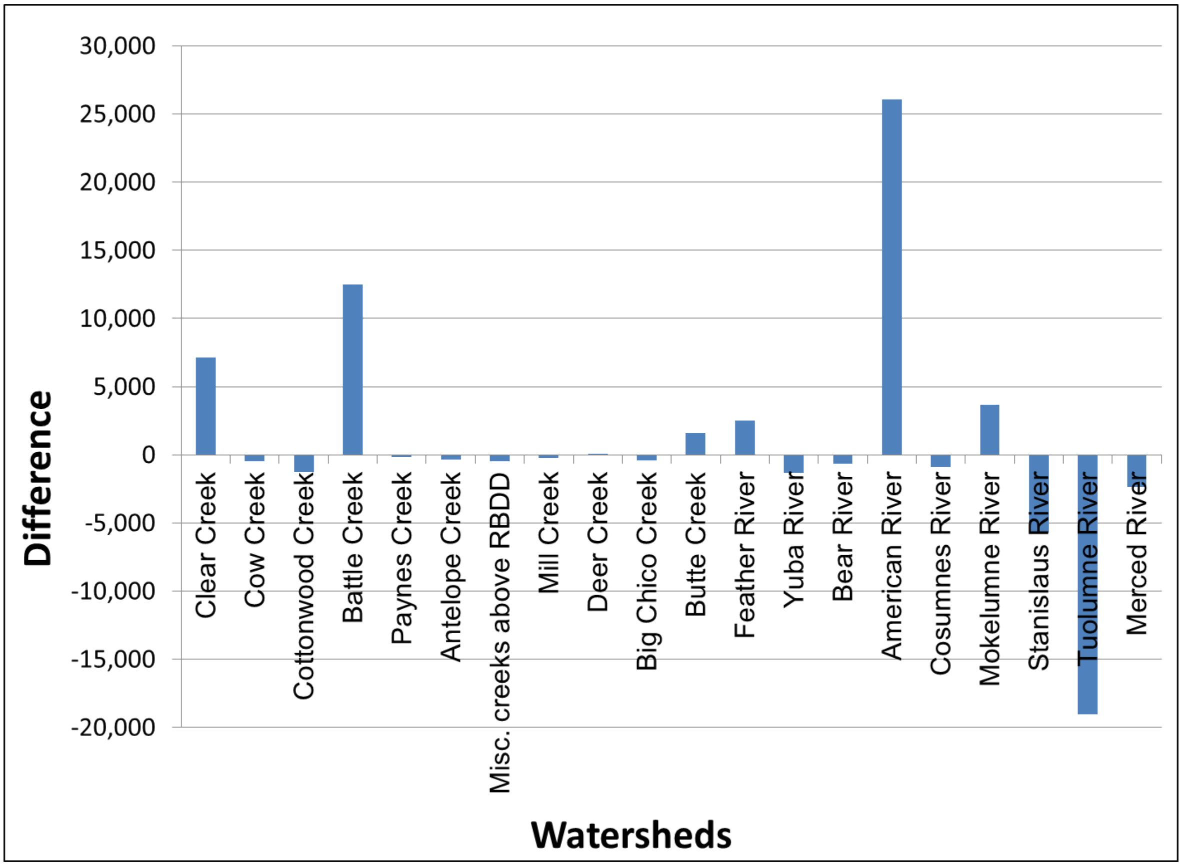


**Figure 19-1. Difference in natural production of adult fall-run Chinook salmon when comparing the 1967-1991 average and the 1992-2011 average in tributaries to the Sacramento or San Joaquin Rivers, showing that salmon declines in the tributaries to the San Joaquin River are greater compared to other watersheds in recent decades. Difference = (1992-2011 time period average of estimated yearly natural production as reported in USFWS 2013a) minus (1967-1991 time period average of estimated yearly natural production as reported in USFWS 2013a) (repeated for each watershed).**

Flows in the SJR Basin affect various life stages of fall-run Chinook salmon, including adult migration, adult spawning, egg incubation, juvenile rearing, and outmigration to the Pacific Ocean. Analyses of historical abundance indicate that late winter and spring flows (February through June) in the tributaries and mainstem SJR have had a strong influence on survival and abundance of SJR Basin salmon since records began in the 1940s or 1950s (Figure 19-2; and CDFG 2005a; Mesick and Marston 2007; Mesick et al. 2007; Mesick 2009; Sturrock et al. 2015).

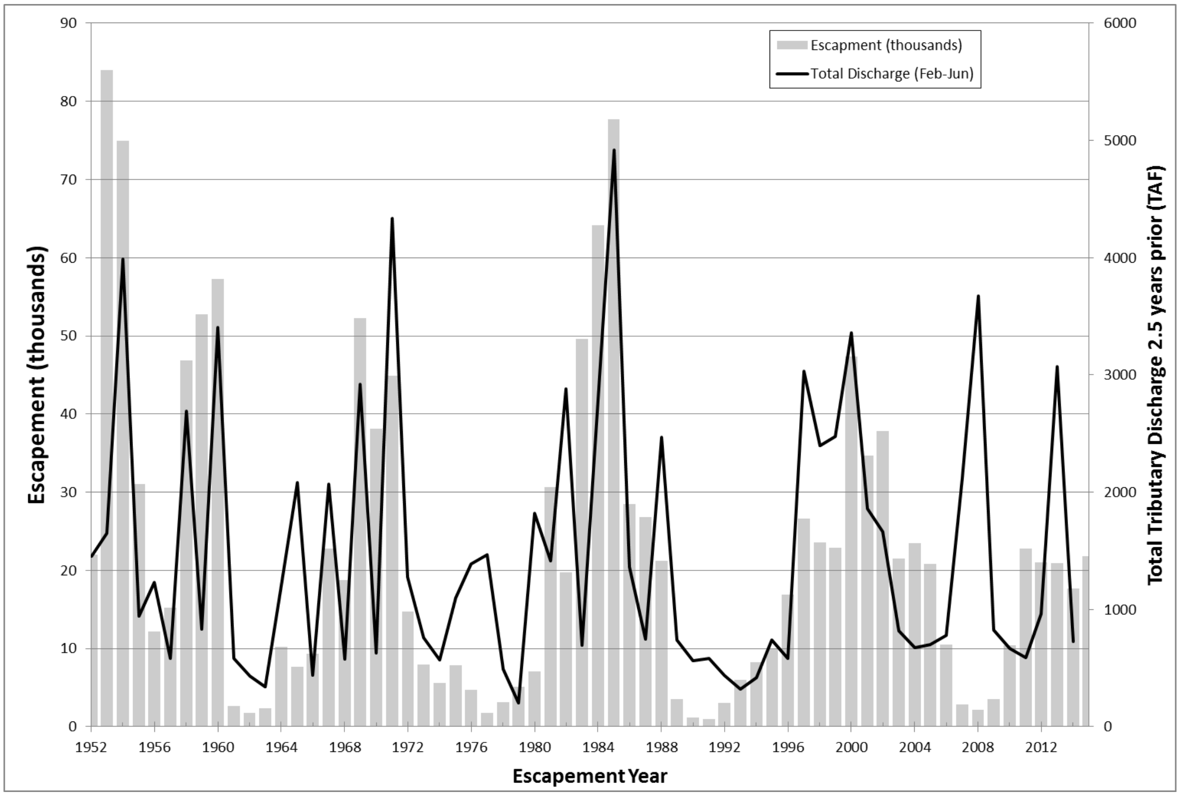


**Figure 19-2. Relationship between adult salmon returns to the San Joaquin basin and the river flows they experienced as juveniles. Fall-run Chinook salmon returns (escapement) to the Stanislaus, Tuolumne, and Merced rivers combined from 1952-2014 relative to the total discharge (Thousand Acre-Feet) during the February through June outmigration period they experienced 2.5 years prior as juveniles. Salmon data from CDFW GrandTab 2014.04.22 and GrandTab 2016.04.11. Flow data for the Stanislaus, Tuolumne, and Merced Rivers combined from USGS gages 11303000, 11290000, and 11270900 respectively. Note that adult abundance estimates have not been corrected for age distributions (we assumed that all adults returned at age 3), or for out-of-basin straying. The large deviation in 2007 reflects poor returns that were attributed to poor ocean conditions (Lindley 2009) and resulted in the closure of the fishery. Adapted from Sturrock et al. 2015.**

Therefore, while SJR Basin flows at other times are also important, the focus of the State Water Board's current review is on flows within the salmon-bearing tributaries and the mainstem SJR at Vernalis (inflows to the Delta) during the critical salmon rearing and outmigration period of February through June. Scientific evidence indicates that in order to protect fish and wildlife beneficial uses in the SJR Basin, including increasing the populations of SJR Basin fall-run Chinook salmon and Central Valley steelhead to sustainable levels, changes to the current flow regime of the SJR Basin are needed. Specifically, a more natural flow regime from the salmon bearing tributaries (Stanislaus, Tuolumne, and Merced Rivers) is needed during the February through June time frame (see Appendix C *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*,).

### 19.1.2 Importance of a Natural Flow Regime

There are many important benefits to maintaining a natural flow regime, some of which are described in the following summary by Kiernan et al. (2012, page 1472):

> The flow regime of a stream is often regarded as the ''master variable'' that determines composition of biotic assemblages (Poff and Ward 1989, Power et al. 1995, Matthews 1998). Many environmental factors that affect assemblage structure, including temperature, water chemistry, and physical habitat complexity, are determined by flow to a certain extent (Bunn and Arthington 2002). For streams in Mediterranean climates, such as northern California, USA, annual patterns of precipitation produce a hydrograph characterized by episodic high-discharge events during winter and by protracted periods of low flow throughout summer and early fall. Although the magnitude and frequency of hydrologic disturbance events such as extreme floods and extended low flows are highly variable from year to year, the timing (seasonality) of these events is largely predictable (Gasith and Resh 1999, Power et al. 2008). Thus, many native freshwater and riparian species have evolved traits and life-history strategies to withstand natural hydrologic variability and to rapidly recover from disturbance (Bonada et al. 2007, Power et al. 2008, Yarnell et al. 2010). Conversely, alien (nonnative) species often lack biological and behavioral mechanisms to cope with region-specific flow regimes and are often disproportionately vulnerable (e.g., via physical displacement, recruitment failure, or direct mortality) to high and low stream flow conditions.

As described in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*, natural flow regimes have been dramatically altered in the Bay-Delta plan area. The Stanislaus, Tuolumne, and Merced Rivers have significantly lower and flatter winter and spring hydrographs, and significantly higher summer and fall hydrographs. See Figure 19-3 as an example of an altered hydrograph during a wet year, and see Figure 19-4 as an example of an altered hydrograph during a critically dry year.

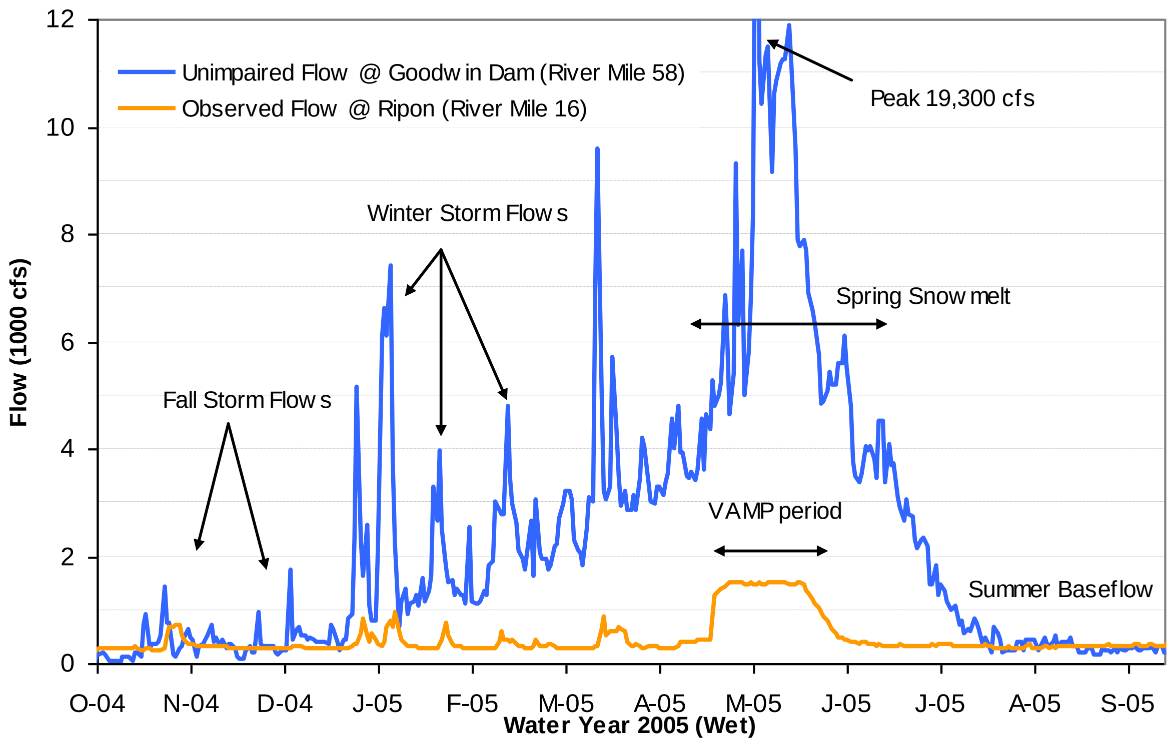


**Figure 19-3. Typical Stanislaus River annual hydrograph of daily average unimpaired and observed flows during a wet water year (2005) illustrating important hydrograph components.**

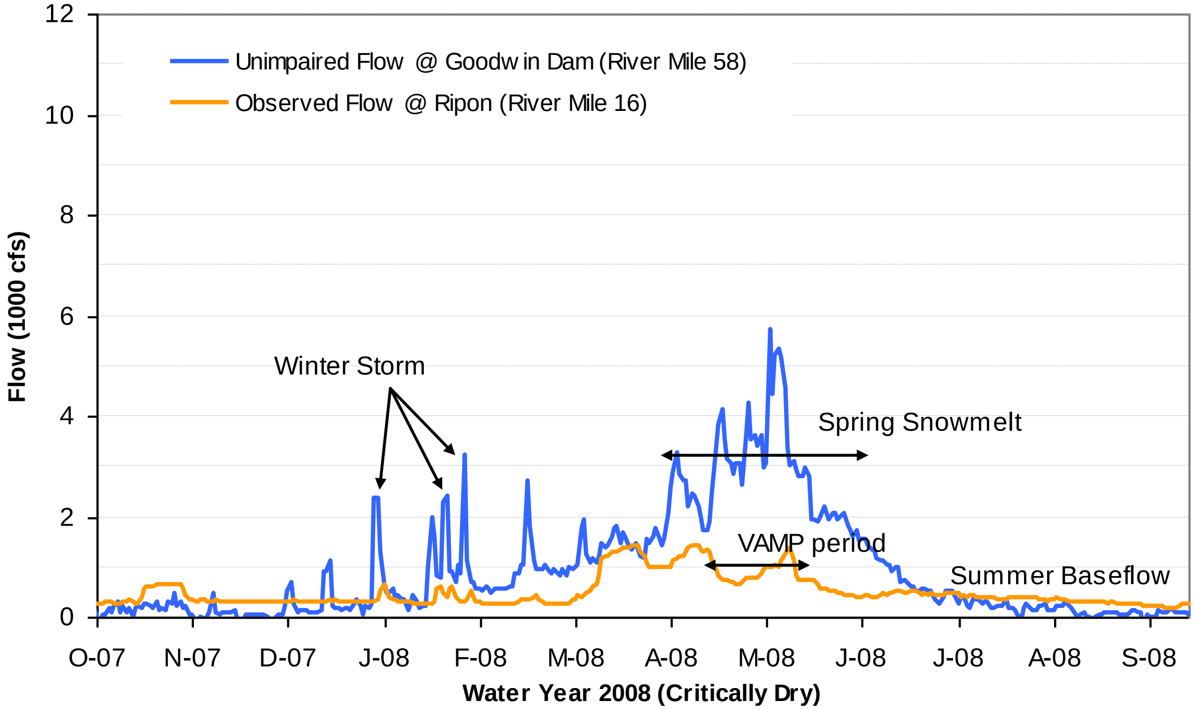


**Figure 19-4. Typical Stanislaus River annual hydrograph of daily average unimpaired and observed flows during a critically dry water year (2008) illustrating important hydrograph components.**

CalFED (2008) suggested that altering the hydrographs of Central Valley rivers has had significant ecological consequences—including changes in the establishment, distribution, composition, and survival of naturally recruited riparian vegetation; and changes in the timing and distribution of migration, spawning, and rearing of green sturgeon, Chinook salmon, and steelhead.

Seasonally-correct variable flow conditions provide the environment needed to support biological and ecosystem processes which are imperative to the protection of native fish and wildlife beneficial uses. Although changes to ecosystem attributes, in addition to flows, are needed to fully restore biological and ecosystem processes in the Bay-Delta plan area, flow remains a critical element of that restoration.

Using a river's unaltered hydrographic conditions as a foundation for determining ecosystem flow requirements is well supported by scientific literature (Poff et al. 1997; Tennant 1976; Orth and Maughan 1981; Marchetti and Moyle 2001; Mazvimavi et al. 2007; Moyle et al. 2011). In addition, major regulatory programs in Texas, Florida, Australia and South Africa have developed flow prescriptions based on unimpaired hydrographic conditions in order to enhance or protect aquatic ecosystems (Arthington et al. 1992; Arthington et al. 2004; NRDC 2005; Florida Administrative Code 2010), and the World Bank now uses a framework for ecosystem flows based on the unaltered quality, quantity, and timing of water flows (Hirji and Davis 2009). Many researchers involved in developing ecologically protective flow prescriptions concur that mimicking the unimpaired hydrographic conditions of a river is essential to protecting populations of native aquatic species and promoting natural ecological functions (Sparks 1995; Walker et al. 1995; Richter et al. 1996; Poff et al. 1997; Tharme and King 1998; Bunn and Arthington 2002; Richter et al. 2003; Tharme

2003; Poff et al. 2006; Poff et al. 2007; Brown and Bauer 2009). Poff et al. (1997) describe that the flow regime limits the distribution and abundance of riverine species (Resh et al. 1988; Power et al. 1995) and regulates the ecological integrity of rivers. The structure and function of riverine ecosystems, and the adaptations of their constituent freshwater and riparian species, are determined by patterns of intra- and inter-annual variation in river flows (Poff et al. 1997; Naiman et al. 2008, Mount et al. 2012). A key foundation of the natural flow paradigm is that the long-term physical characteristics of flow variability have strong ecological consequences at local to regional scales, and at time intervals ranging from days (ecological effects) to millennia (evolutionary effects) (Lytle and Poff 2004). Nearly every other habitat factor that affects community structure, from temperature, to water chemistry to physical habitat complexity, is determined by flow to a certain extent (Bunn and Arthington 2002).

In a recent analysis of methods used for establishing environmental flows for the Bay-Delta, Fleenor et al. (2010) reported on two methods for determining flows needed to protect the ecosystem: 1) flows based on the unimpaired flow, and 2) flows based on the historical flow. These methods attempt to prescribe flows for the protection of the ecosystem as a whole, and use the biological concept that more variable inflows to the Sacramento-San Joaquin Delta (Delta), which mimic unaltered hydrographic conditions to which native aquatic species have adapted, will benefit native aquatic species. In a separate review of instream flow science by Petts (2009), he reports the importance of two fundamental principles that should guide the derivation of flow needs: 1) flow regime shapes the evolution of the aquatic biota and ecological process; and 2) every river has a characteristic flow regime and associated biotic community. Petts (2009) also finds that flow management should sustain flows that mimic the yearly, seasonal, and perhaps daily variability to which aquatic biota have adapted.

The current updates to the Bay-Delta Plan include improving flow conditions during the February through June time period so that they more closely mimic the natural hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur. This document describes the benefits of the project to native salmon and steelhead in terms of improvements to temperature and floodplain habitat in response to the proposed changes in flow conditions which will more closely mimic the natural hydrographic conditions during February through June.

# 19.2 Temperature

Dams and reservoirs, and their associated operations, alter the temperature regime of rivers, often to the detriment of native species such as salmonids and other animals, and plants, that are adapted to the natural flow regime of their native rivers (Richter and Thomas 2007; CDFG 2010b). Typically, water stored in reservoirs is warmer at the surface and cooler below the thermocline in deeper waters. The temperature of water within these layers is generally different than the temperature of water entering the reservoir at any given time depending on the season, and is also dissimilar to downstream water temperatures that would occur under a natural flow regime (USACE 1987; Bartholow 2001). In addition to altering downstream temperature regimes, dams also physically block access to cooler high elevation habitats historically available to native migratory fish species.

Currently, temperature management on the major SJR tributaries can only be achieved directly through flow management (NMFS 2009c). While temperature control devices can control the temperature of water released from dams for the protection of downstream fisheries by varying operations of release gates for example, there are currently no temperature control devices to aid in water temperature management on the major SJR tributary dams.

Often, water released from reservoirs is colder in the summer and warmer in the winter compared to water temperatures that would have occurred in the absence of a dam and reservoir (see Figures 19-7, 19-8, and 19-9; Williams 2006). As a result, native aquatic species can experience additional temperature stress due to the river's altered flow and temperature regimes. However, where temperatures are cooler than they would be under a more natural flow regime (because of reservoir discharges of cold water through the summer), populations of *O. mykiss* (both anadromous and resident forms) are often able to persist at lower elevations than they would have historically. These areas are typically in the reaches immediately below dams.

In addition to the changes in water temperature due to reservoir storage, reservoirs and diversions also modify the temperature regime of downstream river reaches by diminishing the volume and thermal mass of water. A smaller quantity of water has less thermal mass and, therefore, a decreased ability to absorb temperatures from the surrounding environment (air and solar radiation) without being impacted (USACE 1987). The greatest impact typically occurs with less flow (less thermal mass) and warmer climate (increased solar radiation), usually in the late spring, summer, and early fall periods (DWR 2013). In highly altered systems such as the SJR Basin, channelization, levees, and loss of riparian habitat contribute to thermal loading which impacts water temperature and native fish species (Williams 2006; Moyle 2008).

On the Stanislaus, Tuolumne, and Merced Rivers water temperature is largely controlled by flow released from the reservoirs. For example, Figure 19-5 illustrates the relationship between average daily water temperature and average daily flow on the Tuolumne River during May at river mile 28.1 from 1980 to 2010 (modeled historic information from the SJR HEC-5Q model).

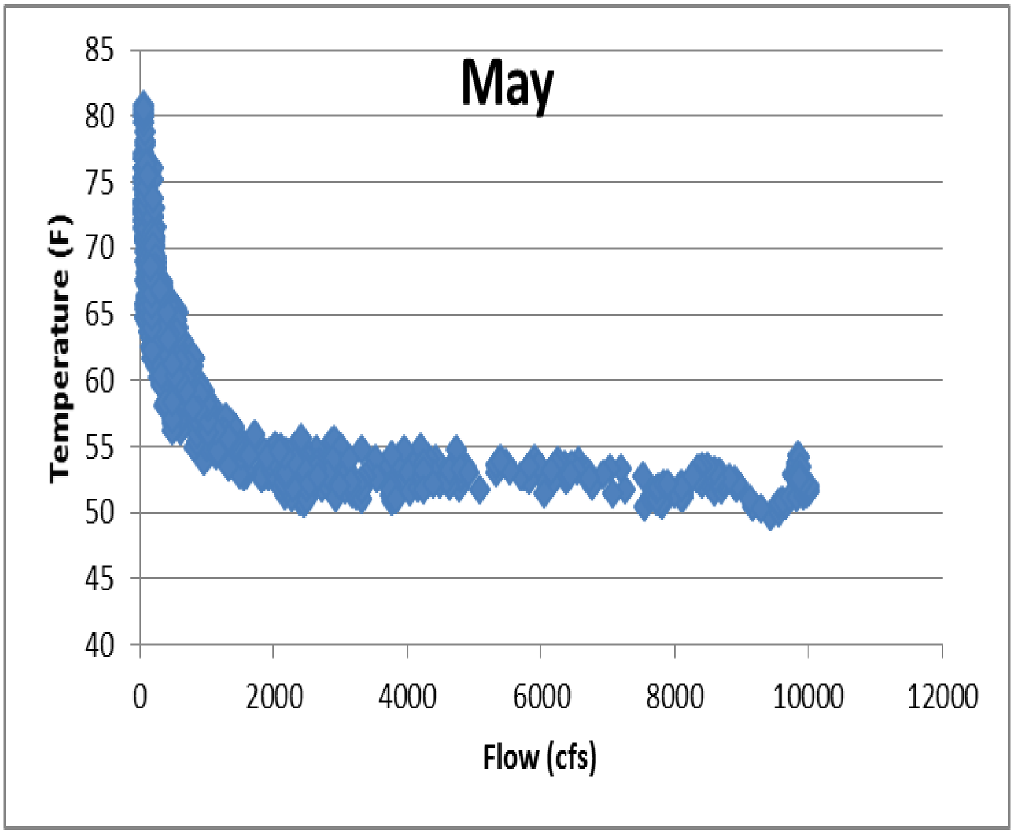


**Figure 19-5. Average daily water temperature versus average daily flow relationship on the Tuolumne River during May at river mile 28.1 from 1980 to 2010 (modeled historic information from the SJR HEC-5Q model).**

The remainder of this section describes the expected temperature benefits from increased flows during the February through June time period, and provides information as to why improved temperature conditions are important to native fish.

## 19.2.1 Importance of a Natural Temperature Regime in Aquatic Environments

### Effects of Temperature on Aquatic Organisms

Water temperature is crucial to aquatic organisms because it directly influences their metabolism, respiration, feeding, growth, and reproduction. Most aquatic species have an optimal temperature range for growth and reproduction, and they are also bound by upper and lower limits in which they can no longer survive or successfully reproduce. Thus, their natural spatial and temporal distributions are largely determined by regional differences in temperatures driven by climate and elevation along with more local effects from riparian shading, groundwater influence, and other physical influences including flow alteration. Furthermore, water temperature can influence water chemistry, such as the solubility of oxygen in water (Carlisle et al. 2013).

Thermal stress to aquatic organisms can occur when a temperature or a change in temperature produces a significant change to biological functions leading to decreased likelihood of survival and reproduction. Thermal stress can lead to lethal effects either immediately, in a period of days, or even weeks or months from the onset of the elevated temperature. Thermal stress can also result in sublethal or indirect effects resulting in reduced fitness that impairs processes such as growth, spawning, or swimming speed. Metabolic processes are directly related to temperature, and the metabolic rate increases as a function of temperature (Marine and Cech 2004). Thus, aquatic organisms are most likely to thrive within their preferred range of temperatures (USEPA 2001a).

## Effects of Temperature on Salmonids

Like other aquatic organisms, water temperatures significantly affect the distribution, health, and survival of native salmonids. Because salmonids are ectothermic (cold-blooded), their survival is dependent on external water temperatures and they will experience adverse effects when exposed to temperatures outside their optimal range. Salmonids have evolved and thrived under the water temperature patterns that historically existed (i.e., prior to significant anthropogenic impacts that altered temperature patterns) in streams and rivers. Although evidence suggests that historical water temperatures exceeded optimal conditions for Pacific salmonids at times, during the summer months on some rivers at some locations, the temperature diversity in these unaltered rivers provided sufficient access to cold water to allow salmonid populations as a whole to thrive (USEPA 2003). Across North America, human-caused elevated water temperatures significantly increase the magnitude, duration, and extent of thermal conditions unsuitable for salmonids (USEPA 2003).

The freshwater life histories of salmonids are closely tied to water temperatures. Cooling rivers in the autumn serve as a signal for upstream migrations. Fall spawning is initiated when water temperatures decrease to suitable temperatures. Eggs generally incubate over the winter or early spring when temperatures are coolest. Rising springtime water temperatures can serve as a cue for downstream migration (USEPA 2003).

Because of the overall importance of water temperature for salmonids in the Pacific Northwest, human-caused changes to natural temperature patterns have the potential to significantly reduce the size of salmonid populations. Of particular concern are human activities that have led to the excess warming of rivers, loss of temperature diversity (USEPA 2003), and the loss of access to coldwater habitats blocked by dams.

In the Central Valley, Myrick and Cech (2001 page iii) suggest that "water temperature is perhaps the physical factor with the greatest influence on Central Valley salmonids, short of a complete absence of water", and that "the changes made to Central Valley rivers have had, and will continue to have far-reaching effects on Chinook salmon and steelhead populations." The National Marine Fisheries Service (2009a) indicated that improving water temperatures in the Merced and Tuolumne Rivers (and many other Central Valley rivers) are key restoration actions for steelhead recovery in these watersheds. Additionally, NMFS (2009b) indicated that the primary limiting factor to the Central Valley steelhead distinct population segment (DPS) is the inaccessibility of more than 95% of its historic spawning and rearing habitat due to impassable dams, which among other factors, block access to cold water habitat found at higher elevations. The California Department of Fish and Game (2010a) indicated that rivers in the San Joaquin Basin do not meet (cool) temperature water quality criteria to protect anadromous fish beneficial uses, and that one critical factor limiting anadromous salmon and steelhead population abundance is high water temperatures which exist during critical life-stages in the tributaries and main-stem.

The following sections further discuss some of the specific mechanisms in which water temperature influences salmonids:

### Influence of Temperature on Salmonid Behavior

Water temperature has the ability to influence the behavior of salmonids in several ways, including: causing movement to habitat with temperature refugia (e.g., stratified pools, shaded habitat, and subsurface flow), causing movement into areas with less cover but additional food resources (Nielsen et al. 1994; Torgersen et al. 1999; Myrick and Cech 2001; Torgersen et al. 2012), increasing competition between different fish species, changing metabolic rates, hindering the ability to avoid and evade predators, diminishing aquatic biodiversity, and increasing susceptibility of both juveniles and adults to certain parasites and diseases (Myrick and Cech 2001; Reese and Harvey 2002). As temperatures rise above optimal conditions, these modifications to behavior can be costly in terms of expending additional energy and increasing predation risk.

### Influence of Temperature on Disease Risk in Salmonids

Chinook salmon are susceptible to a variety of different diseases, many of which have specific water temperature requirements (Boles et al. 1988). The effects of disease on salmonids is directly linked to water temperature, as water temperature greatly influences the immune system of fishes, and the quantity and virulence of water borne pathogens (Nichols and Foot 2002; Ferguson 1981). Although certain diseases become more prevalent in cold water environments, the more prevalent diseases that afflict Chinook salmon occur in warmer water temperatures (>56°F; Boles et al. 1988). Consequently, changes in water temperatures caused by dams and other water infrastructure can alter the susceptibility of salmonids to infection by various pathogens (Spence et al. 1996).

Disease adversely impacts fish populations by directly increasing mortality, and by indirectly contributing to increased susceptibility to predation and decreasing the ability of fish to perform essential functions, such as feeding, swimming, and defending territories (McCullough 1999; Nichols and Foott 2002). The susceptibility of salmonids to disease can also be affected by other stressors including insufficient dissolved oxygen, and chemical pollution. Temperature may interact synergistically with these factors, causing disease to appear in organisms that might be resistant in the absence of other forms of stress (Spence et al. 1996).

Diseased fish are present and have been caught in the Stanislaus, Tuolumne, Merced and San Joaquin Rivers. Naturally produced Chinook salmon juveniles caught in these rivers were infected with the causative agents of bacterial kidney disease (BKD) and proliferative kidney disease (PDK). These diseases and others can rapidly increase in the population as water temperature rises above the optimal temperature range of salmonids (Nichols and Foott 2002).

Flows have dilution effects on the presence of pathogens, flush diseases out of the ecosystem, and can lower water temperatures thus reducing disease outbreaks. Additionally, a greater amount of instream habitat affords individuals with a greater area in which to disperse and, consequently, there can be a lower probability of coming into close contact with diseased individuals (Spence et al. 1996).

### Influence of Temperature on Predation Risk to Salmonids

In addition to disease, Chinook salmon juveniles are also increasingly vulnerable to predation as water temperatures increase. Predation on juvenile Chinook salmon is both directly and indirectly affected by water temperatures (Myrick and Cech 2001; McBain and Trush 2002). These direct and/or indirect impacts related to the influence of temperature on predation can add unnecessary stress to an already struggling salmonid population. First, direct effects can occur when water temperatures rise or fall to levels that alter the behavior of, or physically harm, the juvenile salmonid. An example of a direct effect is increasing water temperature that leads to premature utilization of the yolk sac by developing alevins, which may result in early emergence from the redd in an underdeveloped and vulnerable state. Second, the ability for a juvenile salmonid to maintain normal swimming abilities and adequately avoid predators is an important factor contributing to survival. Specifically, larval and early life-stage salmonids have relatively weak swimming abilities, making them particularly vulnerable to predation (McBain and Trush 2002). Increased temperatures may compound this effect. Third, increased water temperatures may decrease food availability, increase fish metabolic demand, and subsequently decrease growth rates and survival of salmonids (Boles et al. 1988). Increased water temperatures have the potential to drive salmon juveniles away from the more favorable and protective shallow water habitat (due to a limited food supply) into the main drift or deeper waters of the stream to forage for food. As Chinook salmon juveniles venture to more open instream habitats in search of food, they become an easier target for predatory fish who, in addition to salmon juveniles, need to sustain an increased metabolic demand for food as a result of warm water temperatures (Boles et al. 1988). Lastly, warm water temperatures can also increase vulnerability to predation by affecting the performance of juvenile Chinook salmon or by creating favorable conditions for predatory fish (Boles et al. 1988). As optimal water temperatures for salmonids are exceeded, many predatory fish are just beginning to enter their optimal water temperature range (CDFG 2010a). When water temperatures increase above preferred ranges, juvenile salmonids become stressed and potentially disoriented and erratic, which consequently causes them to become more vulnerable to increased predation rates (CDFG 2010a). Marine and Cech (2004) found that juvenile salmon that were reared in 21-24°C (69.8°F-75.2°F) were significantly more vulnerable to predation by striped bass than juvenile salmon reared at lower temperatures.

It is expected that restoring more natural temperature and flow regimes will help to better support the various life history adaptations of native fish and other native aquatic organisms, and may reduce predation from non-natives. The effectiveness of restoring the natural flow regime was demonstrated by Kiernan et al. (2012) in lower Putah Creek where a new flow regime was implemented that mimics the seasonal timing of natural increases and decreases in streamflow. Monitoring of several sites pre- and post- implementation of the new flow regime showed a change in the distribution of the native fish community. At the onset of the study, native fishes were constrained to habitat immediately (<1 km) below the diversion dam, and non-native species were numerically dominant at all downstream sample sites. Following implementation of the new flow regime, native fish populations expanded and regained dominance across more than 20 km of lower Putah Creek. The authors (Kiernan et al. 20012) proposed that that the expansion of native fishes was facilitated by creation of favorable spawning and rearing conditions (e.g., elevated springtime flows), cooler water temperatures, maintenance of lotic (flowing) conditions over the length of the creek, and displacement of alien species by naturally occurring high-discharge events.

## Influence of Temperature on Adult Salmonid Migration

Adult salmonids migrate great distances in river systems throughout the Pacific Northwest, including the Central Valley. The success of these migrations can depend substantially on water temperatures. Most stocks of anadromous salmonids have evolved with the temperature regime of the streams they use for spawning and migration, and alteration of the normal temperature pattern can result in reduced fitness (USEPA 2001a).

If adult salmonid migration occurs at high temperatures just prior to spawning, gametes held internally in adults can be severely affected, resulting in a loss of viability that appears as poor fertilization or poor embryo survival (USEPA 2001a). Additionally, delayed migration caused by sub-optimal water temperatures may also affect the temperature conditions that the juvenile offspring will experience by pushing their in-river development further into the late spring or summer seasons during periods with higher temperatures. Furthermore, upstream migrating adult salmon that are delayed in the mainstem SJR and Delta can be subject to sport harvest, whereas adults that migrate into the tributaries are somewhat protected by sport fishing regulations that generally prohibit angling in the primary spawning reaches and times (Mesick 2001).

Thermal blockage to adult fall-run Chinook salmon migration was reported at a temperature of 21°C in the Sacramento-SJR Delta, but even temperatures as low as 19°C caused a partial blockage (Hallock et al. 1970).

## Influence of Temperature on Salmonid Reproduction

Like with many other organisms, embryonic development of salmonids is a particularly important and sensitive life stage. Temperatures can influence salmonid egg development and success in a variety of ways. For example, sub-optimal temperatures can alter the formation of vertebrae in Central Valley Chinook salmon, and can cause direct mortality at high or low temperatures (Seymour 1959). Seymour (1956 as cited in DWR 1988) found that inadequate temperatures may not always lead to direct egg mortality, but can also cause mortality exceeding 50% of sac-fry (alevin) even when egg mortality was low. Additionally, even before eggs are deposited in gravels, exposure of adult females holding ripe eggs to warm water temperatures can cause egg mortality and can negatively alter egg and alevin development (Rice 1960 and Leitritz and Lewis 1976 as cited in McCullough 1999).

Chinook salmon have a narrow range of temperatures which lead to successful egg development. Myrick and Cech (2001) illustrated the effects of incubation temperature on direct mortality of Chinook salmon eggs from a variety of studies, as seen below in Figure 19-6.

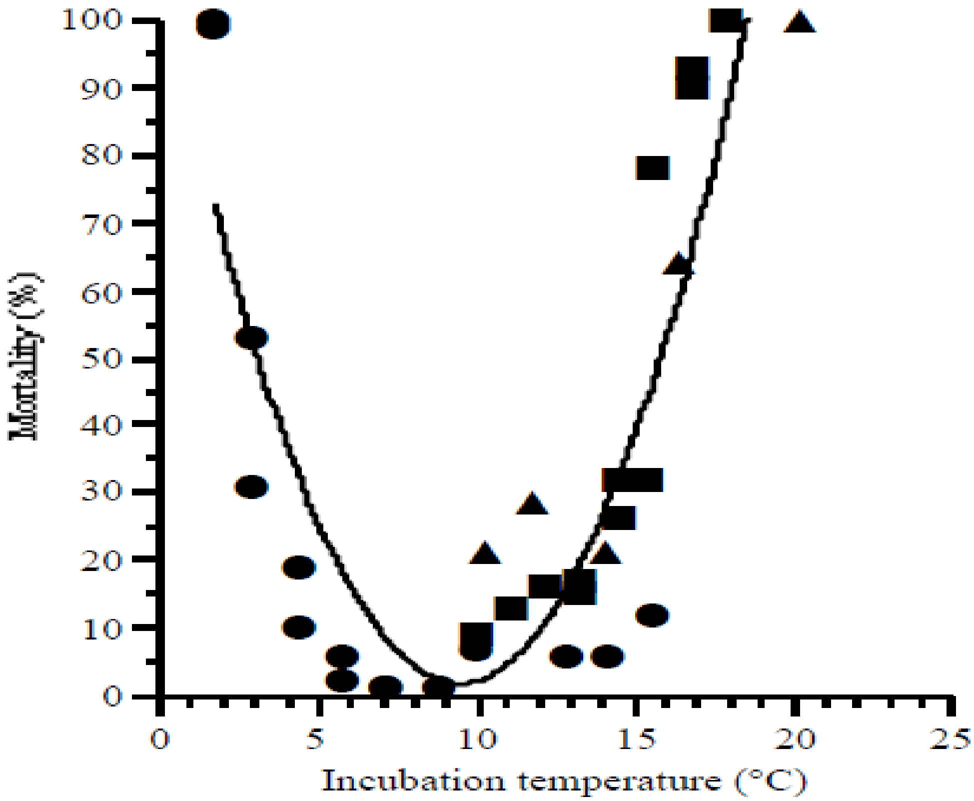


**Figure 19-6. Myrick and Cech (2001) illustrate effects of incubation temperature on mortality of Chinook salmon eggs. Data are from Combs and Burrows (1957; solid circles), USFWS (1999; solid squares), and Jenson and Groot (1991; solid triangles).**

With optimal conditions, Chinook salmon embryos hatch after 40-60 days and remain in the gravel as alevins for another 4-6 weeks, usually until the yolk sac is fully absorbed (Moyle et al 2008). Alevin are the life stage between eggs and fry, and these newly hatched salmon have not yet fully absorbed their yolk sac (NMFS 2009b). During this life stage alevin are still relatively sensitive to temperatures, with thermal requirements similar to those of eggs (USEPA 2001a, Myrick and Cech 2001).

Under existing conditions, elevated water temperatures appear to be impairing reproductive life-stages of salmonids in the SJR Basin, including its tributaries (CDFG 2010a). The magnitude in which poor temperatures effect the survival of incubating eggs, and ultimately population abundance, is currently unknown.

## Influence of Temperature on Juvenile Salmonid Growth, Smoltification, and Emigration

Growth is perhaps the most powerful and complete integrator of environmental, behavioral, and physiological influences on a fish's fitness. Growth is the storage of excess energy and positive growth indicates an energy surplus, which is necessary to advance to and complete later life stages and ultimately complete successful reproduction (Myrick and Cech 2001).

Temperature affects growth directly through its effect on metabolic processes, and indirectly, through its effects on food availability and physical activity. Both Central Valley Chinook salmon and steelhead have high growth rates at temperatures approaching 19°C when they are fed to satiation in laboratory experiments. However, under partial food rations and reduced water quality, maximum growth rates occur at lower temperatures (Myrick and Cech 2001). Additionally, lower temperatures are required to complete the physiological and morphological adaptations that juvenile salmon undergo to transition from living in freshwater to living in saltwater, which is the process known as smoltification (Myrick and Cech 2001).

Freshwater fish are hypertonic to their environment and must actively excrete water and acquire ions (primarily Na+ and Cl-) (Moyle and Cech 2000 as cited in Myrick and Cech 2001). Marine fish are hypotonic (less salty than environment) and must drink copious quantities of sea water (Moyle and Cech 2000 as cited in Myrick and Cech 2001) and actively excrete salt (Myrick and Cech 2001). The smoltification process transforms salmonids from freshwater to saltwater physiology, which has high energetic costs associated with it (Cooperman et al. 2010; Gross et al. 1988, Sheridan et al. 1983). This costly transition suggests that the optimal habitats for growth, survival, and reproduction are necessary and separated spatially and/or seasonally (Northcote 1984). Survival of smolts upon reaching the marine environment depends heavily upon the degree of smoltification, and two of the most important factors regulating seawater adaptability of salmonids are freshwater rearing temperature and time of transfer to seawater (McCullough 1999). Additionally, it appears that the development of seawater tolerance in Chinook salmon and steelhead is partially a function of size (Clarke and Shelbourn 1985; Johnson and Clarke 1988), making it important that salmonids reach an appropriate size before they reach saltwater (Myrick and Cech 2001). Therefore, juvenile salmonids must grow large enough and have access to suitable temperature conditions to undergo the stress of completing the smoltification process and entering the ocean (Morinville and Rasmunsen 2003).

By controlling biochemical and physiological reaction rates, water temperature affects the physiological development of smolts, as well as the timing and duration of smoltification. Of particular significance is the inhibition of the gill ATPase osmoregulatory enzyme at high water temperatures, which leads to a loss of migratory behavior in salmonids (USEPA 2001b). Furthermore, warm water temperatures can decrease, arrest, or reverse the physiological function of smoltification, and subsequently delay the outmigration of juveniles into a more unfavorable timeframe (e.g., June; Boles et al. 1988; CDFG 2010a).

In addition to physiological impairment of smolts caused by elevated temperatures during migration, Baker et al. (1995) found that direct effects of high temperature explain a large part of the smolt mortality observed in the Delta. Additionally, using data from 1986–2010, Mesick (2012) evaluated the hypothesis that recruitment of naturally produced fall-run Chinook salmon in the major SJR tributaries was primarily a function of the suitability of water temperatures for smoltification. He found that the environmental variables that best explained variation in natural recruitment over the period of record were either mean flow in the mainstem SJR during the March 1 to April 30 parr migratory period or the number of days that water temperatures were less than a 15°C threshold for smoltification between March 1 and June 15 in the major SJR tributaries. Others (Baker et al 1995; CDFG 2010a; Kjelson et al 1982; Mesick 2010a) have also reached similar conclusions that temperature is one of the key limiting factors of smolt survival in the Central Valley.

## Summary

The importance of suitable temperature habitats to aquatic organisms in the Central Valley has been well documented. Like other aquatic organisms, water temperature significantly affects the distribution, health, survival, and reproduction of native salmonids, and because salmonids are ectothermic (cold-blooded), their success is dependent on water temperature and they will experience adverse effects when exposed to temperatures outside their optimal range. In the Central Valley, water and land development has dramatically altered natural water temperature regimes available to many of California's native fish and wildlife. The following analysis will evaluate how increasing river discharge during February through June will improve temperature habitat relative to native salmonids in the Stanislaus, Tuolumne, Merced, and Lower San Joaquin Rivers.

# 19.2.2 Methods of Temperature Evaluation

This temperature analysis is based on predicted effects to key evaluation, or "indicator species." For this analysis, the indicator species used are Central Valley fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and California Central Valley steelhead (*Oncorhynchus mykiss*). These indicator species were selected based on their sensitivity to potential changes in environmental conditions in the project area and their utility in evaluating broader ecosystem and community-level effects of these changes on native aquatic resources. The temperature requirements of Central Valley fall-run Chinook salmon and Central Valley steelhead are generally representative of the temperature requirements of other native fishes in the project area (see Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*).

## Computer Modeling Used in Temperature Evaluation

To model effects on temperature in the LSJR and three eastside tributaries[2] for the SED, the State Water Board used the San Joaquin River Basin-Wide Water Temperature and EC Model (shorthand used here is SJR HEC-5Q model or temperature model) developed by a group of consultants between 2003 and 2008 through a series of CALFED contracts that included peer review and refinement (CALFED 2009). The temperature model was most recently updated by the CDFW and released in June of 2013 (CDFW 2013b).

The temperature model uses the Hydrologic Water Quality Modeling System (HWMS-HEC5Q), a graphical user interface that employs HEC-5Q, the USACE Hydrologic Engineering Center (HEC) flow and water quality simulation model, to model reservoir and river temperatures subject to historical climate conditions and user defined operations. The temperature model was designed to provide a SJR basin-wide evaluation of temperature response at 6-hour intervals for alternative conditions, such as operational changes, physical changes, and combinations of the two. The extent of the model includes the Merced, Tuolumne, and Stanislaus River systems from their LSJR confluences to the upstream end of their major reservoirs (i.e., McClure, Don Pedro, and New Melones, respectively). The upstream extent of the model on the LSJR is the Merced River confluence. The downstream extent of the model is the LSJR at Mossdale. The model simulates the reservoir stratification, release temperatures, and downstream river temperatures as a function of the inflow temperatures, reservoir geometry and outlets, flow, meteorology, and river geometry. Calibration data was used to accurately simulate temperatures for a range of reservoir operations, river flows, and meteorology.

---

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

The temperature model interfaces with CALSIM (see Appendix F.1, *Hydrologic and Water Quality Modeling*) or monthly data formatted similarly to CALSIM output. A pre-processing routine converts the monthly output to a format compatible with the SJR HEC-5Q model. This routine serves two purposes: 1) to allow the temperature model to perform a long-term simulation compatible with the period used in CALSIM II, and 2) to convert monthly output to daily values used in the temperature model.

Using the monthly output from the Water Supply Effects (WSE) model (see Appendix F.1), the "CALSIM to HEC-5Q" temperature model pre-processor was used by the State Water Board, and the temperature model was run to determine the river temperature effects of different flow scenarios within the Stanislaus, Tuolumne, Merced, and Lower San Joaquin Rivers. The temperature model was run for the period 1970 through 2003, a period with sufficient length and climatic variation to determine the effects of the LSJR alternatives on river temperatures.

## Temperature Criteria Used in Evaluation

The temperature thresholds used in this evaluation are based on the U.S. Environmental Protection Agency (USEPA) recommended temperature criteria for protection of salmonids using the 7-day average of the daily maximum (7DADM) unit of measurement (USEPA 2003). The 7DADM metric is recommended by USEPA because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day. Thus, it reflects an average of maximum temperatures that fish are exposed to over a week-long period. Because this metric is oriented to daily maximum temperatures, it can be used to protect against acute effects such as lethality and migration blockage conditions and also to protect against sub-lethal or chronic effects (e.g., temperature effects on growth, disease, smoltification, and competition) (USEPA 2003).

For this temperature evaluation of the Bay-Delta Plan update, USEPA's recommended criteria were used as a benchmark to measure changes in protective temperature conditions for Central Valley fall-run Chinook salmon and Central Valley steelhead under a variety of unimpaired flows. These protective temperature criteria represent the upper limits of the optimal temperature range for each evaluated life stage. The percentage of days during each month over the modeled 34-year period (1970-2003; n= number of days per specific month multiplied by 34 years) that USEPA criteria are expected to be met at each river location identified in Table 19-1 and Table 19-2 were used to quantify changes between baseline conditions and the conditions resulting from the modeled unimpaired flows. A 10% change in the amount of time that USEPA criteria is met, in combination with professional judgment, is used to determine a significant benefit or impact. Ten percent was selected because it accounts for a reasonable range of potential error associated with the assumptions used in the various analytical and modeling techniques. In addition, lacking quantitative relationships between a given change in environmental conditions and relevant population metrics (e.g., survival or abundance), a 10% change was considered sufficient to potentially result in beneficial or adverse effects to sensitive species at the population level.

Additionally, the average daily 7DADM values for each month (n= number of days per specific month multiplied by 34 years), and the 90th percentile daily 7DADM values for each month (n= number of days per specific month multiplied by 34 years) were evaluated for both baseline and unimpaired flows during the 34-year temperature model period. The 90th percentile temperature represents the 7DADM value in which temperatures are lower 90% of the time and temperatures are higher 10% of the time. These two temperature metrics provide additional insight into expected effects on native salmonids from different unimpaired flows.

## Life Stage Timing Used in Temperature Evaluation

This evaluation focuses on the most sensitive and relatively abundant salmonid species and life stages during each given time period. The life stage timings which were used are based on the general distribution and abundance of each life stage in the rivers. For example, water temperatures at locations approximately three-quarters of the distance from the mouth of each tributary to the first impassable dam were used to characterize water temperatures in the primary Chinook salmon and steelhead spawning reaches. This location was selected because it generally represents conditions in the spawning reaches, and therefore reflects water temperatures available for spawning and incubation. Table 19-1 provides a summary of the primary points of reference used for this comparative temperature analysis (between baseline and different unimpaired flows) in the Stanislaus, Tuolumne, and Merced Rivers.

On the LSJR, similar life stage timing was used as in the tributaries, except that spawning, egg incubation, and fry emergence were not used because salmonid reproduction typically does not take place in the LSJR, currently. Instead, the adult migration life stage was used during September through December, and the core juvenile rearing life stage was used during January through March. Table 19-2 provides a summary of the points of reference used for this comparative temperature analysis (between baseline and different unimpaired flow cases) in the LSJR.

**Table 19-1. Primary Stanislaus, Tuolumne, and Merced River fall-run Chinook salmon and steelhead (composite) temperature evaluation considerations. For the primary evaluation locations, the anadromous portion of the river was split into quarters, with ¼ River being closer to the confluence and ¾ River being closer to the dam that limits anadromous migrations.**

| Evaluation Time Period | Primary Life Stage (fall-run Chinook and steelhead composite) | Temperature Evaluation Thresholds (°C) | Temperature Evaluation Thresholds (°F) | Primary Evaluation Locations |
|---|---|---|---|---|
| September 1 to October 31 | Adult Migration | 18 (7DADM) | 64.4 (7DADM) | Confluence<br>¼ River<br>½ River |
| October 1 to March 31 | Spawning, Egg Incubation, and Fry Emergence | 13 (7DADM) | 55.4 (7DADM) | ½ River<br>¾ River<br>Dam |
| March 1 to May 31 | Core Juvenile Rearing | 16 (7DADM) | 60.8 (7DADM) | Confluence<br>¼ River<br>½ River<br>¾ River<br>Dam |
| April 1 to June 30 | Smoltification | 14 (7DADM) | 57.2 (7DADM) | Confluence<br>¼ River<br>½ River |
| June 1 to August 31 | Summer Rearing | 18 (7DADM) | 64.4 (7DADM) | ½ River<br>¾ River<br>Dam |

**Table 19-2. Primary Lower San Joaquin River fall-run Chinook salmon and steelhead (composite) temperature evaluation considerations.**

| Evaluation Time Period | Primary Life Stage (fall-run Chinook and steelhead composite) | Temperature Evaluation Thresholds (°C) | Temperature Evaluation Thresholds (°F) | Primary Evaluation Locations |
|---|---|---|---|---|
| September 1 to December 31 | Adult Migration | 18 (7DADM) | 64.4 (7DADM) | Vernalis |
| January 1 to March 31 | Core Juvenile Rearing | 16 (7DADM) | 60.8 (7DADM) | Vernalis |
| April 1 to June 30 | Smoltification | 14 (7DADM) | 57.2 (7DADM) | Vernalis |

## 19.2.3 Results of Temperature Evaluation

Based on this evaluation and the conclusions and discussions of others (Baker et al. 1995; Brandes and McLain 2001; CDFG 2005b, 2010a; Kjelson et al 1982; Kjelson and Brandes 1989; Marine and Cech 2004; Mesick 2010a; Myrick and Cech 2001; NMFS 2009a; Zeug et al. 2014), existing baseline temperature conditions in the Bay-Delta Plan area including the Stanislaus, Tuolumne, and Merced Rivers are likely to be detrimental to salmonids, and other native fishes, that use these waterways. Temperature conditions in September, October, and November are often poor at many locations used by adult migrating and spawning salmon. Furthermore, fry emergence, rearing, smoltification, and emigration life stages are also exposed to suboptimal and even harmful temperature conditions from roughly March through June during many years. Finally, salmonids that stay in the rivers to over summer between June and September have little chance of thriving unless they find the little cold water refugia that potentially exists (depending on the year and river) directly below the dams.

The results of this analysis indicate that significant temperature benefits to Central Valley fall-run Chinook salmon and Central Valley steelhead will occur on the Stanislaus, Tuolumne, Merced, and LSJ Rivers under some of the unimpaired flow alternatives which were evaluated. Significant temperature improvements in the Stanislaus River primarily occur under 50%-60% unimpaired flows, and in the Merced River primarily occur under 30%-60% unimpaired flows. Significant temperature improvements in the Tuolumne River occur under all alternative unimpaired flows with the least benefit occurring under 20% unimpaired flow and the most benefit occurring under 60% unimpaired flow. However, modeling results indicate that significant temperature benefits to the smoltification life stage will occur only with 50% and 60% unimpaired flows on the Stanislaus and Merced Rivers during April and May (Tables 19-3 and 19-9). In the LSJR, significant temperature improvements to the availability of optimal conditions occur during March under the 60% unimpaired flow, with other months and other unimpaired flows not expected to produce significant benefits or impacts on optimal salmonid temperature habitat. Although there are limited benefits to optimal salmonid temperature habitat in the LSJR, there are substantial reductions in average temperatures and 90th percentile temperatures primarily during the March through June time period with higher unimpaired flows providing greater reductions to these measures of temperature.

It is important to note that interpretations of the results do not place too much emphasis on temperature criteria compliance at the dam release locations, because releasing small amounts of cold water can indicate that adequate temperature habitat exists, but may not actually provide favorable conditions for native fish in these rivers due to rapid warming as the water flows downstream under low flow conditions. A better location to evaluate temperature during many months in each river is near the ¾ river location, or further downstream. However, there is information that can be gathered from the temperatures at the dam releases. For example, the temperature of water at the dam release can indicate whether or not there is cold water available for release.

The remainder of this section provides an interpretation of the results presented in Tables 19-3 through 19-14, and is organized in sections specific to each evaluation time period, life stage, and location.

**Table 19-3. The percentage of time on the Stanislaus River that USEPA salmon and steelhead temperature criteria (7DADM unit of measurement) are met each month under modeled baseline (base) conditions during 1970 to 2003, and the magnitude of expected percent change under modeled unimpaired flows of 20%, 30%, 40%, 50% and 60% at different river mile (RM) locations. Positive numbers under the unimpaired flows represent the magnitude of increases compared to baseline in the percentage of time that criteria are expected to be met, and negative numbers under the unimpaired flows represent the magnitude of reductions compared to baseline in the percentage of time that criteria are expected to be met. Expected changes in the amount of time that USEPA temperature criteria are met which are greater than positive 10% or less than negative 10% are highlighted green or red respectively (if applicable), and represent significant changes to salmon and steelhead temperature habitat if indicated at locations which are utilized by that life stage.**

| Stanislaus River | | Confluence (RM0) | | | | | | 1/4 River (RM13.3) | | | | | | 1/2 River (RM28.2) | | | | | | 3/4 River (RM43.7) | | | | | | Below Goodwin (RM58.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life Stage | Month / USEPA Criteria (°F) | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | |
| | | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| AM | Sep (64.4) | **10%** | 0% | 0% | 2% | 0% | -2% | **11%** | 0% | 0% | 8% | 6% | 4% | **17%** | 2% | 0% | 14% | 13% | 11% | **67%** | 3% | -1% | -1% | -1% | -6% | **88%** | 12% | 12% | 12% | 12% | 12% |
| AM | Oct (64.4) | **71%** | 7% | 6% | 12% | 11% | 11% | **75%** | 8% | 7% | 12% | 12% | 10% | **82%** | 9% | 8% | 11% | 11% | 10% | **87%** | 11% | 11% | 12% | 11% | 11% | **88%** | 12% | 12% | 12% | 12% | 12% |
| R | Oct (55.4) | **3%** | 0% | -1% | -3% | -3% | -3% | **3%** | 0% | 0% | -2% | -2% | -3% | **5%** | 0% | 0% | 1% | 0% | -2% | **17%** | 0% | 0% | 2% | -2% | -4% | **55%** | 4% | 1% | -2% | -5% | -9% |
| R | Nov (55.4) | **27%** | 2% | 2% | 3% | 1% | 0% | **27%** | 2% | 1% | 3% | 1% | -1% | **36%** | 2% | 0% | 2% | -1% | -4% | **45%** | 6% | 1% | 3% | 0% | -4% | **64%** | 5% | 1% | 1% | 2% | -4% |
| R | Dec (55.4) | **99%** | 1% | 1% | 1% | 1% | 1% | **99%** | 1% | 1% | 1% | 1% | 1% | **97%** | 3% | 3% | 3% | 3% | 3% | **95%** | 4% | 4% | 5% | 5% | 4% | **90%** | 6% | 6% | 8% | 7% | 7% |
| R | Jan (55.4) | **99%** | 0% | 0% | 0% | 0% | 0% | **99%** | 0% | 0% | 0% | 0% | 0% | **99%** | 0% | 0% | 0% | 0% | 0% | **99%** | 0% | 0% | 0% | 0% | 0% | **99%** | 0% | 0% | 0% | 0% | 0% |
| R | Feb (55.4) | **85%** | 2% | 3% | 3% | 4% | 6% | **85%** | 2% | 3% | 4% | 5% | 7% | **93%** | 1% | 0% | 1% | 2% | 3% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% |
| R | Mar (55.4) | **36%** | 7% | 9.9% | 9.6% | 16% | 21% | **41%** | 4% | 9% | 9.96% | 16% | 21% | **53%** | 0% | 7% | 12% | 16% | 22% | **78%** | -1% | 4% | 11% | 14% | 17% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | Mar (60.8) | **91%** | -1% | 2% | 5% | 7% | 8% | **92%** | -1% | 4% | 5% | 7% | 7% | **97%** | -1% | 2% | 2% | 3% | 3% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | Apr (60.8) | **78%** | -2% | 1% | 3% | 9.9% | 13% | **81%** | -1% | 1% | 8% | 11% | 13% | **90%** | 0% | 5% | 7% | 8% | 8% | **99%** | 1% | 1% | 1% | 1% | 1% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | May (60.8) | **51%** | -2% | 4% | 6% | 14% | 22% | **61%** | -1% | 3% | 7% | 12% | 18% | **73%** | 1% | 6% | 9.7% | 11% | 13% | **94%** | 2% | 2% | 3% | 5% | 6% | **100%** | 0% | 0% | 0% | 0% | 0% |
| S | Apr (57.2) | **39%** | -2% | -1% | 1% | 5% | 9.7% | **45%** | 1% | 2% | 3% | 8% | 11% | **64%** | -1% | 0% | 2% | 4% | 9% | **85%** | 1% | 6% | 8% | 11% | 12% | **99%** | 1% | 1% | 1% | 1% | 1% |
| S | May (57.2) | **5%** | -2% | 0% | 2% | 8% | 17% | **13%** | -4% | -1% | 2% | 11% | 22% | **31%** | -6% | 0% | 7% | 16% | 22% | **67%** | 2% | 3% | 7% | 10% | 13% | **97%** | 3% | 3% | 3% | 3% | 3% |
| S | Jun (57.2) | **0%** | 0% | 0% | 1% | 5% | 7% | **3%** | 0% | 0% | 1% | 5% | 6% | **5%** | 0% | 3% | 4% | 8% | 13% | **27%** | -3% | -1% | 2% | 11% | 17% | **96%** | 2% | 0% | 1% | -1% | -2% |
| SR | Jun (64.4) | **38%** | -1% | 1% | 3% | 12% | 19% | **47%** | -4% | -2% | 2% | 11% | 17% | **56%** | -2% | 3% | 7% | 12% | 15% | **81%** | 3% | 4% | 5% | 5% | 7% | **100%** | 0% | 0% | 0% | 0% | 0% |
| SR | Jul (64.4) | **5%** | 0% | 2% | 2% | 3% | 4% | **8%** | -2% | 2% | 0% | 1% | 3% | **12%** | -1% | 4% | 4% | 5% | 7% | **43%** | 3% | 4% | 9% | 8% | 8% | **100%** | 0% | 0% | 0% | 0% | 0% |
| SR | Aug (64.4) | **5%** | 2% | 0% | -2% | -2% | -4% | **6%** | 2% | -1% | -3% | -3% | -3% | **8%** | 0% | -2% | -5% | -5% | -5% | **47%** | 3% | -2% | 1% | -1% | -7% | **96%** | 4% | 4% | 4% | 4% | 4% |

AM = Adult Migration
R = Reproduction (Spawning, Egg Incubation, and Fry Emergence)
CR = Core Rearing
S = Smoltification
SR = Summer Rearing

**Table 19-4. The average daily 7DADM temperature values for each month on the Stanislaus River under modeled baseline (base) condition from 1970 to 2003, and the modeled difference in °F for each of the unimpaired flow percentages between 20% to 60%. Negative numbers represent the expected magnitude of reductions in 7DADM values and positive numbers represent the expected magnitude of increases in 7DADM values. Expected changes in the magnitude of 7DADM values greater than positive 1°F or less than negative 1°F are highlighted either red or green respectively (if applicable). The green and/or reds cells were highlighted to aid the visual review of this table and do not necessarily represent significant changes to salmon and steelhead temperature habitat.**

| Stanislaus Average 7DADM | Confluence (RM0) | | | | | | 1/4 River (RM13.3) | | | | | | 1/2 River (RM28.2) | | | | | | 3/4 River (RM43.7) | | | | | | Below Goodwin (RM58.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | |
| | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| Sep | **69.6** | -0.2 | 0.0 | -0.5 | -0.3 | -0.1 | **68.9** | -0.3 | -0.1 | -0.6 | -0.4 | -0.2 | **67.3** | -0.4 | -0.2 | -0.7 | -0.5 | -0.2 | **63.4** | -0.7 | -0.5 | -0.9 | -0.7 | -0.3 | **56.6** | -1.2 | -0.9 | -0.8 | -0.6 | -0.1 |
| Oct | **62.0** | -0.6 | -0.4 | -1.2 | -1.1 | -0.9 | **61.5** | -0.7 | -0.5 | -1.2 | -1.1 | -0.9 | **60.4** | -0.8 | -0.6 | -1.3 | -1.1 | -0.9 | **58.7** | -1.0 | -0.8 | -1.2 | -1.1 | -0.8 | **56.4** | -1.3 | -1.0 | -1.2 | -1.0 | -0.7 |
| Nov | **56.8** | -0.4 | -0.3 | -0.4 | -0.3 | -0.2 | **56.8** | -0.4 | -0.3 | -0.4 | -0.3 | -0.2 | **56.6** | -0.5 | -0.4 | -0.5 | -0.4 | -0.3 | **56.2** | -0.7 | -0.6 | -0.7 | -0.6 | -0.4 | **55.6** | -1.0 | -0.8 | -0.9 | -0.8 | -0.5 |
| Dec | **50.9** | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | **51.1** | -0.2 | -0.1 | -0.1 | -0.1 | 0.0 | **51.2** | -0.2 | -0.2 | -0.2 | -0.1 | -0.1 | **51.8** | -0.3 | -0.2 | -0.3 | -0.2 | -0.1 | **52.3** | -0.4 | -0.3 | -0.3 | -0.3 | -0.2 |
| Jan | **49.8** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **50.0** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **49.8** | -0.1 | 0.0 | -0.1 | 0.0 | 0.0 | **49.6** | -0.1 | 0.0 | -0.1 | -0.1 | 0.0 | **49.0** | -0.1 | 0.0 | -0.1 | -0.1 | -0.1 |
| Feb | **52.5** | -0.1 | -0.3 | -0.5 | -0.6 | -0.8 | **52.5** | -0.2 | -0.4 | -0.6 | -0.7 | -0.9 | **51.9** | -0.2 | -0.4 | -0.5 | -0.7 | -0.8 | **50.7** | -0.1 | -0.2 | -0.3 | -0.4 | -0.5 | **48.8** | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 |
| Mar | **56.5** | -0.1 | -0.5 | -0.7 | -1.1 | -1.5 | **56.2** | -0.2 | -0.6 | -0.8 | -1.2 | -1.6 | **55.2** | -0.2 | -0.6 | -0.8 | -1.2 | -1.6 | **53.4** | -0.1 | -0.4 | -0.6 | -0.8 | -1.0 | **50.5** | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 |
| Apr | **58.5** | 0.1 | -0.1 | -0.3 | -0.7 | -1.1 | **57.9** | 0.1 | -0.1 | -0.3 | -0.7 | -1.0 | **56.6** | 0.1 | -0.1 | -0.3 | -0.6 | -0.9 | **54.7** | 0.1 | -0.1 | -0.2 | -0.4 | -0.5 | **51.8** | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| May | **61.5** | 0.0 | -0.4 | -0.8 | -1.4 | -2.1 | **60.8** | 0.0 | -0.4 | -0.8 | -1.4 | -2.0 | **59.1** | 0.0 | -0.4 | -0.7 | -1.2 | -1.7 | **56.6** | 0.0 | -0.3 | -0.4 | -0.8 | -1.1 | **53.0** | 0.0 | 0.0 | 0.0 | -0.1 | -0.2 |
| Jun | **66.8** | 0.1 | -0.4 | -0.8 | -1.6 | -2.4 | **66.0** | 0.1 | -0.4 | -0.8 | -1.7 | -2.4 | **64.1** | 0.0 | -0.4 | -0.9 | -1.6 | -2.2 | **60.3** | -0.1 | -0.4 | -0.7 | -1.2 | -1.6 | **53.8** | -0.1 | 0.0 | -0.1 | 0.0 | 0.0 |
| Jul | **72.8** | -0.1 | -0.4 | -0.9 | -1.0 | -1.1 | **72.0** | -0.1 | -0.4 | -0.9 | -1.0 | -1.1 | **70.0** | -0.2 | -0.5 | -1.0 | -1.1 | -1.1 | **64.8** | -0.3 | -0.4 | -0.9 | -0.9 | -0.8 | **55.0** | -0.3 | -0.1 | -0.1 | 0.1 | 0.3 |
| Aug | **73.0** | -0.3 | -0.1 | 0.0 | 0.1 | 0.3 | **72.2** | -0.3 | -0.1 | -0.1 | 0.0 | 0.3 | **70.2** | -0.4 | -0.1 | -0.1 | 0.0 | 0.2 | **65.0** | -0.6 | -0.3 | -0.3 | -0.1 | 0.2 | **55.8** | -0.7 | -0.5 | -0.4 | -0.1 | 0.4 |

**Table 19-5. The 90th percentile daily 7DADM temperature values for the 1970 to 2003 model period for each month at different Stanislaus River locations, and the expected difference in °F for each of the unimpaired flow percentages between 20% and 60%. Each of the 90th percentile values which are displayed for baseline (base) indicate that daily 7DADM values were less than that temperature 90% of the time, or were greater than that temperature 10% of the time during each month and river location. Expected changes in the magnitude of 90th percentile 7DADM values greater than positive 1°F or less than negative 1°F are highlighted either red or green respectively (if applicable). The green and/or reds cells were highlighted to aid the visual review of this table and do not necessarily represent significant changes to salmon and steelhead temperature habitat.**

| Stanislaus 90th Percentile 7DADM | Confluence (RM0) | | | | | | 1/4 River (RM13.3) | | | | | | 1/2 River (RM28.2) | | | | | | 3/4 River (RM43.7) | | | | | | Below Goodwin (RM58.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | |
| | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| Sep | **74.3** | -0.4 | -0.4 | -0.5 | -0.4 | -0.3 | **74.1** | -0.8 | -0.7 | -0.8 | -0.7 | -0.5 | **73.3** | -1.4 | -1.4 | -1.5 | -1.4 | -1.2 | **70.2** | -3.1 | -2.9 | -3.1 | -3.0 | -2.8 | **65.5** | -6.5 | -6.3 | -6.4 | -6.1 | -5.9 |
| Oct | **68.2** | -1.2 | -1.1 | -2.1 | -2.0 | -1.8 | **67.7** | -1.7 | -1.5 | -2.6 | -2.4 | -2.2 | **66.9** | -2.7 | -2.5 | -3.5 | -3.4 | -3.2 | **66.2** | -5.3 | -5.0 | -5.8 | -5.7 | -5.3 | **65.9** | -7.6 | -7.5 | -8.1 | -7.9 | -7.8 |
| Nov | **60.5** | -0.6 | -0.5 | -0.9 | -0.9 | -0.9 | **60.3** | -0.6 | -0.6 | -0.9 | -0.9 | -0.8 | **59.9** | -0.7 | -0.6 | -0.9 | -0.8 | -0.8 | **60.2** | -2.0 | -1.9 | -2.1 | -2.1 | -2.0 | **60.9** | -3.7 | -3.5 | -3.9 | -4.0 | -4.0 |
| Dec | **53.6** | -0.3 | -0.3 | -0.2 | -0.2 | -0.1 | **53.8** | -0.4 | -0.3 | -0.3 | -0.2 | -0.2 | **53.9** | -0.5 | -0.4 | -0.4 | -0.3 | -0.2 | **54.5** | -0.8 | -0.6 | -0.6 | -0.6 | -0.5 | **55.5** | -1.1 | -0.9 | -1.1 | -1.1 | -1.0 |
| Jan | **52.2** | -0.1 | -0.1 | -0.1 | 0.0 | 0.1 | **52.3** | -0.1 | 0.0 | -0.1 | -0.1 | 0.1 | **52.1** | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | **51.7** | -0.2 | -0.1 | -0.1 | -0.1 | 0.0 | **51.1** | -0.3 | -0.2 | -0.3 | -0.3 | -0.2 |
| Feb | **56.1** | 0.0 | -0.1 | -0.2 | -0.5 | -0.8 | **56.0** | -0.3 | -0.3 | -0.5 | -0.8 | -1.1 | **55.1** | -0.2 | -0.3 | -0.4 | -0.7 | -1.1 | **53.2** | 0.0 | -0.1 | -0.2 | -0.4 | -0.6 | **50.7** | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 |
| Mar | **60.6** | 0.3 | -0.3 | -0.8 | -1.5 | -2.2 | **60.4** | 0.2 | -0.7 | -1.2 | -2.0 | -2.7 | **59.4** | 0.2 | -0.8 | -1.3 | -2.1 | -2.7 | **56.5** | 0.3 | -0.6 | -1.0 | -1.4 | -1.8 | **52.6** | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 |
| Apr | **63.1** | 0.2 | -0.8 | -1.4 | -1.8 | -2.4 | **62.4** | 0.3 | -0.8 | -1.5 | -1.8 | -2.3 | **60.8** | 0.2 | -0.8 | -1.4 | -1.8 | -2.2 | **57.7** | 0.0 | -0.5 | -0.9 | -1.2 | -1.3 | **53.9** | -0.2 | -0.3 | -0.2 | -0.2 | -0.2 |
| May | **66.4** | -0.3 | -1.2 | -1.5 | -1.6 | -2.2 | **65.5** | -0.2 | -1.1 | -1.3 | -1.5 | -2.0 | **63.6** | -0.1 | -1.1 | -1.3 | -1.3 | -1.9 | **60.2** | -0.3 | -0.9 | -0.9 | -1.0 | -1.4 | **54.9** | 0.0 | 0.0 | 0.0 | -0.1 | -0.2 |
| Jun | **73.3** | -0.1 | -0.3 | -0.3 | -0.6 | -1.0 | **72.9** | -0.5 | -0.4 | -0.4 | -0.8 | -1.2 | **71.5** | -0.7 | -0.8 | -0.6 | -1.2 | -1.6 | **66.5** | -0.8 | -0.8 | -0.9 | -1.5 | -1.7 | **56.2** | -0.1 | 0.2 | -0.1 | 0.0 | 0.3 |
| Jul | **77.4** | -0.3 | -0.2 | -0.3 | -0.4 | -0.4 | **76.9** | -0.3 | -0.3 | -0.5 | -0.5 | -0.5 | **75.3** | -0.5 | -0.4 | -0.6 | -0.6 | -0.5 | **69.4** | -0.5 | -0.4 | -0.6 | -0.5 | -0.4 | **57.8** | -0.4 | -0.1 | 0.2 | 0.6 | 0.8 |
| Aug | **76.9** | -0.3 | -0.2 | -0.4 | -0.4 | -0.3 | **76.4** | -0.4 | -0.3 | -0.6 | -0.4 | -0.3 | **75.0** | -0.6 | -0.5 | -0.9 | -0.8 | -0.7 | **70.3** | -1.6 | -1.4 | -1.7 | -1.6 | -1.5 | **60.6** | -2.6 | -1.8 | -1.7 | -1.3 | -1.1 |

**Table 19-6. The percentage of time on the Tuolumne River that USEPA salmon and steelhead temperature criteria (7DADM unit of measurement) are met each month under modeled baseline (base) conditions during 1970 to 2003, and the magnitude of expected percent change under modeled unimpaired flows of 20%, 30%, 40%, 50% and 60% at different river mile (RM) locations. Positive numbers under the unimpaired flows represent the magnitude of increases compared to baseline in the percentage of time that criteria are expected to be met, and negative numbers under the unimpaired flows represent the magnitude of reductions compared to baseline in the percentage of time that criteria are expected to be met. Expected changes in the amount of time that USEPA temperature criteria are met which are greater than positive 10% or less than negative 10% are highlighted green or red respectively (if applicable), and represent significant changes to salmon and steelhead temperature habitat if indicated at locations which are utilized by that life stage.**

| Tuolumne River | | Confluence (RM0) | | | | | | 1/4 River (RM13.2) | | | | | | 1/2 River (RM28.1) | | | | | | 3/4 River (RM38.3) | | | | | | Below La Grange (RM53.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life Stage | Month / USEPA Criteria (°F) | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | |
| | | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| AM | Sep (64.4) | **2%** | 0% | 0% | 0% | 0% | 0% | **3%** | 0% | 0% | 2% | 2% | 1% | **11%** | 0% | -2% | 17% | 17% | 16% | **33%** | 0% | -3% | 7% | 6% | 6% | **100%** | 0% | 0% | 0% | 0% | 0% |
| AM | Oct (64.4) | **25%** | 0% | -1% | 6% | 5% | 6% | **37%** | 0% | -1% | 4% | 3% | 3% | **63%** | 0% | 0% | 3% | 4% | 4% | **81%** | 1% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% |
| R | Oct (55.4) | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **1%** | 0% | -1% | -1% | -1% | -1% | **85%** | 3% | 3% | 3% | 4% | -2% |
| R | Nov (55.4) | **27%** | 0% | 0% | 1% | 0% | -1% | **34%** | 0% | 0% | 1% | -1% | -2% | **23%** | 0% | -1% | -1% | -4% | -5% | **27%** | 0% | -2% | -3% | -9% | -9% | **85%** | 4% | 4% | 5% | 6% | 0% |
| R | Dec (55.4) | **98%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | -1% | -1% | -1% | **95%** | 0% | 0% | 0% | -1% | -2% | **93%** | 1% | 0% | 0% | -2% | -2% | **95%** | 1% | 1% | 1% | 1% | -2% |
| R | Jan (55.4) | **98%** | 0% | 0% | 0% | 0% | 0% | **98%** | 0% | 0% | 0% | 0% | 0% | **97%** | 0% | 0% | 0% | 0% | 0% | **99%** | 0% | 0% | 0% | 0% | -1% | **99%** | 0% | 0% | 0% | 0% | 0% |
| R | Feb (55.4) | **69%** | 2% | 3% | 6% | 8% | 10% | **75%** | 3% | 5% | 6% | 8% | 9.9% | **72%** | 5% | 8% | 9.8% | 14% | 18% | **79%** | 1% | 4% | 9.99% | 12% | 13% | **100%** | 0% | 0% | 0% | 0% | 0% |
| R | Mar (55.4) | **37%** | -3% | -3% | -3% | -1% | 9% | **50%** | -1% | 0% | 2% | 7% | 12% | **54%** | 5% | 8% | 14% | 22% | 27% | **56%** | 9% | 14% | 25% | 30% | 35% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | Mar (60.8) | **65%** | 6% | 8% | 18% | 24% | 28% | **72%** | 5% | 11% | 20% | 23% | 25% | **84%** | 9% | 14% | 15% | 15% | 16% | **91%** | 8% | 9% | 9% | 9% | 9% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | Apr (60.8) | **50%** | 0% | 6% | 21% | 35% | 41% | **57%** | 4% | 18% | 31% | 36% | 38% | **74%** | 16% | 22% | 22% | 24% | 25% | **92%** | 6% | 6% | 7% | 8% | 8% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | May (60.8) | **19%** | 2% | 20% | 34% | 47% | 37% | **34%** | 9% | 32% | 46% | 52% | 58% | **59%** | 21% | 30% | 39% | 41% | 41% | **74%** | 14% | 24% | 26% | 26% | 26% | **100%** | 0% | 0% | 0% | 0% | 0% |
| S | Apr (57.2) | **22%** | 0% | 2% | 5% | 9% | 15% | **36%** | -2% | 2% | 7% | 21% | 31% | **57%** | 3% | 16% | 28% | 34% | 37% | **65%** | 14% | 25% | 29% | 30% | 31% | **100%** | 0% | 0% | 0% | 0% | 0% |
| S | May (57.2) | **3%** | 0% | 1% | 2% | 4% | 3% | **15%** | 3% | 9% | 16% | 30% | 40% | **38%** | 9% | 26% | 39% | 43% | 46% | **56%** | 14% | 28% | 35% | 40% | 43% | **100%** | 0% | 0% | 0% | 0% | 0% |
| S | Jun (57.2) | **0%** | 0% | 0% | 0% | 0% | 0% | **5%** | 1% | 1% | 2% | 5% | 10% | **23%** | -1% | 6% | 13% | 21% | 23% | **34%** | 8% | 20% | 31% | 37% | 39% | **100%** | 0% | 0% | 0% | 0% | 0% |
| SR | Jun (64.4) | **30%** | 1% | 11% | 24% | 35% | 36% | **34%** | 7% | 25% | 33% | 41% | 42% | **42%** | 24% | 33% | 37% | 45% | 48% | **46%** | 29% | 37% | 45% | 45% | 47% | **100%** | 0% | 0% | 0% | 0% | 0% |
| SR | Jul (64.4) | **6%** | -1% | 0% | 1% | 1% | -1% | **19%** | 0% | -2% | 0% | -2% | -4% | **23%** | 2% | -2% | 16% | 17% | 14% | **26%** | 3% | -3% | 15% | 16% | 16% | **100%** | 0% | 0% | 0% | 0% | 0% |
| SR | Aug (64.4) | **0%** | 0% | 0% | 0% | 0% | 0% | **2%** | 0% | 0% | -1% | -1% | -2% | **8%** | 0% | 0% | 1% | 1% | 0% | **9%** | 0% | -1% | 8% | 6% | 5% | **100%** | 0% | 0% | 0% | 0% | 0% |

AM = Adult Migration
R = Reproduction (Spawning, Egg Incubation, and Fry Emergence)
CR = Core Rearing
S = Smoltification
SR = Summer Rearing

**Table 19-7. The average daily 7DADM temperature values for each month on the Tuolumne River under modeled baseline (base) condition from 1970 to 2003, and the modeled difference in °F for each of the unimpaired flow percentages between 20% to 60%. Negative numbers represent the expected magnitude of reductions in 7DADM values and positive numbers represent the expected magnitude of increases in 7DADM values. Expected changes in the magnitude of 7DADM values greater than positive 1°F or less than negative 1°F are highlighted either red or green respectively (if applicable). The green and/or reds cells were highlighted to aid the visual review of this table and do not necessarily represent significant changes to salmon and steelhead temperature habitat.**

| Tuolumne Average 7DADM | Confluence (RM0) | | | | | | 1/4 River (RM13.2) | | | | | | 1/2 River (RM28.1) | | | | | | 3/4 River (RM38.3) | | | | | | Below La Grange (RM53.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | |
| | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| Sep | **75.5** | 0.0 | 0.1 | -1.1 | -1.1 | -1.0 | **74.9** | 0.0 | 0.1 | -1.2 | -1.2 | -1.1 | **70.9** | 0.0 | 0.2 | -1.1 | -1.0 | -1.0 | **68.3** | 0.0 | 0.2 | -0.8 | -0.7 | -0.7 | **53.5** | 0.0 | 0.2 | 0.4 | 0.6 | 0.6 |
| Oct | **67.5** | 0.0 | 0.1 | -0.5 | -0.5 | -0.5 | **66.5** | 0.0 | 0.2 | -0.5 | -0.4 | -0.4 | **63.3** | 0.0 | 0.2 | -0.3 | -0.2 | -0.2 | **61.3** | 0.0 | 0.2 | -0.1 | 0.0 | 0.0 | **53.8** | -0.1 | 0.1 | 0.3 | 0.5 | 0.5 |
| Nov | **57.8** | 0.0 | 0.0 | -0.2 | -0.1 | -0.1 | **56.9** | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | **57.2** | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | **56.7** | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | **53.7** | -0.1 | 0.0 | 0.3 | 0.4 | 0.4 |
| Dec | **50.2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **49.6** | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | **52.6** | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | **53.3** | 0.0 | 0.0 | 0.2 | 0.2 | 0.2 | **52.9** | 0.0 | 0.0 | 0.2 | 0.3 | 0.3 |
| Jan | **50.0** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **49.4** | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | **51.9** | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | **52.2** | 0.0 | 0.1 | 0.2 | 0.2 | 0.2 | **51.0** | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 |
| Feb | **54.2** | -0.1 | -0.2 | -0.3 | -0.4 | -0.7 | **53.3** | -0.1 | -0.2 | -0.3 | -0.5 | -0.7 | **53.6** | -0.1 | -0.4 | -0.5 | -0.8 | -1.0 | **53.1** | -0.1 | -0.4 | -0.5 | -0.7 | -1.0 | **50.0** | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 |
| Mar | **58.5** | -0.4 | -0.7 | -1.2 | -1.6 | -2.2 | **57.2** | -0.5 | -0.9 | -1.3 | -1.7 | -2.2 | **55.7** | -0.8 | -1.2 | -1.7 | -2.0 | -2.4 | **54.5** | -0.8 | -1.2 | -1.6 | -1.9 | -2.2 | **49.7** | 0.0 | -0.1 | -0.1 | -0.2 | -0.2 |
| Apr | **61.7** | -0.7 | -1.6 | -2.5 | -3.2 | -3.8 | **60.1** | -0.8 | -1.7 | -2.5 | -3.2 | -3.8 | **57.0** | -0.7 | -1.4 | -2.0 | -2.5 | -2.9 | **55.2** | -0.6 | -1.2 | -1.7 | -2.1 | -2.5 | **49.7** | 0.0 | 0.0 | -0.1 | -0.1 | -0.2 |
| May | **65.9** | -1.7 | -3.8 | -4.8 | -5.6 | -5.4 | **63.8** | -1.9 | -3.9 | -5.1 | -6.0 | -6.6 | **59.6** | -1.5 | -2.9 | -3.7 | -4.2 | -4.4 | **57.2** | -1.3 | -2.5 | -3.1 | -3.4 | -3.4 | **50.0** | 0.0 | 0.0 | -0.1 | -0.1 | 0.0 |
| Jun | **72.2** | -2.8 | -4.7 | -6.0 | -7.0 | -7.3 | **70.7** | -3.4 | -5.5 | -6.9 | -8.1 | -9.0 | **67.4** | -4.3 | -6.1 | -7.2 | -8.1 | -8.6 | **65.3** | -4.8 | -6.4 | -7.4 | -8.2 | -8.5 | **50.9** | -0.1 | -0.1 | 0.0 | 0.1 | 0.2 |
| Jul | **77.6** | -0.6 | -0.4 | -2.1 | -2.1 | -1.9 | **76.5** | -0.7 | -0.3 | -2.2 | -2.2 | -2.0 | **72.6** | -0.9 | -0.5 | -2.4 | -2.4 | -2.1 | **69.8** | -0.8 | -0.4 | -2.0 | -1.9 | -1.7 | **51.9** | 0.1 | 0.2 | 0.4 | 0.6 | 0.9 |
| Aug | **79.1** | 0.0 | 0.2 | -0.5 | -0.4 | -0.3 | **78.5** | 0.0 | 0.2 | -0.6 | -0.5 | -0.3 | **74.0** | 0.0 | 0.2 | -0.6 | -0.5 | -0.3 | **71.1** | 0.0 | 0.2 | -0.4 | -0.3 | -0.2 | **52.9** | 0.0 | 0.2 | 0.4 | 0.6 | 0.8 |

**Table 19-8. The 90th percentile daily 7DADM temperature values for the 1970 to 2003 model period for each month at different Tuolumne River locations, and the expected difference in °F for each of the unimpaired flow percentages between 20% and 60%. Each of the 90th percentile values which are displayed for baseline (base) indicate that daily 7DADM values were less than that temperature 90% of the time, or were greater than that temperature 10% of the time during each month and river location. Expected changes in the magnitude of 90th percentile 7DADM values greater than positive 1°F or less than negative 1°F are highlighted either red or green respectively (if applicable). The green and/or reds cells were highlighted to aid the visual review of this table and do not necessarily represent significant changes to salmon and steelhead temperature habitat.**

| Tuolumne 90th Percentile 7DADM | Confluence (RM0) | | | | | | 1/4 River (RM13.2) | | | | | | 1/2 River (RM28.1) | | | | | | 3/4 River (RM38.29) | | | | | | Below La Grange (RM53.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | |
| | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| Sep | **80.1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **80.2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **77.7** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **75.8** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **55.6** | -0.3 | -0.1 | -0.1 | -0.3 | -0.3 |
| Oct | **73.5** | 0.0 | 0.0 | -0.6 | -0.6 | -0.6 | **72.6** | 0.0 | 0.0 | -0.3 | -0.2 | -0.2 | **69.7** | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | **66.9** | -0.2 | -0.2 | -0.2 | -0.3 | -0.2 | **56.3** | -0.5 | -0.5 | -0.4 | -0.6 | -0.4 |
| Nov | **62.8** | 0.0 | 0.1 | -0.1 | -0.1 | -0.1 | **61.9** | 0.0 | 0.1 | -0.1 | -0.1 | -0.2 | **60.7** | 0.0 | 0.0 | -0.1 | -0.3 | -0.3 | **59.7** | -0.2 | -0.2 | -0.5 | -0.5 | -0.6 | **56.0** | -0.3 | -0.4 | -0.5 | -0.6 | -0.1 |
| Dec | **53.9** | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | **53.4** | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | **54.8** | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | **55.1** | -0.1 | 0.0 | 0.1 | 0.3 | 0.3 | **54.6** | -0.3 | -0.3 | -0.1 | 0.3 | 0.4 |
| Jan | **53.4** | 0.0 | 0.0 | 0.2 | 0.1 | 0.2 | **52.9** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **54.1** | 0.0 | 0.1 | 0.2 | 0.2 | 0.2 | **54.1** | 0.0 | 0.0 | 0.2 | 0.3 | 0.3 | **52.2** | 0.0 | 0.1 | 0.4 | 0.6 | 0.8 |
| Feb | **59.1** | -0.2 | -0.5 | -0.8 | -1.2 | -1.7 | **58.5** | -0.3 | -0.7 | -1.1 | -1.5 | -2.0 | **57.8** | 0.1 | -0.7 | -1.4 | -1.8 | -2.3 | **56.7** | 0.1 | -0.6 | -1.2 | -1.5 | -1.7 | **51.7** | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 |
| Mar | **65.5** | -1.5 | -2.5 | -3.8 | -4.6 | -5.5 | **64.6** | -1.5 | -2.8 | -4.1 | -5.0 | -5.7 | **62.6** | -2.1 | -3.6 | -4.4 | -5.3 | -6.0 | **60.6** | -2.0 | -3.3 | -4.1 | -4.8 | -5.3 | **51.3** | -0.1 | 0.0 | -0.1 | 0.0 | 0.0 |
| Apr | **69.0** | -2.5 | -4.5 | -6.1 | -7.5 | -8.5 | **67.4** | -2.6 | -4.5 | -6.2 | -7.4 | -8.3 | **63.4** | -2.5 | -4.2 | -5.6 | -6.5 | -7.1 | **60.6** | -2.1 | -3.4 | -4.6 | -5.4 | -5.8 | **51.1** | 0.0 | -0.1 | -0.1 | 0.0 | 0.0 |
| May | **73.2** | -3.0 | -5.7 | -8.0 | -9.6 | -10.0 | **71.5** | -2.8 | -6.0 | -8.3 | -9.8 | -11.0 | **66.2** | -2.1 | -5.2 | -6.8 | -7.7 | -8.4 | **62.8** | -1.9 | -4.5 | -5.7 | -6.5 | -6.9 | **51.5** | -0.1 | -0.1 | 0.0 | 0.0 | 0.1 |
| Jun | **81.2** | -2.5 | -3.7 | -5.7 | -7.7 | -9.4 | **81.0** | -2.9 | -4.7 | -7.3 | -9.5 | -11.5 | **79.0** | -4.9 | -8.5 | -11.5 | -13.3 | -14.7 | **77.0** | -6.1 | -10.8 | -13.1 | -14.4 | -15.4 | **52.6** | -0.2 | -0.2 | -0.1 | 0.0 | 0.2 |
| Jul | **83.8** | -0.2 | -0.2 | -0.3 | -0.3 | -0.3 | **84.0** | -0.2 | -0.2 | -0.3 | -0.4 | -0.5 | **81.2** | -0.3 | -0.4 | -0.4 | -0.5 | -0.5 | **79.3** | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | **53.4** | 0.0 | 0.1 | 0.3 | 0.5 | 0.8 |
| Aug | **83.2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **83.3** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **80.5** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **78.6** | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | **54.7** | -0.2 | 0.0 | 0.0 | 0.0 | 0.2 |

**Table 19-9. The percentage of time on the Merced River that USEPA salmon and steelhead temperature criteria (7DADM unit of measurement) are met each month under modeled baseline (base) conditions during 1970 to 2003, and the magnitude of expected percent change under modeled unimpaired flows of 20%, 30%, 40%, 50% and 60% at different river mile (RM) locations. Positive numbers under the unimpaired flows represent the magnitude of increases compared to baseline in the percentage of time that criteria are expected to be met, and negative numbers under the unimpaired flows represent the magnitude of reductions compared to baseline in the percentage of time that criteria are expected to be met. Expected changes in the amount of time that USEPA temperature criteria are met which are greater than positive 10% or less than negative 10% are highlighted green or red respectively (if applicable), and represent significant changes to salmon and steelhead temperature habitat if indicated at locations which are utilized by that life stage.**

| Merced River | | Confluence (RM2.5) | | | | | | 1/4 River (RM13.5) | | | | | | 1/2 River (RM27) | | | | | | 3/4 River (RM37.8) | | | | | | Below Crocker Huffman (RM52.2) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life Stage | Month / USEPA Criteria (°F) | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | |
| | | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| AM | Sep (64.4) | **3%** | 0% | 0% | 0% | 0% | -1% | **4%** | 0% | 0% | 0% | 0% | -2% | **9%** | 0% | 0% | 0% | -1% | -4% | **14%** | 0% | -1% | 2% | 2% | -2% | **82%** | 10% | 9% | 8% | 6% | -2% |
| AM | Oct (64.4) | **38%** | 5% | 4% | 9% | 9% | 8% | **39%** | 5% | 3% | 8% | 8% | 7% | **51%** | 7% | 6% | 10% | 9% | 6% | **55%** | 8% | 7% | 11% | 9% | 6% | **82%** | 18% | 17% | 16% | 14% | 8% |
| R | Oct (55.4) | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% |
| R | Nov (55.4) | **17%** | 2% | 1% | 2% | 2% | 1% | **14%** | 2% | 2% | 2% | 2% | 1% | **13%** | 3% | 2% | 3% | 2% | 1% | **9%** | 1% | 1% | 1% | 0% | -1% | **31%** | 3% | 1% | 2% | -1% | -5% |
| R | Dec (55.4) | **96%** | 1% | 1% | 2% | 1% | 0% | **93%** | 3% | 3% | 3% | 2% | 2% | **90%** | 5% | 5% | 5% | 4% | 4% | **81%** | 8% | 8% | 8% | 6% | 5% | **86%** | 9% | 9.6% | 9.97% | 8% | 6% |
| R | Jan (55.4) | **98%** | 0% | 0% | 0% | 0% | 0% | **98%** | 0% | 0% | 0% | 0% | 0% | **98%** | 0% | 0% | 0% | 0% | 0% | **98%** | 0% | 0% | 0% | 0% | -1% | **99%** | 0% | 0% | 0% | 0% | 0% |
| R | Feb (55.4) | **74%** | -2% | -1% | 1% | 2% | 3% | **73%** | -2% | -1% | 1% | 2% | 4% | **81%** | -3% | -2% | -1% | 2% | 2% | **74%** | -2% | -2% | 0% | 3% | 5% | **100%** | -1% | -1% | -1% | -1% | -1% |
| R | Mar (55.4) | **24%** | -1% | -1% | -1% | 2% | 6% | **25%** | -1% | 0% | 0% | 3% | 7% | **29%** | -1% | 0% | 3% | 7% | 13% | **28%** | -1% | 0% | 4% | 7% | 14% | **97%** | -2% | -2% | -1% | 0% | 0% |
| CR | Mar (60.8) | **70%** | 0% | 2% | 5% | 11% | 16% | **72%** | 0% | 1% | 6% | 12% | 17% | **85%** | 0% | 3% | 7% | 9.8% | 11% | **87%** | -1% | 1% | 6% | 8% | 9% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | Apr (60.8) | **22%** | -1% | 5% | 10% | 25% | 34% | **25%** | -1% | 7% | 17% | 32% | 43% | **39%** | -2% | 17% | 26% | 38% | 45% | **43%** | 3% | 21% | 32% | 40% | 45% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | May (60.8) | **8%** | 0% | 6% | 8% | 15% | 24% | **12%** | 2% | 10% | 17% | 30% | 37% | **18%** | 6% | 21% | 26% | 37% | 43% | **24%** | 12% | 25% | 32% | 40% | 45% | **99%** | 1% | 1% | 1% | 1% | 1% |
| S | Apr (57.2) | **7%** | -1% | 0% | 1% | 5% | 10% | **9%** | -1% | 2% | 2% | 9% | 14% | **12%** | 0% | 5% | 6% | 14% | 19% | **16%** | 0% | 6% | 8% | 17% | 22% | **95%** | 2% | 2% | 3% | 3% | 3% |
| S | May (57.2) | **2%** | 0% | 0% | 0% | 0% | 1% | **5%** | 0% | 0% | 0% | 3% | 8% | **7%** | 0% | 1% | 1% | 9% | 15% | **10%** | 0% | 6% | 9% | 16% | 24% | **88%** | 0% | 4% | 5% | 5% | 5% |
| S | Jun (57.2) | **0%** | 0% | 0% | 0% | 0% | 0% | **2%** | 0% | 0% | 0% | -1% | -1% | **8%** | -2% | -2% | -2% | -3% | -3% | **11%** | 0% | -2% | -1% | -3% | -2% | **69%** | 3% | 2% | 0% | 0% | -1% |
| SR | Jun (64.4) | **16%** | 2% | 0% | 1% | 7% | 13% | **21%** | 3% | 3% | 5% | 11% | 15% | **26%** | 3% | 8% | 10% | 16% | 21% | **28%** | 6% | 13% | 18% | 26% | 31% | **97%** | 3% | 3% | 3% | 3% | 3% |
| SR | Jul (64.4) | **5%** | 0% | -1% | -1% | -1% | -3% | **16%** | 0% | -2% | -2% | -5% | -7% | **20%** | 0% | -3% | -3% | -7% | -9% | **23%** | 0% | -3% | -4% | -6% | -9.8% | **96%** | 2% | 4% | 3% | 0% | -8% |
| SR | Aug (64.4) | **0%** | 0% | 0% | 0% | 0% | 0% | **1%** | 0% | 0% | 0% | 0% | 0% | **4%** | 0% | 0% | 0% | -1% | -2% | **19%** | -1% | -4% | -4% | -9% | -11% | **87%** | 9% | 9% | 5% | 3% | -3% |

AM = Adult Migration
R = Reproduction (Spawning, Egg Incubation, and Fry Emergence)
CR = Core Rearing
S = Smoltification
SR = Summer Rearing

**Table 19-10. The average daily 7DADM temperature values for each month on the Merced River under modeled baseline (base) condition from 1970 to 2003, and the modeled difference in °F for each of the unimpaired flow percentages between 20% to 60%. Negative numbers represent the expected magnitude of reductions in 7DADM values and positive numbers represent the expected magnitude of increases in 7DADM values. Expected changes in the magnitude of 7DADM values greater than positive 1°F or less than negative 1°F are highlighted either red or green respectively (if applicable). The green and/or reds cells were highlighted to aid the visual review of this table and do not necessarily represent significant changes to salmon and steelhead temperature habitat.**

| Merced Average 7DADM | Confluence (RM2.5) | | | | | | 1/4 River (RM13.5) | | | | | | 1/2 River (RM27) | | | | | | 3/4 River (RM37.8) | | | | | | Below Crocker Huffman (RM52.2) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | |
| | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| Sep | **72.2** | 0.0 | 0.2 | -0.1 | -0.1 | 0.0 | **73.0** | -0.1 | 0.2 | -0.2 | -0.2 | -0.1 | **72.0** | -0.2 | 0.2 | -0.3 | -0.2 | -0.1 | **71.9** | -0.3 | 0.1 | -0.5 | -0.3 | -0.1 | **60.5** | -0.8 | -0.6 | -0.4 | 0.1 | 0.9 |
| Oct | **65.9** | -0.4 | -0.3 | -0.7 | -0.6 | -0.4 | **66.0** | -0.5 | -0.4 | -0.8 | -0.7 | -0.5 | **65.1** | -0.7 | -0.6 | -0.9 | -0.8 | -0.4 | **64.9** | -0.9 | -0.8 | -1.0 | -0.9 | -0.4 | **60.1** | -1.4 | -1.2 | -1.2 | -0.9 | -0.3 |
| Nov | **58.5** | -0.5 | -0.4 | -0.6 | -0.5 | -0.3 | **58.9** | -0.6 | -0.5 | -0.7 | -0.7 | -0.4 | **58.8** | -0.8 | -0.7 | -0.9 | -0.8 | -0.5 | **59.6** | -0.9 | -0.8 | -1.1 | -0.9 | -0.6 | **57.6** | -1.3 | -1.3 | -1.3 | -1.1 | -0.6 |
| Dec | **51.6** | -0.2 | -0.2 | -0.2 | -0.1 | -0.1 | **52.1** | -0.3 | -0.3 | -0.2 | -0.2 | -0.1 | **52.4** | -0.3 | -0.3 | -0.3 | -0.2 | -0.1 | **53.5** | -0.4 | -0.4 | -0.3 | -0.2 | -0.1 | **52.7** | -0.5 | -0.5 | -0.4 | -0.3 | -0.2 |
| Jan | **50.4** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **50.6** | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | **50.6** | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | **51.4** | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | **49.8** | 0.2 | 0.2 | 0.1 | 0.1 | -0.1 |
| Feb | **53.7** | 0.1 | 0.1 | 0.0 | 0.0 | -0.2 | **53.6** | 0.2 | 0.1 | 0.0 | -0.1 | -0.3 | **53.0** | 0.2 | 0.1 | 0.1 | 0.0 | -0.3 | **53.5** | 0.2 | 0.2 | 0.1 | 0.0 | -0.3 | **50.2** | 0.4 | 0.3 | 0.3 | 0.2 | -0.1 |
| Mar | **58.6** | 0.0 | -0.2 | -0.4 | -0.8 | -1.2 | **58.3** | 0.0 | -0.2 | -0.5 | -0.9 | -1.4 | **57.1** | 0.1 | -0.1 | -0.4 | -0.7 | -1.2 | **57.0** | 0.1 | -0.1 | -0.5 | -0.8 | -1.3 | **51.9** | 0.3 | 0.2 | 0.1 | -0.1 | -0.4 |
| Apr | **64.0** | -0.5 | -1.6 | -2.2 | -3.1 | -3.8 | **63.9** | -0.7 | -2.1 | -2.8 | -3.7 | -4.5 | **61.9** | -0.6 | -1.8 | -2.3 | -3.0 | -3.7 | **61.5** | -0.8 | -2.0 | -2.5 | -3.1 | -3.7 | **53.1** | 0.0 | -0.3 | -0.4 | -0.7 | -1.0 |
| May | **68.2** | -2.1 | -3.6 | -4.3 | -5.1 | -5.7 | **68.1** | -2.8 | -4.4 | -5.2 | -6.2 | -6.9 | **65.9** | -2.7 | -3.9 | -4.6 | -5.3 | -6.0 | **65.0** | -2.8 | -4.0 | -4.6 | -5.3 | -5.9 | **53.8** | -0.4 | -0.6 | -0.8 | -0.9 | -1.0 |
| Jun | **72.3** | -1.6 | -2.6 | -3.3 | -4.0 | -4.6 | **72.4** | -2.3 | -3.5 | -4.3 | -5.1 | -5.8 | **70.7** | -2.7 | -3.8 | -4.5 | -5.2 | -5.6 | **69.9** | -3.2 | -4.3 | -5.0 | -5.6 | -6.0 | **55.4** | -0.5 | -0.5 | -0.4 | -0.3 | 0.0 |
| Jul | **75.3** | -0.3 | -0.1 | -0.6 | -0.5 | -0.4 | **75.7** | -0.4 | -0.2 | -0.8 | -0.7 | -0.5 | **74.1** | -0.5 | -0.2 | -0.9 | -0.8 | -0.6 | **73.3** | -0.5 | -0.1 | -0.9 | -0.7 | -0.4 | **57.2** | -0.2 | 0.2 | 0.4 | 0.9 | 1.8 |
| Aug | **74.6** | 0.1 | 0.5 | 0.2 | 0.5 | 0.6 | **75.2** | 0.1 | 0.6 | 0.2 | 0.5 | 0.7 | **73.8** | 0.1 | 0.7 | 0.1 | 0.4 | 0.6 | **73.2** | 0.0 | 0.7 | 0.0 | 0.3 | 0.7 | **58.8** | -0.5 | -0.1 | 0.2 | 0.8 | 1.7 |

**Table 19-11. The 90th percentile daily 7DADM temperature values for the 1970 to 2003 model period for each month at different Merced River locations, and the expected difference in °F for each of the unimpaired flow percentages between 20% and 60%. Each of the 90th percentile values which are displayed for baseline (base) indicate that daily 7DADM values were less than that temperature 90% of the time, or were greater than that temperature 10% of the time during each month and river location. Expected changes in the magnitude of 90th percentile 7DADM values greater than positive 1°F or less than negative 1°F are highlighted either red or green respectively (if applicable). The green and/or reds cells were highlighted to aid the visual review of this table and do not necessarily represent significant changes to salmon and steelhead temperature habitat.**

| Merced 90th Percentile 7DADM | Confluence (RM2.52) | | | | | | 1/4 River (RM13.41) | | | | | | 1/2 River (RM27.07) | | | | | | 3/4 River (RM37.79) | | | | | | Below Crocker Huffman (RM52.2) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | | Base (°F) | Percent Unimpaired Flow | | | | |
| | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| Sep | **76.8** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **78.3** | -0.1 | 0.0 | -0.1 | 0.0 | 0.1 | **78.3** | -0.2 | -0.2 | -0.1 | 0.0 | 0.2 | **80.2** | -0.4 | -0.4 | -0.3 | -0.1 | 0.2 | **67.7** | -4.0 | -3.8 | -3.6 | -2.9 | -0.5 |
| Oct | **70.9** | -0.7 | -0.4 | -0.6 | -0.5 | 0.0 | **71.7** | -0.9 | -0.7 | -1.0 | -0.8 | -0.1 | **70.8** | -1.6 | -1.4 | -1.7 | -1.4 | -0.3 | **70.8** | -2.5 | -2.2 | -2.6 | -2.2 | -0.3 | **67.4** | -6.0 | -6.3 | -6.2 | -5.4 | -2.4 |
| Nov | **62.7** | -0.7 | -0.7 | -1.1 | -1.1 | -0.7 | **63.3** | -1.1 | -1.0 | -1.4 | -1.3 | -0.8 | **63.2** | -1.7 | -1.7 | -1.9 | -1.7 | -1.2 | **64.4** | -2.4 | -2.4 | -2.7 | -2.5 | -2.0 | **63.5** | -4.7 | -4.8 | -4.9 | -4.4 | -3.5 |
| Dec | **54.3** | -0.4 | -0.4 | -0.4 | -0.3 | -0.2 | **55.0** | -0.7 | -0.7 | -0.7 | -0.6 | -0.3 | **55.4** | -1.0 | -1.0 | -1.0 | -0.8 | -0.5 | **56.7** | -1.3 | -1.2 | -1.2 | -1.0 | -0.9 | **56.1** | -1.6 | -1.6 | -1.5 | -1.4 | -1.1 |
| Jan | **52.8** | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | **53.1** | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | **52.9** | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | **53.7** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **52.0** | -0.3 | -0.2 | -0.3 | -0.3 | -0.4 |
| Feb | **57.8** | 0.1 | 0.0 | 0.0 | -0.2 | -0.4 | **58.0** | 0.0 | 0.0 | 0.0 | -0.3 | -0.5 | **56.9** | 0.1 | 0.1 | 0.0 | -0.3 | -0.5 | **57.4** | 0.1 | 0.1 | 0.1 | -0.3 | -0.4 | **52.6** | 0.4 | 0.4 | 0.3 | 0.2 | 0.1 |
| Mar | **63.4** | -0.2 | -0.6 | -1.2 | -1.7 | -2.1 | **63.4** | -0.1 | -0.6 | -1.2 | -1.9 | -2.3 | **61.4** | 0.1 | -0.2 | -0.9 | -1.4 | -1.8 | **61.0** | 0.2 | -0.1 | -0.7 | -1.3 | -1.6 | **54.5** | 0.6 | 0.4 | 0.4 | 0.2 | 0.1 |
| Apr | **69.6** | -2.0 | -3.6 | -4.7 | -5.4 | -6.0 | **70.3** | -2.8 | -4.7 | -5.9 | -6.7 | -7.3 | **67.6** | -2.5 | -4.1 | -5.0 | -5.6 | -6.1 | **67.2** | -2.8 | -4.5 | -5.2 | -5.7 | -6.1 | **56.1** | 0.0 | -0.6 | -0.8 | -0.6 | -0.7 |
| May | **74.3** | -3.7 | -4.9 | -5.8 | -6.7 | -7.3 | **75.5** | -4.8 | -6.5 | -7.4 | -8.3 | -9.1 | **72.8** | -4.4 | -5.9 | -6.8 | -7.3 | -8.0 | **71.7** | -4.1 | -5.9 | -6.7 | -7.1 | -7.7 | **57.4** | 0.0 | -0.4 | -0.5 | -0.4 | -0.5 |
| Jun | **78.9** | -1.5 | -2.3 | -3.0 | -3.6 | -4.2 | **79.9** | -1.9 | -2.7 | -3.7 | -4.8 | -5.5 | **78.1** | -2.0 | -3.0 | -4.1 | -5.3 | -6.0 | **77.4** | -2.0 | -3.3 | -5.0 | -6.1 | -6.6 | **60.5** | -1.6 | -1.4 | -0.9 | -0.6 | -0.1 |
| Jul | **80.6** | -0.2 | -0.2 | -0.6 | -0.6 | -0.7 | **81.8** | -0.1 | -0.2 | -0.4 | -0.4 | -0.4 | **80.9** | -0.4 | -0.3 | -0.4 | -0.4 | -0.2 | **81.3** | -0.7 | -0.7 | -0.6 | -0.4 | 0.0 | **62.8** | -1.5 | -1.2 | -0.6 | 0.2 | 1.8 |
| Aug | **79.8** | 0.0 | 0.1 | -0.1 | -0.1 | -0.1 | **81.4** | 0.0 | 0.1 | -0.2 | -0.2 | -0.2 | **80.5** | 0.0 | 0.1 | 0.0 | 0.1 | 0.2 | **80.7** | -0.4 | -0.3 | -0.2 | 0.0 | 0.6 | **65.1** | -2.3 | -1.6 | -1.3 | -0.8 | 1.1 |

**Table 19-12. The percentage of time on the San Joaquin River that USEPA salmon and steelhead temperature criteria (7DADM unit of measurement) are met each month under modeled baseline (base) conditions during 1970 to 2003, and the magnitude of expected percent change under modeled unimpaired flows of 20%, 30%, 40%, 50% and 60% at different river mile (RM) locations. Positive numbers under the unimpaired flows represent the magnitude of increases compared to baseline in the percentage of time that criteria are expected to be met, and negative numbers under the unimpaired flows represent the magnitude of reductions compared to baseline in the percentage of time that criteria are expected to be met. Expected changes in the amount of time that USEPA temperature criteria are met which are greater than positive 10% or less than negative 10% are highlighted green or red respectively (if applicable), and represent significant changes to salmon and steelhead temperature habitat if indicated at locations which are utilized by that life stage.**

| San Joaquin River | | Vernalis (RM 69.31) | | | | | | Above Stanislaus Confluence (RM 72.501) | | | | | | Above Tuolumne Confluence (RM 81.401) | | | | | | Above Merced Confluence (RM 116.001) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life Stage | Month / USEPA Criteria (°F) | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | |
| | | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| AM | Sep (64.4) | **3%** | 0% | 0% | -1% | -1% | -1% | **1%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% |
| AM | Oct (64.4) | **50%** | 4% | 3% | 10% | 9% | 9% | **33%** | 1% | 0% | 4% | 4% | 4% | **27%** | 1% | 0% | 2% | 3% | 2% | **8%** | 0% | 0% | 0% | 0% | 0% |
| AM | Nov (64.4) | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **98%** | 0% | 0% | 0% | 0% | 0% |
| AM | Dec (64.4) | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | Jan (60.8) | **99%** | 0% | 0% | 0% | 0% | 0% | **99%** | 0% | 0% | 0% | 0% | 0% | **99%** | 0% | 0% | 0% | 0% | 0% | **99%** | 0% | 0% | 0% | 0% | 0% |
| CR | Feb (60.8) | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% |
| CR | Mar (60.8) | **82%** | 0% | 2% | 5% | 8% | 11% | **76%** | 1% | 3% | 6% | 9% | 12% | **53%** | 0% | 0% | 1% | 3% | 4% | **52%** | 0% | 0% | 0% | 0% | 0% |
| S | Apr (57.2) | **5%** | 0% | 1% | 0% | 1% | 3% | **3%** | 0% | 0% | 1% | 1% | 2% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% |
| S | May (57.2) | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% |
| S | Jun (57.2) | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% |

AM = Adult Migration
CR = Core Rearing
S = Smoltification

**Table 19-13. The average daily 7DADM temperature values for each month on the San Joaquin River (SJR) under modeled baseline (base) condition from 1970 to 2003, and the modeled difference in °F for each of the unimpaired flow percentages between 20% to 60%. Negative numbers represent the expected magnitude of reductions in 7DADM values and positive numbers represent the expected magnitude of increases in 7DADM values. Expected changes in the magnitude of 7DADM values greater than positive 1°F or less than negative 1°F are highlighted either red or green respectively (if applicable). The green and/or reds cells were highlighted to aid the visual review of this table and do not necessarily represent significant changes to salmon and steelhead temperature habitat.**

| SJR Average 7DADM | Vernalis (RM 69.31) | | | | | | Above Stanislaus Confluence (RM 72.501) | | | | | | Above Tuolumne Confluence (RM 81.401) | | | | | | Above Merced Confluence (RM 116.001) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | |
| | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| Sep | 72.4 | -0.1 | 0.0 | -0.3 | -0.2 | -0.1 | 73.6 | 0.0 | 0.1 | -0.4 | -0.3 | -0.3 | 74.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 76.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Oct | 64.7 | -0.3 | -0.2 | -0.8 | -0.8 | -0.7 | 66.2 | -0.1 | 0.0 | -0.4 | -0.3 | -0.3 | 66.8 | -0.1 | -0.1 | -0.3 | -0.3 | -0.2 | 68.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Nov | 56.9 | -0.2 | -0.1 | -0.2 | -0.2 | -0.1 | 57.2 | -0.1 | -0.1 | -0.2 | -0.1 | -0.1 | 57.9 | -0.1 | -0.1 | -0.2 | -0.2 | -0.1 | 59.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Dec | 49.7 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | 49.8 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | 50.7 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | 52.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jan | 49.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 49.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 50.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 51.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Feb | 53.2 | 0.0 | 0.0 | 0.0 | -0.1 | -0.2 | 53.6 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 54.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 55.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Mar | 58.0 | 0.1 | -0.1 | -0.2 | -0.4 | -0.8 | 58.7 | 0.0 | -0.1 | -0.3 | -0.4 | -0.8 | 60.7 | 0.0 | 0.0 | -0.1 | -0.2 | -0.3 | 60.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Apr | 61.6 | 0.0 | -0.3 | -0.7 | -1.1 | -1.5 | 63.3 | -0.3 | -0.9 | -1.4 | -1.9 | -2.4 | 66.2 | 0.0 | -0.5 | -0.8 | -1.1 | -1.5 | 66.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| May | 65.7 | -0.35 | -1.2 | -1.8 | -2.4 | -2.8 | 67.9 | -0.99 | -2.4 | -3.2 | -3.9 | -4.1 | 71.2 | -0.56 | -1.3 | -1.6 | -2.0 | -2.3 | 72.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jun | 70.3 | -0.1 | -0.97 | -1.7 | -2.5 | -3.0 | 72.7 | -1.2 | -2.5 | -3.3 | -4.1 | -4.6 | 75.6 | -0.5 | -1.0 | -1.3 | -1.7 | -2.0 | 77.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jul | 75.4 | -0.1 | -0.2 | -0.69 | -0.7 | -0.7 | 76.7 | -0.3 | -0.2 | -0.97 | -1.0 | -0.9 | 78.4 | -0.1 | 0.0 | -0.17 | -0.2 | -0.1 | 81.7 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 |
| Aug | 75.6 | -0.1 | 0.1 | 0.0 | 0.2 | 0.3 | 76.8 | 0.0 | 0.2 | 0.0 | 0.1 | 0.2 | 77.2 | 0.0 | 0.2 | 0.1 | 0.3 | 0.4 | 81.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Table 19-14. The 90th percentile daily 7DADM temperature values for the 1970 to 2003 model period for each month at different San Joaquin River (SJR) locations, and the expected difference in °F for each of the unimpaired flow percentages between 20% and 60%. Each of the 90th percentile values which are displayed for baseline (base) indicate that daily 7DADM values were less than that temperature 90% of the time, or were greater than that temperature 10% of the time during each month and river location. Expected changes in the magnitude of 90th percentile 7DADM values greater than positive 1°F or less than negative 1°F are highlighted either red or green respectively (if applicable). The green and/or reds cells were highlighted to aid the visual review of this table and do not necessarily represent significant changes to salmon and steelhead temperature habitat.**

| SJR 90th Percentile 7DADM | Vernalis (RM 69.31) | | | | | | Above Stanislaus Confluence (RM 72.501) | | | | | | Above Tuolumne Confluence (RM 81.401) | | | | | | Above Merced Confluence (RM 116.001) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | | Base | Percent Unimpaired Flow | | | | |
| | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% | | 20% | 30% | 40% | 50% | 60% |
| Sep | 75.9 | -0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 77.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 77.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 79.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Oct | 70.2 | -0.3 | -0.2 | -0.9 | -0.9 | -0.8 | 71.4 | 0.0 | 0.1 | -0.3 | -0.3 | -0.3 | 71.7 | -0.1 | 0.0 | -0.2 | -0.2 | -0.1 | 72.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Nov | 61.1 | -0.4 | -0.4 | -0.7 | -0.6 | -0.6 | 61.6 | -0.2 | -0.2 | -0.4 | -0.3 | -0.3 | 62.2 | -0.3 | -0.3 | -0.4 | -0.3 | -0.2 | 63.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Dec | 52.3 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | 52.4 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | 53.0 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | 54.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jan | 51.9 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 52.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 53.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Feb | 56.4 | 0.4 | 0.3 | 0.2 | 0.0 | -0.2 | 57.1 | 0.0 | 0.0 | -0.1 | -0.2 | -0.4 | 58.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 57.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Mar | 61.9 | 0.2 | -0.2 | -0.8 | -1.2 | -1.7 | 63.1 | -0.3 | -0.6 | -1.1 | -1.5 | -2.0 | 64.5 | 0.0 | 0.0 | -0.2 | -0.2 | -0.4 | 64.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Apr | 65.5 | -0.3 | -1.4 | -1.9 | -2.3 | -2.9 | 68.1 | -1.4 | -2.6 | -3.3 | -4.0 | -4.5 | 70.3 | -0.4 | -1.1 | -1.6 | -2.1 | -2.6 | 70.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| May | 69.9 | -0.9 | -1.9 | -2.5 | -3.3 | -3.9 | 72.7 | -1.7 | -3.6 | -4.4 | -5.4 | -5.8 | 75.4 | -0.96 | -1.8 | -2.1 | -2.5 | -2.8 | 75.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jun | 75.7 | -0.2 | -0.8 | -1.2 | -1.8 | -2.3 | 78.1 | -1.3 | -2.2 | -2.8 | -3.7 | -4.4 | 79.4 | -0.4 | -0.7 | -1.2 | -1.6 | -1.9 | 80.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jul | 79.1 | -0.1 | -0.1 | -0.2 | -0.2 | -0.2 | 80.6 | -0.2 | -0.2 | -0.3 | -0.4 | -0.4 | 81.3 | -0.1 | -0.3 | -0.6 | -0.7 | -0.7 | 83.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Aug | 78.8 | -0.1 | 0.1 | -0.1 | -0.1 | 0.1 | 80.3 | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | 80.5 | 0.0 | 0.1 | 0.0 | -0.1 | 0.0 | 83.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Adult Migration Evaluation Time Period, September 1 to October 31:

USEPA temperature criteria for adult salmon and steelhead migration were evaluated during the September 1 through October 31 time period. During September, adult salmon are beginning to enter the Stanislaus, Tuolumne, and Merced Rivers as they return from the ocean to spawn. During the first part of September there are few salmon found in these rivers. By the end of September, more salmon are beginning to migrate up each river, although most of the upstream migration occurs after September with peak migration typically occurring in late October and early November (CFS 2007a; CDFG 2001, 2002). The USEPA criteria used in this evaluation, and which corresponds with the adult migration life stage is less than or equal to 64.4°F using the 7-day average of the daily maximum (7DADM) unit of measurement.

### Stanislaus River Adult Migration September 1 to October 31 (results in Tables 19-3, 19-4, and 19-5)

**Baseline:** Under modeled baseline conditions in the Stanislaus River, USEPA temperature criteria are met 10% of the time on average during September and 71% of the time on average during October at the confluence with the LSJR. Adult salmon experience temperature improvements as they swim upstream until they reach their spawning grounds (near ¾ river) where USEPA adult migration temperature criteria are met 67% of the time during September and 87% of the time during October.

**20-60% Unimpaired Flows:** During September, the model results indicate that compliance with USEPA adult temperature criteria (64.4°F) will increase by 12% under each unimpaired flow at the Goodwin Reservoir release location, thus achieving 100% compliance with the recommended USEPA temperature criteria for each unimpaired flow at the dam release in September. At the ½ river evaluation location, the 40%, 50%, and 60% unimpaired flows provide 14%, 13% and 11% improvements in USEPA temperature criteria compliance respectively during September. The confluence temperatures are not expected to change significantly under any of the alternative flows in September.

During October, the model results indicate that compliance with USEPA temperature criteria for adult migration (64.4°F) will increase by approximately 11%-12% under each of the unimpaired flows between the ¾ river and Goodwin evaluation locations. Additionally, model results indicate the 40%, 50%, and 60% unimpaired flows will result in increased compliance with adult migration criteria by approximately 10%-12% between the confluence and ½ river locations. However, the amount of time that reproductive criteria (55.4°F) are met in October did not increase at these locations.

### Tuolumne River Adult Migration September 1 to October 31 (results in Tables 19-6, 19-7, and 19-8)

**Baseline:** Under modeled baseline conditions in the Tuolumne River, USEPA temperature criteria for adult migration (64.4°F) are met 2% of the time on average during September and 25% of the time on average during October at the confluence with the LSJR. Moving upstream during September, criteria are met 3%, 11%, 33%, and 100% of the time at the ¼, ½, ¾, and dam release evaluation locations respectively on average. Moving upstream during October, criteria are met 37%, 63%, 81%, and 100% of the time at the ¼, ½, ¾, and dam release evaluation locations respectively on average. Although the water released from the dam meets USEPA temperature criteria 100% of the time in September, the water temperature quickly warms, and by the time it reaches the ¾ river location USEPA compliance has already dropped to 33%. During October this warming between the dam (100% compliance) and the ¾ river (81% compliance) locations is not as dramatic.

**20-60% Unimpaired Flows:** Modeling indicates that the compliance with USEPA adult salmon migration criteria (64.4°F) will increase by approximately 17% under the 40% to 60% unimpaired flows at the ½ river location. No significant changes from baseline were predicted by model results on the Tuolumne River during October under any of the evaluated unimpaired flows to the amount of time that adult migration criteria (64.4°F) are met.

### Merced River Adult Migration September 1 to October 31 (results in Tables 19-9, 19-10, and 19-11)

**Baseline:** Under modeled baseline conditions in the Merced River, USEPA adult migration temperature criteria (64.4°F) are met 3% of the time on average during September and 38% of the time on average during October at the confluence with the LSJR. Moving upstream during September, adult migration temperature criteria are met 4%, 9%, 14%, and 82% of the time at the ¼, ½, ¾, and dam evaluation locations respectively on average. Moving upstream during October, adult migration temperature criteria are met 39%, 51%, 55%, and 82% of the time at the ¼, ½, ¾, and dam evaluation locations respectively on average.

**20-60% Unimpaired Flows:** Modeling indicates that the 20% unimpaired flows may increase the amount of time that adult migration criteria (64.4°F) are met below Crocker Huffman Dam by approximately 10%. No other significant changes are expected in the amount of time that adult migration criteria (64.4°F) are met during September. During October, modeling results indicate that the dam release will meet adult migration criteria approximately 14% to 18% more often under the 20% to 50% unimpaired flows. The 60% unimpaired flow modeling indicates near significant improvements (8%) in the amount of time adult migration temperature criteria are met at the dam release.

## Reproduction Evaluation Time Period, October 1 to March 31:

USEPA temperature criteria for salmon and steelhead reproductive life stages, which include pre-spawning, spawning, egg incubation, and fry emergence, were evaluated during the October 1 to March 31 time period. Most SJR fall-run Chinook salmon spawn between late October and early January when temperatures in the rivers are less than 55°F. Spawning generally occurs in areas where suitable habitat exists. In the Stanislaus, Tuolumne, and Merced Rivers, suitable habitat generally exists in the upper half of the anadromous portion of each river, with the majority of spawning activity typically occurring upstream of this point. Egg incubation typically occurs between November and March, lasting 40–60 days, but can vary depending on water temperatures and timing of spawning. Optimal water temperatures for egg incubation range from 41°F to 55°F (Moyle 2002; USEPA 2003). Eggs that incubate at temperatures higher than 60°F and lower than 38°F often suffer high mortality rates (Boles et al. 1988; Myrick and Cech 2001).

Newly hatched salmon (alevin) remain in the gravel for about 4–6 weeks (temperature dependent) until their yolk sacs have been absorbed (Moyle 2008). Generally, alevins suffer low mortality when consistently incubated at water temperatures between 50°F and 55°F. However, if incubated at constant temperatures between 55°F and 57.5°F, mortality has been shown to increase in excess of

50% (Boles et al. 1988). Once alevins emerge with their yolk-sac absorbed, they become fry, which tend to aggregate along stream edges, seeking cover in bushes, swirling water, and dark backgrounds (Moyle et al. 2008).

The USEPA criteria used in this evaluation, and which corresponds with the spawning, egg incubation, and fry emergence life stages is less than or equal to 55.4°F using the 7-day average of the daily maximum (7DADM) unit of measurement. For this evaluation on the Stanislaus, Tuolumne, and Merced Rivers; ½ river, ¾ river, and dam locations were used as primary indicator locations for the spawning and egg incubation life stages and all river evaluation locations were used to evaluate temperatures related to the fry life stage during this time period.

### Stanislaus River Reproduction October 1 to March 31 (results in Tables 19-3, 19-4, and 19-5)

**Baseline:** At the ½ river, ¾ river, and dam release locations, which are representative of the spawning reach, USEPA spawning and incubation temperature criteria are met 5%, 17%, and 55% of the time respectively during October, and 36%, 45%, and 64% of the time respectively during November under baseline conditions. These sub-optimal temperature conditions during many years in in the heart of the spawning period and location may limit reproductive success on the Stanislaus River.

During December through the end of February, USEPA reproductive criteria are met greater than 90% of the time at all primary spawning locations on the Lower Stanislaus River under baseline conditions. During December, the river is warmer on average at the dam release (52.3 average 7DADM) than at the confluence (50.9 °F average 7DADM).

During March, USEPA reproductive temperature criteria (55.4°F) are met 100% of the time at the dam release under baseline conditions, but temperatures gradually warm heading downstream until USEPA criteria compliance drops to 53% of the time at ½ river.

**20-60% Unimpaired Flows:** The modeled flows indicate significant temperature improvements compared to baseline in the amount of time USEPA reproductive criteria are met on the Stanislaus River during the October through March time period. These temperature improvements occur in March under the 40% to 60% unimpaired flows from the confluence up to the ¾ river location. At the dam release, USEPA reproductive criteria are already met 100% of the time under baseline condition during March.

### Tuolumne River Reproduction October 1 to March 31 (results in Tables 19-6, 19-7, and 19-8)

**Baseline:** At the ¾ river evaluation location, which is representative of much of the spawning reach, USEPA spawning and incubation temperature criteria are met less than 1% of the time during October and less than 27% of the time during November under baseline conditions. These sub-optimal temperature conditions in the heart of the spawning period and location may limit reproductive success on the Tuolumne River under baseline conditions.

During December through the end of January, USEPA reproductive temperature criteria are met greater than 93% of the time at all river locations on the Lower Tuolumne River under baseline conditions. During December, the river is warmer at the dam release (52.9 °F average 7DADM) than at the confluence (50.2 °F average 7DADM).

During February through the end of March, USEPA temperature criteria are met 100% of the time at the dam release. Temperatures gradually warm moving downstream until USEPA temperature criteria compliance drops to 72% and 54% of the time in February and March respectively at the ½ river evaluation location.

**20-60% Unimpaired Flows:** During this time period, significant improvements to USEPA reproductive temperature criteria compliance occur in February and March under the 30%, 40%, 50%, and 60% unimpaired flows. No significant temperature changes, relative to the reproductive criteria, are expected during October through January under any of the modeled unimpaired flows.

During February, the 60% unimpaired flow resulted in significant temperature improvements to reproductive criteria at most river evaluation locations. The 50% unimpaired flow results in significant improvements at the ½ river and ¾ river locations during February. Under the 40% unimpaired flow, temperature conditions had near significant improvements at ½ river and ¾ river during February where criteria compliance improved by 9.8% and 9.99% of the time, respectively.

During March, improvements to reproductive criteria compliance at the ¾ river evaluation location improve significantly under each of the unimpaired flows between 30-60%. At ½ river, 40-60% unimpaired flows result in significant improvements to reproductive criteria.

### Merced River Reproduction October 1 to March 31 (results in Tables 19-9, 19-10, and 19-11)

**Baseline:** In the spawning reach (between ½ river and Crocker Huffman Dam), USEPA spawning and incubation criteria are met 0% of the time during October and between 9% and 31% of the time (depending on location) during November under baseline conditions. In November, 7DADM temperatures greater than 64°F occur 10% of the time at ¾ river. During October the frequency of warm temperatures is worse in the spawning reach with temperatures greater than 70.5°F occurring 10% of the time at ¾ river. These sub-optimal temperature conditions in the heart of the spawning period and location, likely limit reproductive success on the Merced River.

Between December and the end of February, river temperatures meet USEPA reproductive temperature criteria greater than 74% of the time at the primary spawning locations under baseline conditions.

During March, USEPA criteria are met less than 28% of the time between ¾ river and ½ river under baseline conditions.

**20-60% Unimpaired Flows:** The only significant temperature improvements during this time period to the USEPA reproductive temperature criteria occur during March under 60% unimpaired flow at the ½ river and ¾ river locations where compliance increases by approximately 13% of the time.

## Core Juvenile Rearing Evaluation Time Period, March 1 to May 31

The USEPA salmon and steelhead core juvenile rearing temperature criterion (less than or equal to 60.8°F using the 7DADM metric) was evaluated from March 1 to May 31. During March and April fry, parr, and smolt life stages can all be found in the Stanislaus, Tuolumne, and Merced Rivers. This time period is one of relatively fast growth rates for these juvenile life stages, and is a transitional time period where fry are becoming less frequent and smolts are becoming more frequent (see CFS 2007b). By May most of the juvenile fish are classified as smolts and the fast growth rates observed in March and April have slowed as the smolts prepare for ocean entry. Juvenile salmonids can be found throughout much of the Stanislaus, Tuolumne, and Merced Rivers in March, April, and May.

### Stanislaus River Core Juvenile Rearing March 1 to May 31 (results in Tables 19-3, 19-4, and 19-5)

**Baseline:** During March in the Stanislaus River, USEPA core juvenile rearing temperature criteria (60.8°F using the 7DADM metric) are met greater than 91% of the time at all river evaluation locations. During April this rearing criterion is met 78%, 81%, 90%, 99%, and 100% of the time at the confluence, ¼, ½, ¾, and dam release locations respectively. During May this rearing criterion is met 51%, 61%, 73%, 94%, and 100% of the time at the confluence, ¼, ½, ¾, and dam release locations respectively.

**20-60% Unimpaired Flows:** During March the core rearing temperature criteria was met greater than 91% of the time at all river locations under baseline conditions, therefore significant increases (>10%) in the amount of time that this criteria is met is not applicable. However, the higher unimpaired flows (40%-60%) increased USEPA core juvenile rearing temperature compliance to 100%, or close to 100%, at most river locations.

During April, modeling indicates that the 60% unimpaired flow increases core juvenile rearing temperature criteria compliance by 13% at both the confluence and ¼ river. The 50% unimpaired flow also produces significant increases in temperature compliance (11%) at the ¼ river location and near significant improvements (9.9%) at the confluence.

During May, the 50% and 60% unimpaired flows produced significant increases ranging from 11% to 22% in the amount of time that USEPA core juvenile rearing temperature criteria were met between the confluence and ½ river. Modeling also indicates that the 40% unimpaired flow increased the amount of time that USEPA juvenile rearing temperature criteria are met at the ½ river location by 9.7%.

### Tuolumne River Core Juvenile Rearing March 1 to May 31 (results in Tables 19-6, 19-7, and 19-8)

**Baseline:** During March, the core juvenile rearing criteria are met approximately 65%, 72%, 84%, 91%, and 100% of the time at the time at the confluence, ¼, ½, ¾, and dam release locations respectively on the Tuolumne River.

During April, the core juvenile rearing criteria are met approximately 50%, 57%, 74%, 92%, and 100% of the time at the confluence, ¼, ½, ¾, and dam release locations respectively on the Tuolumne River.

During May, the core juvenile rearing criteria are met approximately 19%, 34%, 59%, 74%, and 100% of the time at the confluence, ¼, ½, ¾, and dam release locations respectively on the Tuolumne River.

**20-60% Unimpaired Flows:** During March through May, 30-60% unimpaired flows indicate significant temperature benefits at the confluence and ¼ river evaluation location, and 20-60% unimpaired flows indicate significant temperature benefits at the ½ and ¾ river evaluation locations. At each of the evaluation locations the higher unimpaired flows indicate greater temperature benefits when compared to the lower unimpaired flows or baseline. Modeling indicates that the largest increase in the amount of time that USEPA core juvenile rearing temperature criteria is met could occur under the 60% unimpaired alternative at the ¼ river location where criteria compliance increases by 58% during May.

### Merced River Core Juvenile Rearing March 1 to May 31 (results in Tables 19-9, 19-10, and 19-11)

**Baseline:** During March, the core juvenile rearing criteria (60.8°F) are met approximately 70%, 72%, 85%, 87%, and 100% of the time at the confluence, ¼, ½, ¾, and dam release locations respectively on the Merced River.

During April, the core juvenile rearing criteria are met approximately 22%, 25%, 39%, 43%, and 100% of the time at the confluence, ¼, ½, ¾, and dam release locations respectively on the Merced River.

During May, the core juvenile rearing criteria are met approximately 8%, 12%, 18%, 24%, and 99% of the time at the confluence, ¼, ½, ¾, and dam release locations respectively on the Merced River.

**20-60% Unimpaired Flows:** Temperature modeling in March indicates that 50-60% unimpaired flows will result in significant increases in the amount of time that USEPA core juvenile rearing temperature criteria are met at the confluence and ¼ river evaluation locations. Additionally, 60% unimpaired flows will increase core juvenile rearing temperature criteria compliance at the ½ evaluation location.

During April and May, each of the 30-60% unimpaired flows result in significant increases in the amount of time that USEPA core juvenile rearing temperatures criteria are met at the ½, and ¾ river evaluation locations. At the confluence evaluation location only the 40% to 60% unimpaired flows produce significant increases in temperature criteria compliance. At each evaluation location, the higher unimpaired flows result in greater temperature benefits when compared to the lower unimpaired flows or baseline. Modeling indicates that the largest increases in the amount of time that USEPA core juvenile rearing temperature criteria are met could occur under the 60% unimpaired alternative at the ¼, ½, and ¾ river locations where criteria compliance increases by between 37% and 45% during April and May.

## Smoltification Evaluation Time Period, April 1 to June 30

The primary evaluation life stages considered during the April 1 to June 30 time period are smoltification and emigration. During this time many ocean bound juvenile salmonids (steelhead and salmon) are finishing the in river growing stage and are exiting the tributaries on their way to the ocean (CFS 2006, CFS 2007b, Fish BIO 2007, Ford and Kirihara 2010). This transition from the freshwater to ocean environment (smoltification) requires significant physiological and morphological changes (Cooperman et al. 2010, Gross et al. 1988, Sheridan et al. 1983), and smolts are particularly sensitive to high temperatures during this transition (Mesick 2010a, Mesick and Marston 2007; Myrick and Cech 2001; USEPA 2003).

The USEPA temperature criteria used in this evaluation, and which corresponds with the smoltification and emigration life stages is 57.2°F or lower using the 7-day average of the daily maximum (7DADM) unit of measurement. For this evaluation on the Stanislaus, Tuolumne, and

Merced Rivers during April, May, and June; the confluence, ¼ river, and ½ river locations were used as primary indicator locations for smoltification and emigration.

## Stanislaus River Smoltification April 1 to June 30 (results in Tables 19-3, 19-4, and 19-5)

**Baseline:** During April, May, and June Goodwin Reservoir release temperatures meet USEPA smoltification temperature criteria (57.2°F) greater than 96% of the time under baseline conditions. The river water temperature warms going downstream until the water reaches the confluence with the LSJR where USEPA criteria is met 39% of the time during April, 5% during May, and 0% during June. During May near the confluence, the 90th percentile 7DADM temperature is 66.4°F. During June near the confluence, the 90th percentile 7DADM temperature is 73.3°F under baseline conditions, which means that 10% of the time temperatures are greater than 73.3°F at the confluence in June.

**20-60% Unimpaired Flows:** The 50% and 60% unimpaired flows produced significant improvements in the amount of time USEPA smoltification criteria is met on the Stanislaus River during the April 1 to June 30 time period. The other alternative unimpaired flows did not produce significant improvements or reductions in temperature criteria compliance during this period.

During April on the Stanislaus River, significant improvements to smoltification temperature compliance occur under the 50% and 60% unimpaired flows at the ¾ river location by approximately 11%. Under the 60% unimpaired flow, improved temperature compliance is expected at the ¼ river evaluation location by approximately 11%.

Under 60% unimpaired flows on the Stanislaus River during May, compliance with USEPA smoltification temperature criteria increased by 17%, 22%, 22%, and 13% at the confluence, ¼ river, ½ river, and ¾ river respectively. Under 50% unimpaired flow in May, significant improvements occur at the ¼ river, ½ river, and ¾ river locations (11%, 16%, and 10% respectively). During June under the 60% unimpaired flow significant improvements (13-17%) are expected in the amount of time that smoltification criteria are met at ½ river and ¾ river locations, and under the 50% unimpaired flow significant improvements (11%) are expected at ¾ river.

## Tuolumne River Smoltification April 1 to June 30 (results in Tables 19-6, 19-7, and 19-8)

**Baseline:** During April, May, and June La Grange Reservoir release temperatures are meeting USEPA criteria 100% of the time. Water temperature warms heading downstream until the water reaches the confluence with the LSJR where USEPA criteria is met 22% during April, 3% during May, and 0% during June under baseline conditions. The rate of warming as water flows downstream is affected by the amount of water being discharged from the reservoir.

**20-60% Unimpaired Flow:** Each of the evaluated unimpaired flows produced significant temperature improvements during April and May on the Tuolumne River. However during June only the 30-60% unimpaired flows indicate that significant improvements to smoltification criteria compliance will occur. Generally, the lower unimpaired flows (20% and 30%) do not result in significant improvements to smoltification temperatures in the lower reaches of the river (confluence and ¼ river locations).

On the Tuolumne River during this time period the expected temperature benefits from increased flow are greater than in any of the other time periods and/or rivers. These results indicate that the smoltification life stage within the Tuolumne River will experience far better temperature conditions under the higher unimpaired flows compared to baseline.

Modeling results indicate that the 90th percentile 7DADM temperature is reduced by up to 15.4°F (from 77.0°F to 61.6°F) under 60% unimpaired flow during June at the ¾ river location in the Tuolumne River. These reductions in high temperatures are substantial and would provide significant benefits to salmon and steelhead during June.

### Merced River Smoltification April 1 to June 30 (results in Tables 19-9, 19-10, and 19-11)

**Baseline:** During April, May, and June at the confluence, USEPA temperature criteria are met 7%, 2%, and 0% of the time respectively under baseline conditions. At the ¾ river location USEPA temperature criteria are met 16% during April, 10% during May, and 11% during June under baseline conditions. At the dam release, USEPA temperature criteria are met 95%, 88%, and 69% during April, May, and June respectively. The dramatic decrease in USEPA temperature criteria compliance between the dam release and the ¾ river location (approximately 14.4 miles downstream) is partially a result of low releases of water. Between these same two locations, there is an approximately eleven degree difference (65.0°F at the ¾ river location versus 53.8°F at the dam release) in average daily 7DADM temperatures during May. During June a similar condition occurs where average daily 7DADM temperatures at the dam release (55.4°F) are substantially cooler than those observed at the ¾ river evaluation location (69.9°F).

**20-60% Unimpaired Flow:** During April in the Merced River, only the 50% and 60% unimpaired flows result in significant increases to the amount of time USEPA smoltification temperature criteria are met. Under the 60% unimpaired flow during April, significant temperature improvements occur at the confluence, ¼, ½, and ¾ river locations. Under the 50% unimpaired flow, only the ½ river and ¾ river evaluation locations improve significantly compared to baseline temperatures.

During May, the 60% unimpaired flow produced significant increases in the time of compliance with USEPA temperature criteria by 15% and 24% at the ½ river and ¾ river locations respectively. The 50% unimpaired flow produced significant benefits to smoltification temperature compliance (16%) at the ¾ river location.

During June there are not any expected temperature benefits to compliance with USEPA smoltification criteria at any Merced River locations or alternatives. However, there are substantial reductions in average daily and 90$^{th}$ percentile 7DADM temperatures during April, May, and June at multiple river locations.

## Summer Rearing Evaluation Time Period, June 1 to August 31:

The focus of the summer rearing evaluation is on juvenile salmon and steelhead that over summer in the tributaries during the hottest time of the year and then may migrate to the ocean at a later date when water temperatures are cooler. Suitable over summering temperature habitats in the project area are usually limited to areas immediately below the impassable dams, however, during certain years there may be little or no suitable over summering temperature habitats in these tributaries. The USEPA recommended temperature criteria for the salmon and steelhead summer rearing life stage is 18°C (64.4°F) using the 7DADM metric.

## Stanislaus River Summer Rearing June 1 to August 31 (results in Tables 19-3, 19-4, and 19-5)

**Baseline:** Modeled baseline temperatures meet USEPA summer rearing criteria 38%, 5%, and 5% of the time at the confluence during June, July, and August respectively. At ¾ river, USEPA criteria are met 81%, 43%, and 47% of the time respectively, and at the dam release USEPA criteria are met 100%, 100%, and 96% respectively during June, July, and August.

August is the month with the highest average 7DADM temperatures on the Stanislaus River. At the confluence during the modeled period, the average 7DADM temperature is 73.0 °F, and the 90$^{th}$ percentile temperature is 76.9°F.

**20-60% Unimpaired Flow:** During June, the 50% and 60% unimpaired flows produce significant improvements in the amount of time that USEPA summer rearing temperature criteria are met at the confluence, ¼ river, and ½ river evaluation locations. These unimpaired flows improve USEPA temperature compliance between 11% and 19% of the time at these locations during this time period. The other alternative unimpaired flows do not produce significant temperature benefits or impacts during June.

None of the evaluated unimpaired flows produce significant changes to the amount of time USEPA summer rearing temperature criteria are met on the Stanislaus River during July or August.

## Tuolumne River Summer Rearing June 1 to August 31 (results in Tables 19-6, 19-7, and 19-8)

**Baseline:** Under modeled baseline conditions, June confluence temperatures meet USEPA summer rearing criteria 30% of the time, and the ¾ river evaluation location meets USEPA criteria 46% of the time. During July, modeled baseline conditions meet USEPA criteria 6% and 26% at the confluence and ¾ river evaluation locations respectively. During August, USEPA criteria are met 0% and 9% of the time at the confluence and ¾ river evaluation locations, respectively.

During June through August, the La Grange Reservoir release meets USEPA criteria 100% of the time, although the amount of water being released influences how far downstream the suitable temperatures are maintained.

During June through August, the 90th percentile 7DADM temperatures are above 81.2°F for each month at the confluence. Even at the ¾ river location the 90th percentile 7DADM temperatures are above 77.0°F during June through August.

**20-60% Unimpaired Flow:** During this time period modeling indicates that significant temperature benefits to summer rearing will occur during June and July, but not August. During June, each of the unimpaired flows produced significant temperature benefits at the ½ river and ¾ river evaluation locations. At the ¾ river evaluation location during June, USEPA temperature criteria compliance increases by 29%-47% under the 20% through 60% unimpaired flows. At the confluence only the 30% to 60% unimpaired flows produce significant temperature benefits which range from 11% to 36% improvement in USEPA temperature criteria compliance.

Maximum temperatures during June are dramatically reduced under most of the unimpaired flows evaluated at all river locations except at the dam release. For example, at the ½ river location during June the 90th percentile temperature is reduced 14.7°F from 79.0°F under baseline to 64.3°F under the 60% unimpaired flow.

### Merced River Summer Rearing June 1 to August 31 (results in Tables 19-9, 19-10, and 19-11)

**Baseline:** During June through August, USEPA summer rearing temperature criteria are met at the confluence evaluation location 16%, 5%, and 0% of the time respectively. At the ¾ river evaluation location, USEPA temperature criteria are met 28%, 23%, and 19% during June, July, and August respectively. At the Crocker Huffman Reservoir release, USEPA temperature criteria are met greater than 87% of the time during this period, however, the distance in which suitable temperatures travel downstream is dependent on the amount of flow in the river.

**20-60% Unimpaired Flow:** Modeling during the June through August time period indicates that there are both significant increases and reductions in the amount of time that USEPA summer rearing temperature criteria are met under some of the alternative unimpaired flows.

During June, improvements to USEPA summer rearing temperature compliance occur under the 30% to 60% unimpaired flows at the ¾ river evaluation location, occur under the 40% to 60% unimpaired flows at the ½ river evaluation location, occur under the 50% and 60% unimpaired flows at the ¼ river evaluation locations, and occur under the 60% unimpaired flow at the confluence.

The reduction in USEPA summer rearing temperature criteria compliance occurs in August under the 60% unimpaired flow at the ¾ river evaluation location. Although the compliance was reduced significantly under this unimpaired flow, average daily temperatures and 90th percentile temperatures did not change substantially.

## Lower San Joaquin River Temperature Analysis All Time Periods (results in Tables 19-12, 19-13, and 19-14)

On the LSJR, modeling indicates that significant temperature benefits occur during March under the 60% unimpaired flow, while other months and other unimpaired flows are not expected to produce significant benefits or impacts on optimal salmonid temperature habitat. Although there are limited benefits to optimal salmonid temperature habitat in the LSJR, there are substantial reductions in average temperatures and 90th percentile temperatures primarily during the March through June time period with higher flows providing greater reductions to these measures of temperature. These expected temperature reductions may benefit salmonids by reducing suboptimal and lethal temperature exposure. Additionally, increased flows may provide reduced travel times in the LSJR, which can reduce the time of exposure to harmful temperatures experienced by juvenile salmonids migrating in the LSJR.

## Summarized Temperature Results

When considering temperature results at different river locations and different times of the year, it becomes difficult to provide an overall picture of potential temperature benefits. One way to summarize the temperature benefits of different unimpaired flows is to consider a data output we refer to as “mile-days”. This result is a measure of temperature criteria compliance in both space and time.

To calculate mile-days of temperature compliance on the Stanislaus, Tuolumne, and Merced Rivers, first 19 points are selected along each river based on output of the HEC-5Q temperature model. The rivers are then divided into 19 sections around the selected locations. The length of each section around a particular location is equal to half the distance from the preceding location plus half the distance to the following location. For example, if A, B, and C are three consecutive locations, the section around location B would have a length equal to half the distance from B to A plus half the distance from B to C. If location A is at the confluence then its corresponding section is only equal to half the distance from A to B. Similarly, if location C is at one of the dams, then the length of its corresponding section is only equal to half the distance from B to C.

7DADM temperature results are then extracted from the temperature model for each of the 19 locations. To summarize compliance with USEPA temperature criteria listed in Table 19-1, the length of each section, in miles, is multiplied by the amount of time that the corresponding location is below the temperature criterion. For example, the length of section around location B is multiplied by the number of days each month that the 7DADM temperature at location B did not exceed the specified criteria for that month. Another way to describe it is that this measurement represents the total number of river miles in compliance with the temperature criteria across all days in a given month. This is similar to the acre-days measurement that is frequently used for evaluating floodplain inundation (see USFWS 2014). Mile-days and acre-days are useful because they summarizes spatial and temporal changes while considering both frequency and magnitude. However, some of the details of exactly when and where certain changes may occur are absent in this type of statistic. Table 19-15 provides a summary of the expected temperature benefits from the proposed project for the Stanislaus, Tuolumne, and Merced Rivers combined.

**Table 19-15. Summary of Mean Annual Temperature Benefits Combined for the Stanislaus, Tuolumne, and Merced Rivers from Different February through June Unimpaired Flow (UF) Percentages for all Modeled Water Years.**

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 4,926 | 1,222 | 25% | 26% | 25% | 30% | 29% | 28% |
| AM | Oct | 64.4 | 5,090 | 3,268 | 64% | 70% | 69% | 72% | 72% | 71% |
| R | Oct | 55.4 | 5,090 | 343 | 7% | 7% | 6% | 7% | 5% | 5% |
| R | Nov | 55.4 | 4,926 | 1,430 | 29% | 31% | 29% | 30% | 28% | 26% |
| R | Dec | 55.4 | 5,090 | 4,677 | 92% | 95% | 95% | 95% | 94% | 94% |
| R | Jan | 55.4 | 5,090 | 4,972 | 98% | 98% | 98% | 98% | 98% | 98% |
| R | Feb | 55.4 | 4,762 | 3,806 | 80% | 80% | 81% | 83% | 84% | 85% |
| R | Mar | 55.4 | 5,090 | 2,574 | 51% | 52% | 55% | 57% | 62% | 66% |
| CR | Mar | 60.8 | 5,090 | 4,382 | 86% | 87% | 90% | 93% | 95% | 96% |
| CR | Apr | 60.8 | 4,926 | 3,388 | 69% | 71% | 78% | 83% | 87% | 91% |
| CR | May | 60.8 | 5,090 | 2,730 | 54% | 60% | 68% | 73% | 78% | 82% |
| S | Apr | 57.2 | 4,926 | 2,353 | 48% | 49% | 53% | 56% | 61% | 66% |
| S | May | 57.2 | 5,090 | 1,612 | 32% | 34% | 38% | 42% | 49% | 54% |
| S | Jun | 57.2 | 4,926 | 851 | 17% | 19% | 21% | 23% | 26% | 28% |
| SR | Jun | 64.4 | 4,926 | 2,275 | 46% | 53% | 59% | 63% | 68% | 71% |
| SR | Jul | 64.4 | 5,090 | 1,387 | 27% | 28% | 27% | 30% | 30% | 29% |
| SR | Aug | 64.4 | 5,090 | 1,007 | 20% | 21% | 19% | 19% | 19% | 18% |

AM = Adult Migration
R = Reproduction (Spawning, Egg Incubation, and Fry Emergence)
CR = Core Rearing
S = Smoltification
SR = Summer Rearing

The number of mile-days generally increases under increasing unimpaired flows, relative to baseline. Temperatures targets are already achieved much of the time under baseline during the cold weather and high flow months of December and January. The biggest improvements occur for the core rearing life stage in April and May. Under baseline, 69 and 54 percent of maximum attainment is achieved in April and May, respectively, for this critical core rearing life stage. Attainment increases to 83 and 73 percent, respectively for April and May, with 40 percent unimpaired flow. This summary statistic of temperature improvement for all year types, however, masks the benefits in critically dry years when baseline flows are lowest and benefits to temperature habitat are highest from increased flows.

Table 19-16 shows the average number of mile-days that these temperature targets are achieved in all three tributaries, combined, under baseline, and also for unimpaired flows of 20, 30, 40, 50, and 60 percent, for only critically dry years. The improvements from baseline are much bigger than the average over all years. This is important because low flow conditions in dry years currently have a negative effect on salmon survival. Under baseline in the three tributaries, 38 and 22 percent of maximum compliance is achieved in April and May, respectively for core rearing in critically dry years. Attainment of the temperature criteria increases to 64 and 46 percent, respectively for April and May, with 40 percent unimpaired flow. The temporal and spatial attainment of the temperature targets more than doubles in May. Table 19-17 also shows a similar pattern of potential improvements for dry years, and additional tables in Attachment 1 provide tributary specific summary tables.

**Table 19-16. Summary of Mean Annual Temperature Benefits Combined for the Stanislaus, Tuolumne, and Merced Rivers from Different February through June Unimpaired Flow (UF) Percentages for Critically Dry Water Years**

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 4,926 | 353 | 7% | 10% | 10% | 10% | 10% | 9% |
| AM | Oct | 64.4 | 5,090 | 2,627 | 52% | 64% | 63% | 66% | 65% | 63% |
| R | Oct | 55.4 | 5,090 | 235 | 5% | 5% | 4% | 5% | 3% | 3% |
| R | Nov | 55.4 | 4,926 | 1,043 | 21% | 24% | 23% | 25% | 22% | 18% |
| R | Dec | 55.4 | 5,090 | 4,491 | 88% | 96% | 96% | 96% | 96% | 94% |
| R | Jan | 55.4 | 5,090 | 5,011 | 98% | 98% | 98% | 98% | 98% | 98% |
| R | Feb | 55.4 | 4,762 | 3,159 | 66% | 65% | 65% | 66% | 68% | 70% |
| R | Mar | 55.4 | 5,090 | 827 | 16% | 16% | 20% | 25% | 30% | 35% |
| CR | Mar | 60.8 | 5,090 | 3,803 | 75% | 76% | 80% | 85% | 88% | 91% |
| CR | Apr | 60.8 | 4,926 | 1,876 | 38% | 46% | 55% | 64% | 70% | 76% |
| CR | May | 60.8 | 5,090 | 1,135 | 22% | 30% | 39% | 46% | 50% | 55% |
| S | Apr | 57.2 | 4,926 | 818 | 17% | 20% | 25% | 30% | 35% | 40% |
| S | May | 57.2 | 5,090 | 486 | 10% | 12% | 16% | 20% | 22% | 26% |
| S | Jun | 57.2 | 4,926 | 121 | 2% | 4% | 6% | 7% | 7% | 8% |
| SR | Jun | 64.4 | 4,926 | 645 | 13% | 20% | 26% | 31% | 35% | 39% |
| SR | Jul | 64.4 | 5,090 | 361 | 7% | 9% | 9% | 9% | 9% | 9% |
| SR | Aug | 64.4 | 5,090 | 313 | 6% | 8% | 8% | 8% | 7% | 7% |

AM = Adult Migration
R = Reproduction (Spawning, Egg Incubation, and Fry Emergence)
CR = Core Rearing
S = Smoltification
SR = Summer Rearing

**Table 19-17. Summary of Mean Annual Temperature Benefits Combined for the Stanislaus, Tuolumne, and Merced Rivers from Different February through June Unimpaired Flow (UF) Percentages for Dry Water Years**

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 4,926 | 783 | 16% | 16% | 15% | 15% | 14% | 13% |
| AM | Oct | 64.4 | 5,090 | 3,640 | 72% | 71% | 70% | 71% | 70% | 70% |
| R | Oct | 55.4 | 5,090 | 351 | 7% | 7% | 6% | 7% | 6% | 5% |
| R | Nov | 55.4 | 4,926 | 1,907 | 39% | 38% | 37% | 36% | 35% | 34% |
| R | Dec | 55.4 | 5,090 | 4,999 | 98% | 98% | 98% | 98% | 98% | 98% |
| R | Jan | 55.4 | 5,090 | 4,992 | 98% | 98% | 98% | 98% | 98% | 98% |
| R | Feb | 55.4 | 4,762 | 3,469 | 73% | 70% | 72% | 73% | 76% | 79% |
| R | Mar | 55.4 | 5,090 | 1,534 | 30% | 26% | 29% | 36% | 45% | 51% |
| CR | Mar | 60.8 | 5,090 | 4,154 | 82% | 80% | 86% | 91% | 93% | 95% |
| CR | Apr | 60.8 | 4,926 | 2,876 | 58% | 62% | 70% | 78% | 86% | 89% |
| CR | May | 60.8 | 5,090 | 2,110 | 41% | 50% | 53% | 62% | 70% | 76% |
| S | Apr | 57.2 | 4,926 | 1,654 | 34% | 34% | 38% | 44% | 50% | 55% |
| S | May | 57.2 | 5,090 | 914 | 18% | 21% | 25% | 30% | 34% | 38% |
| S | Jun | 57.2 | 4,926 | 247 | 5% | 7% | 8% | 10% | 11% | 13% |
| SR | Jun | 64.4 | 4,926 | 1,038 | 21% | 26% | 31% | 37% | 44% | 49% |
| SR | Jul | 64.4 | 5,090 | 513 | 10% | 10% | 10% | 11% | 11% | 11% |
| SR | Aug | 64.4 | 5,090 | 582 | 11% | 11% | 11% | 10% | 10% | 10% |

AM = Adult Migration
R = Reproduction (Spawning, Egg Incubation, and Fry Emergence)
CR = Core Rearing
S = Smoltification
SR = Summer Rearing

As indicated by these summary tables and the previously discussed temperature results tables, there is tremendous potential to increase suitable temperature habitat in these rivers under the proposed project. Temperature targets that are protective of salmonids are attained more frequently under 30, 40, and 50 percent unimpaired flow than under baseline for all life stages from February through June. These improvements are low estimates of the temperature improvements that can be achieved with increased flow, because flow patterns were not optimized to achieve temperature benefits. Adaptive implementation of the blocks of water represented by the various percentages of unimpaired flow can result in even larger benefits.

## 19.2.4 Summary and Conclusions of Temperature Evaluation

Of all of the habitat attributes for native fishes, water temperature is likely the most important one (besides having water itself), because without adequate water temperature all of the other habitat attributes (including floodplain inundation) become unusable. This temperature evaluation indicates that increasing flows during the February through June time period can provide significant temperature benefits to juvenile Fall-run Chinook salmon and steelhead. Significant temperature improvements in the Stanislaus River primarily occur under 50%-60% unimpaired flows, and in the Merced River primarily occur under 30%-60% unimpaired flows. Significant temperature improvements in the Tuolumne River occur under all alternative unimpaired flows with the least benefit occurring under 20% unimpaired flow and the most benefit occurring under 60%

unimpaired flow. Modeling results on the Tuolumne River also indicate that the 90th percentile temperature can be reduced by 15.4°F (from 77.0°F to 61.6°F) during June at the ¾ river location under 60% unimpaired flow, and that the other unimpaired flows evaluated also provide substantial reductions of the hottest temperatures at multiple locations when compared to baseline. Reductions of the hottest temperatures are possible in each month from February through June on the Tuolumne River, and would provide significant benefits to salmon and steelhead during this time period. On the Stanislaus and Merced Rivers, modeling results indicate that significant improvements in the amount of time USEPA smoltification criteria is met will only occur under the 50% or 60% unimpaired flows during April, May, and June. This is an important result because temperature impacts on the smolt life stage have been repeatedly reported as one of the limiting factors to salmonid populations in the Central Valley and SJR Basin (Kjelson et al 1982; Newman and Rice 1997; Mesick 2010a). However, there are substantial reductions to both average and 90th percentile 7DADM temperatures under all of the evaluated unimpaired flows on the Merced River during this time period that will likely benefit salmonids. Temperature improvements in the LSJR to optimal salmonid temperature habitat are expected only in March under the 60% unimpaired flow. However there are expected reductions to both average and 90th percentile 7DADM temperatures on the LSJR primarily during March through June that may be beneficial to migrating salmonids. These temperature reductions occur under all modeled unimpaired flows with the higher flows providing greater temperature improvements.

As explained by the CDFW (CDFG 2010a page 3):

> Elevated water temperatures appear to be a factor in the continued decline in adult salmon escapement abundance in the San Joaquin River Basin Watershed, either by: (1) inducing adult mortality as adults migrate into the San Joaquin River, and tributaries, to spawn (i.e., pre-spawn mortality); (2) reducing egg viability for eggs deposited in stream gravels (redds), (3) increasing stress levels and therefore reducing survival of juveniles within the tributary nursery habitats, and (4) reducing salmon smolt out-migration survival as smolts leave the nursery habitats within tributaries to migrate down the San Joaquin River to Vernalis and through the south Delta.

The results of this analysis support these conclusions by CDFW (formerly the California Department of Fish and Game [CDFG]), and the conclusions and discussions of others (Baker et al. 1995; Brandes and McLain 2001; CDFG 2005b, 2010a; Kjelson et al 1982; Kjelson and Brandes 1989; Marine and Cech 2004; Mesick 2010a; Myrick and Cech 2001; NMFS 2009a; Zeug et al. 2014) who have suggested that temperature is a limiting factor to fall-run Chinook salmon in the Bay-Delta plan area. Temperature conditions in September, October, and November are generally poor at most locations used by adult migrating and spawning salmon. Furthermore, fry emergence, rearing, smoltification, and emigration life stages are also exposed to suboptimal and even harmful temperature conditions from roughly March through June during many years. Finally, salmonids that stay in the rivers to over summer between June and September have little chance of thriving unless they find the little cold water refugia that potentially exists (depending on the year and river) directly below the dams.

Extending optimal temperature conditions both spatially (further downstream) and temporally (further into each year) will provide many juvenile salmonids with additional space and time to complete their freshwater rearing and outmigration life stages under suitable conditions. The addition of suitable temperature habitats in both space and time will reduce negative temperature effects to native fish, and will provide additional life history flexibility which can help to avoid risks that are associated with populations which lack spatial and temporal habitat diversity. Additionally, improving February through June temperature conditions will allow many anadromous salmonids to better prepare for the physiological and morphological transition they must make before entering the saltwater environment. Improving temperature conditions during this crucial and energetically expensive life stage (smoltification) (Cooperman et al. 2010, Gross et al. 1988, Sheridan et al. 1983) should increase the odds of survival of many fish, and should therefore minimize one of the key limiting factors (unsuitable water temperature) of fall-run Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers (Baker et al. 1995; Brandes and McLain 2001; CDFG 2005b; Kjelson et al. 1981; Kjelson et al 1982; Marine and Cech 2004; Mesick 2010a; Myrick and Cech 2001; NMFS 2009a; Zueg et al. 2014).

Although not the focus of this project, fall spawning temperatures are less than ideal on the Stanislaus, Tuolumne, and Merced Rivers under existing baseline conditions. For example, the amount of time that USEPA spawning temperature criteria are met under modeled baseline conditions at the ¾ river locations in October and November are as follows: Stanislaus River equals 17% and 45% respectively, Tuolumne River equals 1% and 27% respectively, and Merced River equals 0% and 9% respectively. These sub-optimal temperature conditions during the core spawning period and locations are likely to dramatically limit salmon egg survival in these rivers. Reservoirs in California are often touted as being able to store cold water, and while this can be true, they also often have the unfortunate consequence of storing warm water and/or heating the stored cold water. Releases of stored warm water in the fall or early winter can delay the availability of cold water habitat needed by salmon to spawn, and this is likely impacting fall-run Chinook salmon reproductive success in the LSJR tributaries. To illustrate the delay in suitable fall-spawning temperatures, the 1960 to 2010 average daily reservoir inflow temperatures from the SJR HEC-5Q Temperature Model (CDFW 2013b) have been plotted against downstream river temperatures for each of the LSRJ tributaries (Figures 19-7, 19-8, and 19-9). The inflow temperature provides insight into temperature conditions that salmon and steelhead would have historically had access to without the current dam configurations and operations. The reservoir release temperatures and ¾ river temperatures represent the current temperature conditions that salmon and steelhead now have access to. The reservoir release temperature is a "best case" scenario, and represents temperature habitat that few fish actually experience because temperatures can warm rapidly moving downstream under many flow conditions. The approximately 1-month delay (see Figures 19-7 and 19-8) in access to optimal spawning temperatures (55.4 °F) that occurs on the Merced and Stanislaus Rivers during the fall season, creates a disconnect between migratory cues that salmon and steelhead experience in the ocean, and the currently available spawning habitat in these rivers. This delay in access to optimal spawning temperature likely affects egg viability, and potentially shortens the overall window of opportunity available to juvenile salmon and steelhead for successful development and migration prior to ocean entry.

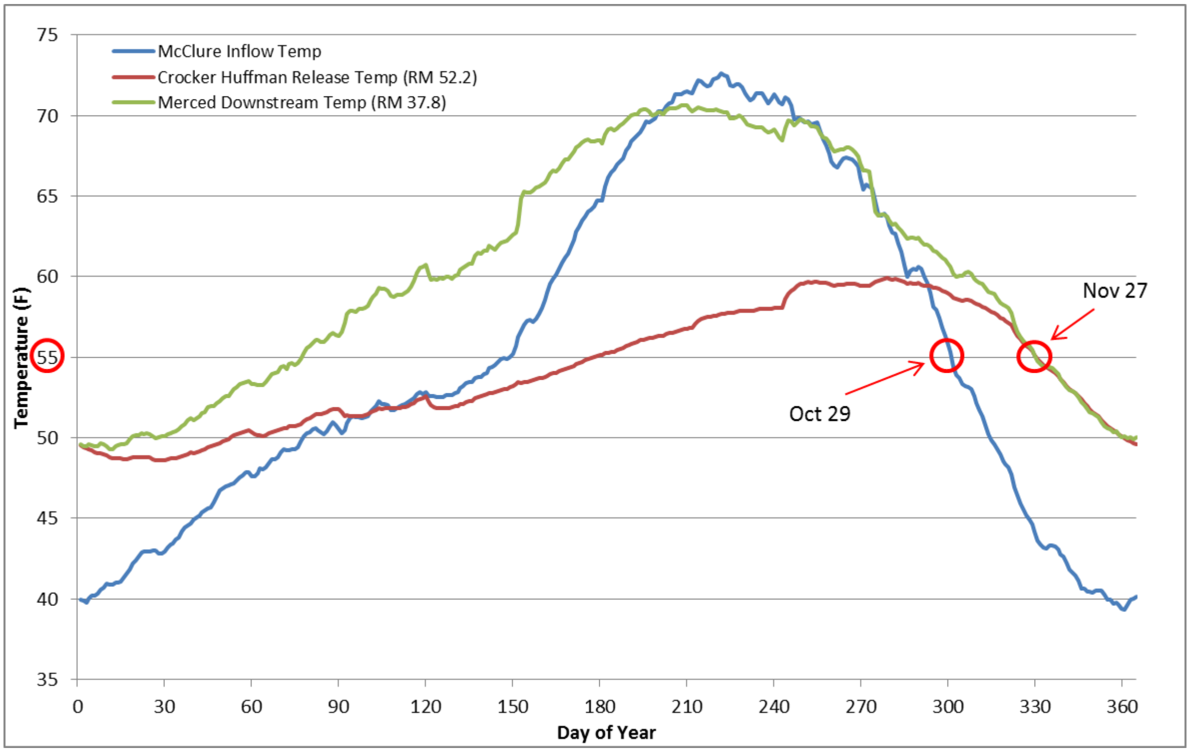


**Figure 19-7. Merced River average daily temperature under baseline conditions from 1960 to 2010 at three different locations, which illustrates that both fall and spring temperature windows have been negatively altered compared to more natural conditions. There is an approximately 1-month delay from when fall-run Chinook salmon should be able to access optimal spawning temperatures (less than 55.4 °F) to when they can under current conditions.**

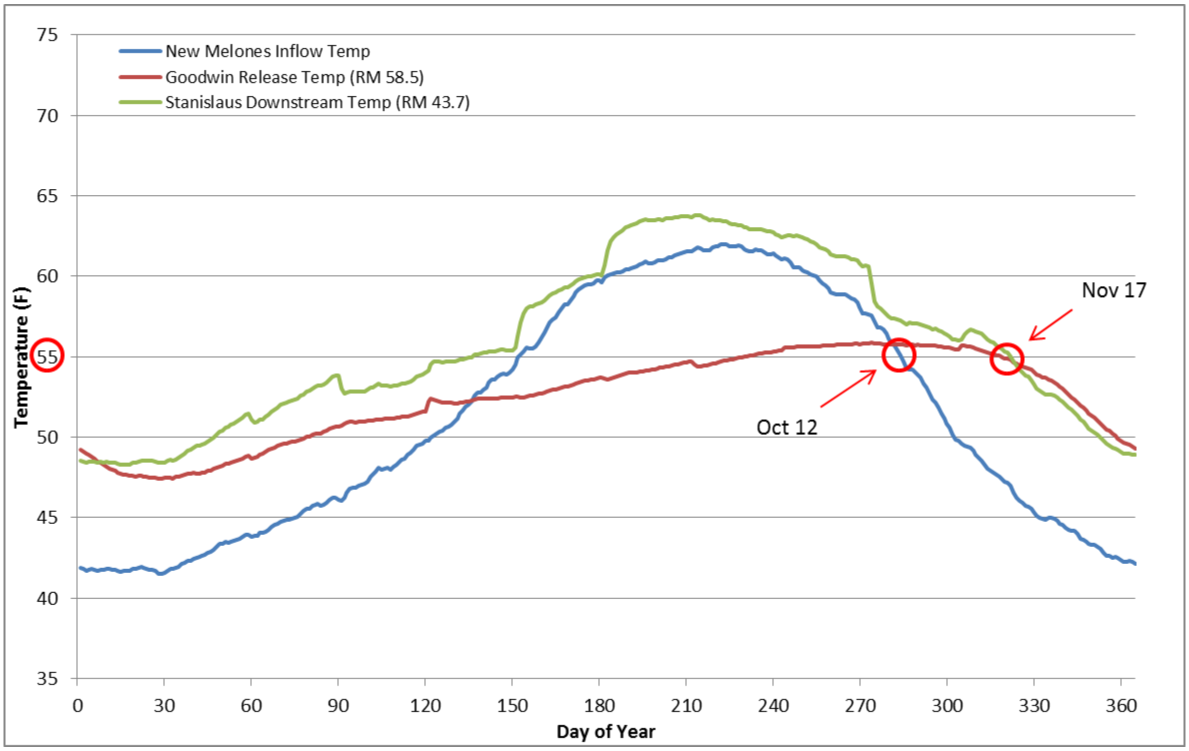


**Figure 19-8. Stanislaus River average daily temperature under baseline conditions from 1960 to 2010 at three different locations. There is an approximately 1-month delay from when fall-run Chinook salmon should be able to access optimal spawning temperatures (less than 55.4 °F) to when they can under current conditions.**

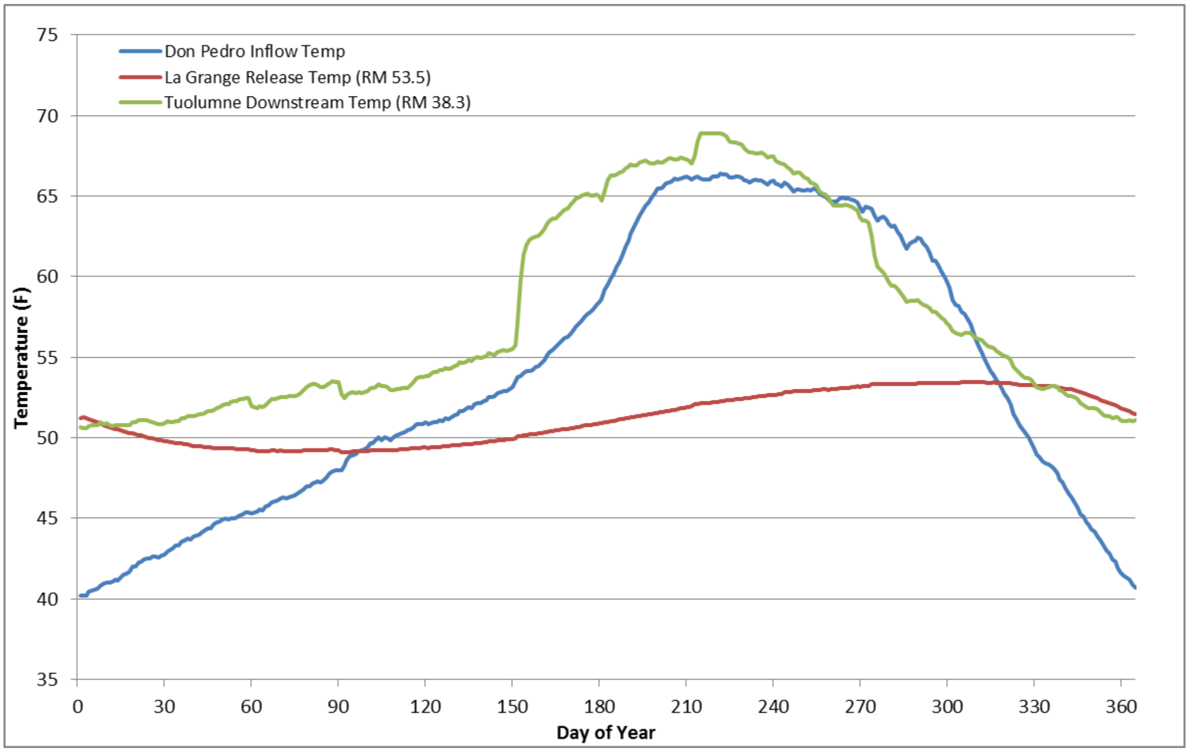


**Figure 19-9. Tuolumne River average daily temperature under baseline conditions from 1960 to 2010 at three different locations, which illustrates that there is an altered temperature regime.**

# 19.3 Floodplain Inundation

On the Stanislaus, Tuolumne, and Merced Rivers floodplain inundation is largely controlled by flows released from the reservoirs. This section describes the expected floodplain inundation benefits to juvenile salmonids and other native fishes from increased flows during the February through June time period, and provides information as to why improved floodplain inundation is important to native fish.

## 19.3.1 Importance of a Natural Floodplain Inundation Regime

### General Introduction to Floodplain Habitat

Wetlands are celebrated world-wide for the many services they provide. They help regulate climate, store surface water, control pollution and flooding, replenish aquifers, promote nutrient cycling, protect shorelines, maintain natural communities of plants and animals, serve as critical nursery areas, and provide opportunities for education and recreation (CNRA 2010).

Within the SJR Basin and related to this Bay Delta Plan update, perhaps the most important type of wetland habitats are floodplain habitats which are adjacent to the Stanislaus, Tuolumne, Merced, and LSJ Rivers. Opperman (2012, pages 1-3) describes that:

> Floodplains are among the most biologically productive and diverse ecosystems on Earth… However, floodplains are also among the most converted and threatened ecosystems. Floodplain habitats in the

> Sacramento-San Joaquin Delta, and throughout California's Central Valley, have been greatly reduced from their historic extent and key processes that create and maintain floodplains, such as flood flows and meander migration, have been greatly altered. These widespread alterations to habitats and processes have led to declines in many species' populations in California's Central Valley and Delta.
>
> …Before the expansion of the European population in California, the Central Valley contained approximately one million hectares of floodplain habitats, including riparian forests and savannas, oxbow lakes and other water bodies, and vast expanses of tule marsh (Katibah 1984; TBI 1998). These habitats supported large, culturally important populations of fish, waterfowl, and ungulates. Diverse economic activities lead to conversion of these habitat types and it is estimated that currently less than 10% of original floodplain habitats remain (Katibah 1984; Barbour and Billings 1988)… Hydrological connectivity between rivers and floodplains has declined further because of flow regulation from large upstream multipurpose dams…

In the last 2 decades, numerous studies have demonstrated that both aquatic and riparian ecosystems benefit from dynamic connectivity between rivers and their floodplains (see Jeffres et al. 2008). Riparian species benefit from nutrients mobilized by inundation of floodplain areas (Junk et al. 1989), while riverine species benefit by having access to the floodplain for foraging, spawning, and as a refuge from high velocities found in the river during high flow events (Moyle et al. 2007). Additionally, fish yields in watersheds generally increase when water surface area in floodplains is increased (Bayley 1991 as cited in Jeffres et al. 2008; USFWS 2014).

## Use of Floodplains by Salmonids

Floodplain habitats in the Central Valley have been found to have a positive effect on growth of juvenile Central Valley salmonids (Sommer et al. 2001; Sommer et al. 2005; Jeffres et al. 2008), and larger and faster growth has been associated with increased survivorship in river and to adulthood (Bond et al. 2008; Healey 1982; Fritts and Pearsons 2006; Mesick and Marston 2007a; Parker 1971; Unwin 1997; Ward et al. 1989; Zabel and Williams 2002). On the Stanislaus River, USFWS (2014) found a significant relationship between juvenile survival and floodplain acre-days, with floodplain acre-days explaining 77% of the year to year variation in juvenile survival.

The higher growth rates of juvenile Chinook salmon using Central Valley floodplains, relative to other river habitat types, have largely been attributed to the greater availability of prey within floodplain habitats (Sommer et al. 2001; Jeffres et al. 2008). For example, prey items can be orders of magnitude greater in floodplains than in adjacent rivers (Sommer et al. 2001; Grosholz and Gallo 2006). Additionally, increased growth rates may also be related to improved velocity conditions that ephemeral floodplain habitat and other side-channels can provide for juvenile salmon compared to river channels during high flow events when, in the absence of such habitat, juvenile salmon may expend excessive energy or are displaced downstream (Jeffres et al. 2008) before they are ready for downstream migration.

The timing of floodplain inundation for the protection of Central Valley Chinook salmon should generally occur from winter to mid-spring to coincide with the peak juvenile Chinook salmon outmigration period (which itself generally coincides with historic peak flows) (see State Water Board 2010). The benefits of floodplain inundation generally increase with increasing duration, with even relatively short periods of 2 weeks providing potential benefits to salmon (Jeffres et al. 2008). Benefits to salmon may also increase with increasing inter-annual frequency of flooding. Repeated pulse flows and associated increased residence times may be associated with increased productivity which would benefit salmon growth rates and potentially reduce stranding (see State Water Board 2010).

The USFWS's 2005 *Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin* (AFRP 2005), concludes that the declines in salmon in the SJR Basin primarily resulted from reductions in the frequency and magnitude of spring flooding in the basin from 1992-2004 compared to the baseline period of 1967-1991. In addition to floodplain being important to salmon, it may also be important to steelhead, sturgeon, splittail (as discussed below), bank swallow, western pond turtle, Fremont cottonwood and many other species important to the riverine ecosystems (CalFED 2008).

Population trend analyses for the SJR Basin suggest that salmon recruitment, which is the number of salmon that survive to the adult stage, is highly correlated with the magnitude and duration of spring flows when the fish were sub-yearling juveniles rearing in the tributaries (Mesick and Marston 2007a; Sturrock et al. 2015; USFWS 2014). The number of smolt-sized outmigrants from the Stanislaus and Tuolumne Rivers is also highly correlated with flow magnitude between February and mid-June (Mesick et al. 2007). These results suggest that fry survival in the tributaries is highest during prolonged periods of flooding and that adult recruitment is highly dependent on fry survival in the tributaries. It is likely that prolonged flooding affects fry survival by providing additional food resources, providing refuge from predators, reducing water temperatures particularly during downstream migrations in May and June, slowing the rate of disease infestation, diluting contaminants, and reducing entrainment (Mesick et al. 2007). Some of these benefits such as increased food resources and refuge from predators could be provided either by higher flows inundating existing floodplains or by constructing lower-elevation floodplains that become inundated on an annual basis with existing flows. However, other benefits such as reduced water temperatures and contaminant dilution would probably only occur during high flows (USFWS 2008).

## Use of Floodplains by Splittail

The primary focus of this document is to quantify some of the benefits to salmon and steelhead from a more natural flow regime during February through June. As discussed before, native salmonids were chosen as indicator species, and providing them with more natural habitat conditions is expected to provide many other native species with more natural habitat conditions. However, when considering floodplain habitat a very important species to mention is the Sacramento splittail (*Pogonichthys macrolepidotus*), because the splittail may be one of the few native California fish that can be considered an obligate floodplain spawner (Opperman 2012), with population dynamics closely associated with annual patterns of flow and floodplain inundation (Moyle et al. 2004). Adults can spawn from late January through early July (Wang 1986), but most frequently spawning occurs during March and April (Moyle et al. 2004).

Floodplain inundation appears to be a primary factor required for strong year-classes of splittail (Sommer et al. 1997). Long-duration floodplain inundation is necessary for successful spawning, incubation, and initial rearing of larval splittail, because splittail eggs require 3 to 5 days to hatch and larval and juvenile splittail will remain on the floodplain while conditions are appropriate (Moyle et al. 2004). Long-duration flooding also allows adults time to feed on earthworms on floodplains before they spawn, and may improve spawning success by improving their condition and egg production (Moyle et al. 2004).

The splittail was historically one of the most abundant estuarine species in the Sacramento-San Joaquin estuary and supported a small hook-and-line fishery (Caywood 1974 as cited in Young and Cech 1996). It was once widely distributed in lakes and rivers throughout California's Central Valley

(Moyle et al. 2004) but disappeared from much of its native range because of loss or alteration of lowland habitats following dam construction, water diversion, and agricultural development (Young and Cech 1996). The species is now largely restricted to the Sacramento-San Joaquin estuary except during upstream spawning migrations (Moyle et al. 2004).

### Food Production of Floodplains

Inundated floodplains produce phytoplankton and other algae (Ahearn et al. 2006), which are sources of biologically available carbon that are particularly important to downstream food-limited ecosystems such as the Sacramento–San Joaquin Delta (Sobczak et al. 2002; Opperman 2012). The flow of energy from algae to zooplankton and other invertebrates influences floodplain resources for native fish. In the Yolo Bypass drift macroinvertebrates, including chironomids and terrestrial invertebrates, were the primary food resource for juvenile Chinook salmon (Sommer et al. 2001), and were positively correlated with flow (Opperman 2012). In the Yolo Bypass, these organisms attain high densities soon after inundation, providing a food source to fish that is available before food web productivity develops, which requires longer inundation events (Sommer et al. 2004).

### Quality of Floodplain Habitat

While it is important to have a natural flow regime which inundates floodplains with proper timing, frequency, magnitude, and duration, it is also important to note that the quality of floodplain habitat is important. A floodplain with sufficient heterogeneity and habitat complexity will facilitate desired ecosystem responses (i.e. diversity of the food web) that may be utilized by salmonids (Bellmore et al. 2013). However, as an example, flooding a parking lot with sufficient timing, frequency, magnitude, and duration necessary for fish will not produce the kinds of ecosystem responses that are desired. In addition, areas with engineered and managed water control structures can have comparatively higher rates of stranding fish (Sommer et al. 2005). Further, floodplains that are too shallow or that lack vegetative cover may also make salmon more susceptible to avian predation (Gawlik 2002). Therefore, it is important that restored floodplains, or multi-benefit projects (i.e. agriculture/floodplain projects) are managed and designed in a manner that provides cost effective results and do not have unintended ecological consequences.

### Summary

The importance of floodplain habitats to native fish and wildlife in the Central Valley has been well documented, but floodplains and the frequency which the remaining ones are inundated, have been greatly reduced from their historic extent. Properly managed floodplains can have widespread benefits at multiple levels ranging from individual organisms to ecosystems (Junk et al. 1989; Moyle et al. 2007). The following analysis will evaluate how increasing river flow during February through June will improve floodplain inundation in the Stanislaus, Tuolumne, Merced, and LSJ Rivers.

## 19.3.2 Methods of Floodplain Inundation Evaluation

Modeled flow outputs were used to predict the frequency and magnitude of monthly flow and floodplain events during the February through June time period in the Stanislaus, Tuolumne, Merced, and LSJ Rivers under baseline and several unimpaired flow percentages. Average monthly flow for each month (February through June) during 1922 to 2003 (n=82 years for each month) was used to estimate the expected frequency and magnitude of floodplain inundation. The February through June time period represents the time period that this project could potentially benefit rearing juvenile salmonids by increasing floodplain habitat. The following methods sections provide additional details regarding the flow modeling, evaluation criteria, and floodplain versus flow relationships used for each water body evaluated.

## Methods: Computer Modeling Used in Floodplain Evaluation

The State Water Resource Control Board (State Water Board) developed the WSE model to simulate the baseline and LSJR alternatives for water years 1922-2003 and to determine the effects on reservoir operations, water supply diversions, and river flow for each of the eastside tributaries (Stanislaus, Tuolumne, and Merced Rivers) and flow and salinity at Vernalis on the SJR. The WSE model was used for this floodplain inundation analysis by estimating monthly average flows for the 82-year period under different unimpaired flow scenarios. The scientific basis for the WSE model is described in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*, and the detailed methods and results for the LSJR alternatives are presented in Appendix F.1, *Hydrologic and Water Quality Modeling*.

## Methods: Floodplain Evaluation Criteria

The frequency during the 82-year modeling period (1922 to 2003) that different monthly average flows, and the related floodplain acreages, are achieved was compared between baseline and unimpaired flows of 20%, 30%, 40%, 50%, and 60%. A 10% change in the frequency of floodplain flows, in combination with professional judgment, is used to determine a significant benefit or impact. Ten percent was selected because it accounts for a reasonable range of potential error associated with the assumptions used in the various analytical and modeling techniques. In addition, lacking quantitative relationships between a given change in environmental conditions and relevant population metrics (e.g., survival or abundance), a 10% change was considered sufficient to potentially result in beneficial or adverse effects to sensitive species at the population level.

## Methods: Floodplain Versus Flow Relationships

### Stanislaus River

This section presents a summary of the methods used by USFWS to develop floodplain versus flow relationships on the Stanislaus River. The USFWS (2011, 2012, and 2013) documentation should be reviewed for a complete description of the methods used.

The USFWS (2011, 2012, and 2013) developed two-dimensional hydraulic models to quantify the relationship between floodplain area and flow for the following four reaches of the Stanislaus River: 1) mouth of Stanislaus River to Ripon, 2) Ripon to Jacob Meyers, 3) Jacob Meyers to Orange Blossom, and 4) Orange Blossom to Knight’s Ferry (Figure 19-10). Light Detection and Ranging (LIDAR) and Sound Navigation and Ranging (SONAR) data collected for the Stanislaus River instream flow study was used as the topographic data source for the hydraulic model.

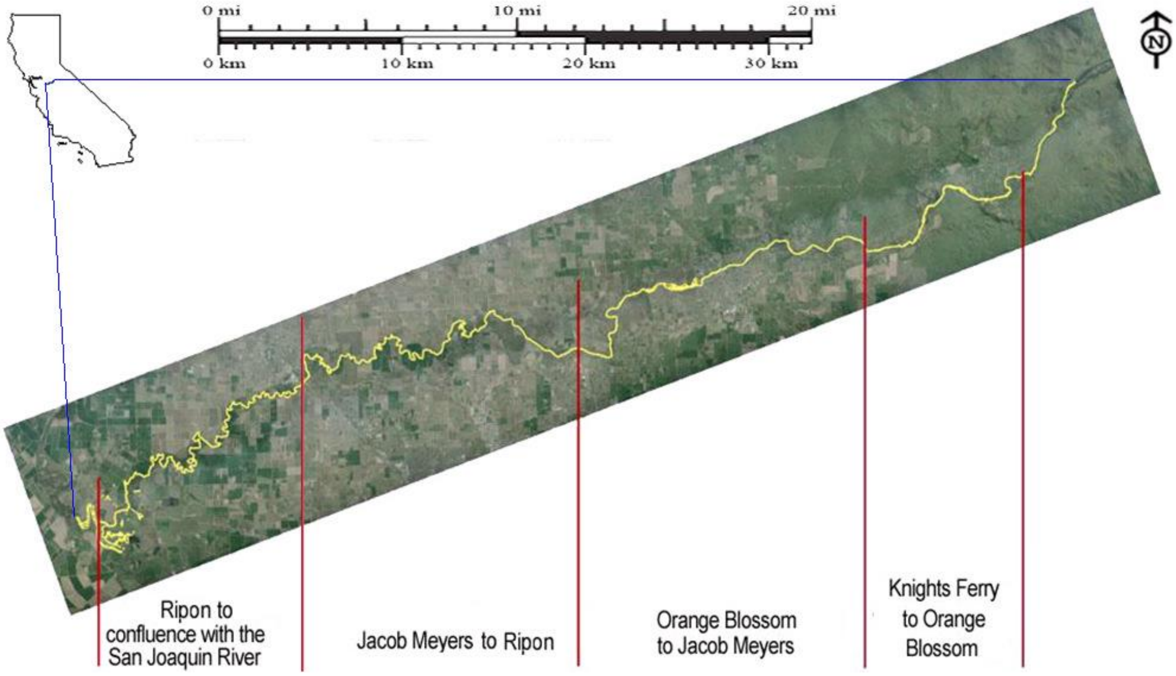


**Figure 19-10. Reaches for Stanislaus River floodplain area versus flow modeling. This figure was developed by the USFWS (2013).**

The calibrated model was then used for hydraulic simulations at flows ranging from 250 to 5,000 cfs. The model output was then processed in SMS to compute the total wetted area at each flow. The resulting total wetted area versus flow graph was then examined to determine the flow at which floodplain inundation begins, as shown by an inflection point in the graph. The total wetted area at higher flows was then subtracted from the total wetted area at which floodplain inundation begins to determine the inundated floodplain area at each flow and for each reach.

USFWS (2011, 2012, 2013) found that in the Stanislaus River confluence (with the LSJR) to Ripon reach floodplain inundation starts at 1,500 cfs, in the Ripon to Jacob Meyers reach floodplain inundation starts at 1,250 cfs, in the Jacob Meyers to Orange Blossom reach floodplain inundation starts at 1,000 cfs, and in the Orange Blossom to Knight's Ferry reaches floodplain inundation starts at 1,250 cfs. They were not able to develop hydraulic models for the Goodwin Dam to Knight's Ferry Bridge reach, because SONAR data is not available for that reach.

The current State Water Board floodplain analysis uses USFWS' Stanislaus River floodplain area versus flow relationship (Table 19-18) to analyze the potential effects that a range of unpaired flows (20%, 30%, 40%, 50%, and 60%) could have on available floodplain habitat used by fall-run Chinook salmon and steelhead.

**Table 19-18. Floodplain versus flow relationship for the entire modeled portion (Knight Ferry (RM 54.5) to the confluence (RM 0)) of the Stanislaus River (from USFWS 2013b and personal communication Mark Gard 2013)**

| Flow (cfs) | FP Acres |
|---|---|
| 250 | 0 |
| 500 | 0 |
| 750 | 0 |
| 1000 | 0 |
| 1250 | 19 |
| 1500 | 46 |
| 1750 | 111 |
| 2000 | 161 |
| 2250 | 207 |
| 2500 | 250 |
| 2750 | 289 |
| 3000 | 326 |
| 3250 | 362 |
| 3500 | 399 |
| 3750 | 427 |
| 4000 | 455 |
| 4250 | 500 |
| 4500 | 536 |
| 4750 | 572 |
| 5000 | 609 |

## Tuolumne River

This section presents a summary of the methods used by USFWS (2008) to develop floodplain versus flow relationships on the Tuolumne River. The USFWS documentation should be reviewed for a complete description of the methods used.

The USFWS (2008) used direct observation, aerial photography, and GIS techniques to map the wetted surface area for a range of flows between 100 cfs and about 8,500 cfs in order identify potential floodplain habitat on the Tuolumne River. The lower Tuolumne River was chosen for this study, as appropriate GIS data were available for the reach between La Grange Dam at RM 52 and just upstream of Santa Fe Bridge at RM 21.5 near the town of Empire. The data used for this analysis were originally developed as part of the FERC relicensing proceedings for the Don Pedro Project (Project No. 2299). From the information available, USFWS developed a wetted surface area versus flow relationship for the study site (Figure 19-11).

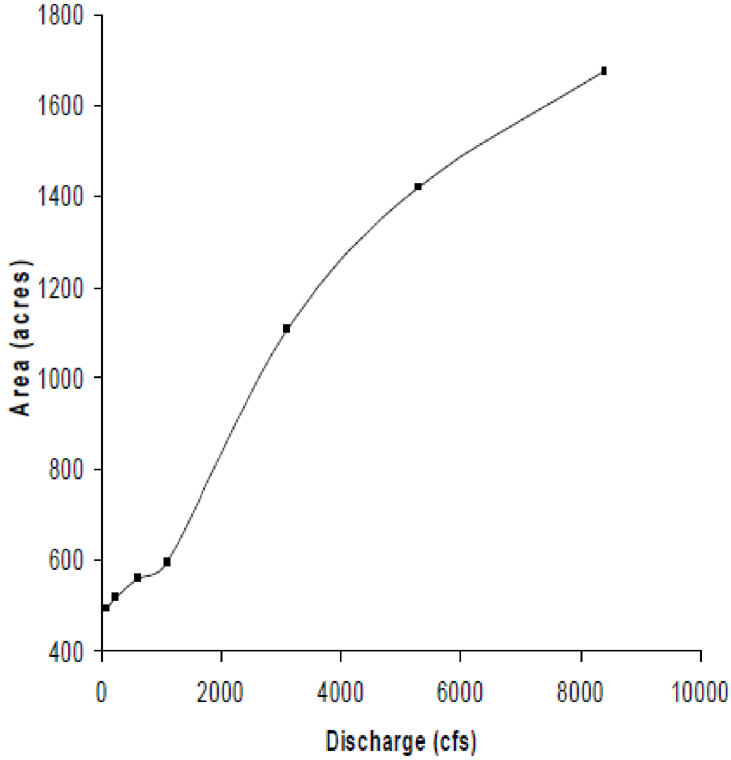


**Figure 19-11. Lower Tuolumne River wetted surface area as a function of discharge from RM 52 to RM 21.5. This figure and relationship were developed by USFWS (2008).**

The wetted surface area versus discharge relationship indicates a primary inflection around 1,100 cfs which suggests that this is the minimum point where flows may begin to inundate "overbank" areas, or extend out of the channel and into the floodplain. Using the wetted surface area versus discharge relationship and the overbank flow of 1,100 cfs, USFWS developed an overbank (floodplain) area versus discharge relationship by subtracting the in-channel area from the total wetted area for each flow value above initial inundation (Figure 19-12).

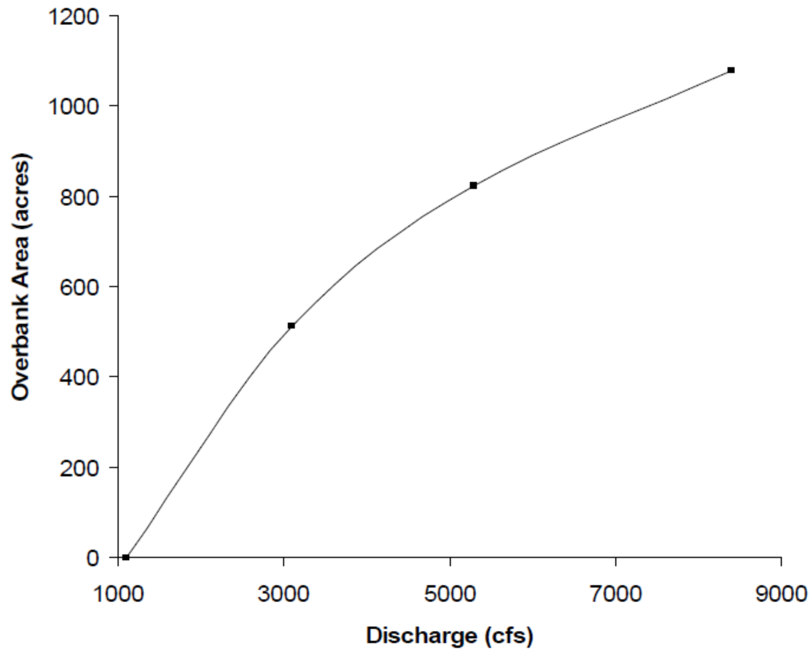


**Figure 19-12. Lower Tuolumne River overbank (floodplain) inundated area as a function of discharge from RM 52 to RM 21.5. This relationship was developed by USFWS (2008).**

We used this Tuolumne River floodplain area versus flow relationship (Figure 19-12 and Table 19-19) to analyze the potential effects that a range of unpaired flows (20%, 30%, 40%, 50%, and 60%) could have on available floodplain habitat used by fall-run Chinook salmon and steelhead.

**Table 19-19. Lower Tuolumne River overbank (floodplain) inundated area as a function of discharge from RM 52 to RM 21.5. These table values were developed by USFWS (2008).**

| Flow (cfs) | FP Acres |
|---|---|
| 1100 | 0 |
| 3100 | 513 |
| 5300 | 823 |
| 8400 | 1079 |

To provide further information for this State Water Board evaluation, additional floodplain values were estimated by fitting a line to the data in Table 19-19. The resulting equation is: $y=530.68\ln(x) - 3728.5$ ($R^2 = 0.9986$), where y equals floodplain acreage and x equals flow in cubic feet per second (cfs).

## Merced River

On the Merced River, floodplain versus flow relationships have not been developed to the level of detail of those developed on the Stanislaus, Tuolumne, and LSJR. Therefore, water surface widths (cross sections) from the HEC-5Q temperature model were used at roughly 1-mile increments along the Merced River for a range of flow values. These cross sections were used between Crocker Huffman Dam (RM 52.2) and Santa Fe Road (RM 27) to develop a reach wide water surface area versus flow relationship to estimate floodplain acreage. The relationship for this portion of the river indicated that floodplain inundation begins between 500 and 1000 cfs. We determined that a floodplain inundation threshold of 1000 cfs on the Merced River above RM 27 was appropriate for this evaluation based on the above information, and on the inundation thresholds determined by USFWS on the Stanislaus (1000 cfs) and Tuolumne (1100 cfs) Rivers. Once the inundation threshold was determined, the in-channel water surface area was subtracted from the total water surface area to determine the out-of-channel surface area (floodplain area). The resulting floodplain versus flow relationship used is: $y = 342.69\ln(x) - 2380.9$ ($R^2 = 0.9952$) (Table 19-20), where y equals floodplain acreage and x equals flow in cfs.

**Table 19-20. Merced River floodplain area versus flow from Crocker Huffman Dam (RM 52.2) to Santa Fe Road (RM 27).**

| Flow (cfs) | Floodplain Acreage |
|---|---|
| 1000 | 0 |
| 1250 | 63 |
| 1500 | 125 |
| 2000 | 224 |
| 3000 | 363 |
| 4000 | 461 |
| 5000 | 538 |

## Lower San Joaquin River

cbec, inc. (2010) utilized a 1D hydraulic model for the SJR, between the Merced River confluence and the Mossdale Bridge, to characterize the relationship between floodplain inundation and flow (Table 19-21 (data from cbec's Table 5)). Inundation mapping was performed by running a range of flows through the model in increments of 1,000 cfs from 1,000 cfs up to 25,000 cfs. The inundation mapping data was delineated into four reaches: Reach 1 is from Newman (Hills Ferry Road just downstream from the Merced River) to E Las Palmas Avenue (19 miles), Reach 2 is from E Las Palmas Avenue to the Tuolumne River (14 miles), Reach 3 is from the Tuolumne River to the Stanislaus River (10 miles), and reach 4 is from the Stanislaus River to Mossdale (Interstate 5) Bridge (17 miles). Flow versus floodplain inundation relationships developed by cbec, were used in this State Water Board analysis to evaluate effect of different unimpaired flows on floodplain in the LSJR.

**Table 19-21. Inundated floodplain acreage in San Joaquin River between Mossdale (Interstate-5 Bridge (RM 56.2) and the confluence with the Stanislaus River (RM 72.5). This information is from Table 5 in cbec 2010, but acres are rounded to the nearest whole number.**

| Flow (cfs) at Vernalis | Reach 1 and 2 combined: Merced to Tuolumne River (33 miles) | Reach 3: Tuolumne to Stanislaus River (10 miles) | Reach 4: Stanislaus to Mossdale (17 miles) |
|---|---|---|---|
| 1000 | 67 | 8 | 62 |
| 2000 | 39 | 23 | 75 |
| 3000 | 129 | 29 | 83 |
| 4000 | 287 | 40 | 91 |
| 5000 | 753 | 100 | 99 |
| 6000 | 1286 | 213 | 108 |
| 7000 | 2020 | 286 | 125 |
| 8000 | 2767 | 400 | 231 |
| 9000 | 3630 | 574 | 353 |
| 10000 | 4480 | 780 | 500 |
| 15000 | 6707 | 1865 | 908 |

## 19.3.3 Results of Floodplain Inundation Evaluation

The results of the current floodplain analysis indicate that improvements (compared to baseline) to the frequency of floodplain inundation can be achieved by implementing the 20%, 30%, 40%, 50%, or 60% unimpaired flows. The improvements to the frequency of floodplain inundation events primarily occur during April, May, and June, although the higher unimpaired flows (40-60%) provide some benefit in February and March. During April through June, most of the unimpaired flows evaluated provide some benefit compared to baseline, with the lower unimpaired flow providing less benefit and the higher unimpaired flows providing greater benefit (Tables 19-22 through 19-27).

**Table 19-22. Percentage of years under baseline (base) conditions with average monthly Stanislaus River flows at Goodwin Dam greater than the specified flow, and the expected percent change under each of the unimpaired flows between 20% and 60%. Corresponding floodplain acreages are from Knights Ferry (RM 54.5) to the confluence with the SJR (RM 0). The gray shading indicates flows which are below the floodplain inundation threshold. Changes to frequency of occurrence which are greater than positive 10% are highlighted green, and changes to frequency of occurrence which are less than negative 10% are highlighted red (if applicable).**

| **Stanislaus River** | | February | | | | | | March | | | | | | April | | | | | | May | | | | | | June | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow (cfs) | Floodplain Acreage | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% |
| 100 | 0 | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% |
| 200 | 0 | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | -1% | 0% | 0% | 0% | 0% |
| 250 | 0 | **49%** | 5% | 13% | 23% | 32% | 37% | **61%** | 2% | 21% | 28% | 34% | 38% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **85%** | 6% | 9% | 9% | 11% | 10% |
| 500 | 0 | **21%** | 1% | 12% | 23% | 32% | 40% | **48%** | -7% | 0% | 10% | 28% | 37% | **98%** | 0% | 1% | 1% | 2% | 2% | **89%** | 4% | 7% | 9% | 10% | 10% | **44%** | 1% | 11% | 23% | 30% | 37% |
| 750 | 0 | **12%** | 0% | 10% | 15% | 27% | 34% | **37%** | -2% | 0% | 0% | 10% | 24% | **84%** | 2% | 6% | 7% | 13% | 12% | **73%** | -1% | 10% | 17% | 18% | 24% | **41%** | -6% | 5% | 11% | 21% | 29% |
| 1000 | Initiates | **10%** | 1% | 2% | 12% | 15% | 26% | **30%** | 2% | 4% | 2% | 2% | 12% | **60%** | -1% | 5% | 13% | 23% | 28% | **59%** | 9% | 17% | 21% | 28% | 30% | **37%** | -4% | 1% | 6% | 18% | 26% |
| 1250 | 19 | **10%** | 0% | 1% | 4% | 12% | 13% | **29%** | 4% | 1% | 0% | 0% | 4% | **57%** | 0% | 1% | 7% | 13% | 24% | **59%** | 2% | 12% | 13% | 18% | 28% | **7%** | -4% | 5% | 16% | 29% | 44% |
| 1500 | 46 | **7%** | 2% | 4% | 2% | 9.8% | 13% | **29%** | 4% | 1% | -4% | -4% | 0% | **43%** | -9% | -9.8% | -1% | 12% | 22% | **40%** | -7% | 11% | 17% | 27% | 35% | **5%** | -2% | 2% | 9% | 29% | 34% |
| 2000 | 161 | **7%** | 1% | 1% | 1% | 2% | 5% | **4%** | 0% | -1% | 0% | 1% | 6% | **0%** | 0% | 0% | 4% | 15% | 34% | **11%** | -2% | 5% | 20% | 40% | 51% | **1%** | 0% | 4% | 4% | 12% | 26% |
| 3000 | 326 | **4%** | 0% | 0% | 1% | 1% | 1% | **2%** | 0% | 0% | -1% | -1% | 1% | **0%** | 0% | 0% | 0% | 1% | 2% | **0%** | 0% | 1% | 7% | 15% | 40% | **1%** | 0% | 0% | 0% | 4% | 6% |
| 4000 | 455 | **1%** | 0% | 0% | 0% | 1% | 1% | **1%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 1% | 5% | 11% | **1%** | 0% | 0% | 0% | 0% | 4% |
| 5000 | 609 | **0%** | 0% | 0% | 0% | 0% | 1% | **1%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 1% | 4% | **0%** | 0% | 0% | 0% | 1% | 1% |

**Table 19-23. Percentage of years under baseline (base) conditions with average monthly Tuolumne River flows at La Grange Dam greater than the specified flow, and the expected percent change under each of the unimpaired flows between 20% and 60%. Corresponding floodplain acreages are from La Grange Dam (RM 52) to just upstream of Santa Fe Bridge (RM 21.5). The gray shading indicates flows which are below the floodplain inundation threshold. Changes to frequency of occurrence which are greater than positive 10% are highlighted green, and changes to frequency of occurrence which are less than negative 10% are highlighted red (if applicable).**

| Tuolumne River | | February | | | | | | March | | | | | | April | | | | | | May | | | | | | June | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow (cfs) | Floodplain Acreage | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% |
| 75 | 0 | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **78%** | 16% | 18% | 18% | 21% | 21% |
| 150 | 0 | **93%** | 2% | 6% | 6% | 6% | 6% | **91%** | 7% | 9% | 9% | 9% | 9% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **49%** | 38% | 43% | 46% | 48% | 50% |
| 300 | 0 | **46%** | 9% | 16% | 23% | 34% | 41% | **67%** | 5% | 23% | 26% | 30% | 32% | **94%** | 2% | 5% | 6% | 6% | 6% | **95%** | 2% | 5% | 5% | 5% | 5% | **28%** | 46% | 59% | 63% | 67% | 68% |
| 500 | 0 | **44%** | 4% | 10% | 10% | 18% | 28% | **56%** | 4% | 6% | 24% | 30% | 37% | **70%** | 12% | 22% | 28% | 30% | 30% | **66%** | 22% | 32% | 34% | 34% | 34% | **27%** | 40% | 49% | 60% | 63% | 65% |
| 1000 | 0 | **38%** | 0% | 0% | -2% | 1% | 11% | **55%** | -2% | -2% | -10% | 0% | 15% | **52%** | 0% | 13% | 27% | 40% | 45% | **51%** | 9% | 32% | 45% | 46% | 48% | **24%** | 18% | 37% | 48% | 51% | 59% |
| 1100 | Initiates | **38%** | -1% | -2% | -5% | 0% | 6% | **55%** | -4% | -2% | -9.8% | -7% | 7% | **44%** | -2% | 15% | 33% | 44% | 54% | **35%** | 15% | 45% | 57% | 62% | 63% | **24%** | 13% | 35% | 48% | 50% | 55% |
| 1250 | 56 | **37%** | -1% | -4% | -5% | -1% | 2% | **51%** | -4% | -4% | -9.8% | -9.8% | -1% | **41%** | -1% | 11% | 29% | 39% | 50% | **26%** | 22% | 52% | 60% | 72% | 72% | **22%** | 7% | 34% | 45% | 50% | 54% |
| 1500 | 152 | **34%** | -1% | -5% | -9% | -2% | 1.2% | **46%** | -4% | -7% | -7% | -9.8% | -4% | **37%** | -1% | 4% | 20% | 38% | 45% | **20%** | 13% | 44% | 63% | 70% | 78% | **22%** | 0% | 24% | 38% | 50% | 50% |
| 2000 | 305 | **28%** | 0% | -4% | -7% | -5% | 4% | **40%** | -2% | -4% | -9% | -9% | -5% | **33%** | -1% | -1% | 2% | 18% | 37% | **17%** | 1% | 29% | 51% | 65% | 68% | **21%** | -1% | 7% | 23% | 39% | 48% |
| 3000 | 520 | **22%** | -4% | -5% | -5% | -6% | -4% | **34%** | 0% | -5% | -11% | -12% | -9.8% | **21%** | 0% | 0% | -2% | -4% | 5% | **13%** | 1% | 2% | 18% | 45% | 59% | **15%** | 0% | 0% | 2% | 26% | 34% |
| 4000 | 673 | **11%** | 0% | -1% | -2% | -1% | -1% | **16%** | -2% | -2% | -2% | -5% | -5% | **11%** | 0% | -1% | 0% | -1% | -2% | **11%** | 1% | 1% | 0% | 13% | 38% | **10%** | 0% | 0% | 0% | 6% | 22% |
| 5000 | 791 | **10%** | 0% | -1% | -2% | -2% | -1% | **7%** | 0% | 0% | 0% | -1% | 0% | **5%** | 0% | 0% | -1% | -1% | -1% | **7%** | 1% | 0% | 0% | 4% | 15% | **5%** | 0% | 0% | 1% | 2% | 9% |

**Table 19-24. Percentage of years under baseline (base) conditions with average monthly Merced River flows at Crocker Huffman Dam greater than the specified flow, and the expected percent change under each of the unimpaired flows between 20% and 60%. Corresponding floodplain acreages are from Crocker Huffman Dam (RM 52.2) to Santa Fe Road (RM 27). The gray shading indicates flows which are below the floodplain inundation threshold. Changes to frequency of occurrence which are greater than positive 10% are highlighted green, and changes to frequency of occurrence which are less than negative 10% are highlighted red (if applicable).**

| Merced River | | February | | | | | | March | | | | | | April | | | | | | May | | | | | | June | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow (cfs) | Floodplain Acreage | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% |
| 100 | 0 | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **98%** | 2% | 2% | 2% | 2% | 2% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% |
| 200 | 0 | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **65%** | 23% | 30% | 33% | 35% | 35% | **70%** | 29% | 29% | 30% | 30% | 30% | **24%** | 49% | 65% | 71% | 72% | 74% |
| 300 | 0 | **40%** | 1% | 6% | 5% | 11% | 23% | **90%** | 4% | 2% | 6% | 9% | 9% | **56%** | 13% | 35% | 40% | 41% | 44% | **62%** | 33% | 37% | 37% | 37% | 38% | **23%** | 33% | 51% | 60% | 68% | 71% |
| 400 | 0 | **38%** | 0% | 2% | 0% | 9% | 12% | **26%** | 4% | 11% | 24% | 49% | 59% | **50%** | 4% | 33% | 44% | 48% | 48% | **50%** | 37% | 46% | 49% | 49% | 49% | **23%** | 28% | 43% | 52% | 60% | 66% |
| 500 | 0 | **34%** | -1% | 0% | 4% | 6% | 11% | **24%** | 1% | 5% | 12% | 30% | 52% | **46%** | -12% | 22% | 43% | 49% | 51% | **43%** | 29% | 46% | 55% | 55% | 56% | **23%** | 16% | 34% | 48% | 52% | 57% |
| 750 | 0 | **30%** | 0% | -1% | 2% | 4% | 7% | **20%** | 0% | 1% | 4% | 7% | 23% | **20%** | -2% | 15% | 38% | 56% | 70% | **23%** | 23% | 51% | 60% | 73% | 74% | **22%** | 4% | 21% | 30% | 41% | 49% |
| 1000 | Initiates | **29%** | -1% | -4% | -1% | 0% | 5% | **15%** | 0% | 0% | 0% | 4% | 9% | **5%** | 0% | 11% | 20% | 43% | 66% | **22%** | 11% | 37% | 52% | 61% | 70% | **22%** | 0% | 6% | 17% | 29% | 40% |
| 1250 | 63 | **26%** | 0% | -1% | -4% | -2% | 4% | **12%** | 0% | 0% | 0% | 1% | 4% | **4%** | 0% | 2% | 5% | 26% | 40% | **16%** | 4% | 26% | 40% | 59% | 66% | **20%** | 1% | 2% | 9% | 21% | 32% |
| 1500 | 125 | **17%** | 1% | 2% | -1% | -2% | 4% | **10%** | 0% | 0% | 0% | -1% | 1% | **2%** | 0% | 0% | 2% | 9% | 29% | **15%** | 0% | 15% | 28% | 49% | 60% | **18%** | 0% | -1% | 1% | 11% | 22% |
| 2000 | 224 | **11%** | 1% | 1% | -2% | -1% | -1% | **6%** | 0% | 0% | 0% | 0% | 0% | **1%** | 0% | 0% | 0% | 1% | 6% | **12%** | 0% | 2% | 6% | 27% | 44% | **16%** | 1% | -2% | -2% | 2% | 9% |
| 3000 | 363 | **6%** | 1% | 0% | -4% | -4% | -4% | **4%** | 1% | 1% | 1% | 1% | 1% | **1%** | 0% | 0% | 0% | 0% | 0% | **5%** | 0% | 1% | 1% | 2% | 12% | **10%** | -1% | -2% | -1% | -2% | 0% |
| 4000 | 461 | **4%** | 0% | -1% | -1% | -2% | -2% | **1%** | 1% | 1% | 1% | 1% | 1% | **1%** | 0% | 0% | 0% | 0% | 0% | **1%** | 0% | 0% | 0% | 0% | 1% | **6%** | 0% | 0% | 0% | -1% | -5% |
| 5000 | 538 | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **1%** | 0% | 0% | 0% | 0% | 0% | **1%** | 0% | 0% | 0% | 0% | 0% |

**Table 19-25. Percentage of years under baseline (base) conditions with average monthly San Joaquin River flows (above the Tuolumne River confluence) greater than the specified flow, and the expected percent change under each of the unimpaired flows between 20% and 60%. Corresponding floodplain acreages are from Newman (Hills Ferry Road just downstream from the Merced River) to the Tuolumne River (33 miles). Changes to frequency of occurrence which are greater than positive 10% are highlighted green, and changes to frequency of occurrence which are less than negative 10% are highlighted red (if applicable).**

| **San Joaquin River Reach 1 and 2** | | February | | | | | | March | | | | | | April | | | | | | May | | | | | | June | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow (cfs) | Floodplain Acreage | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% |
| 1000 | 67 | **73%** | 0% | 0% | -1% | 0% | 4% | **55%** | 0% | 1% | 4% | 7% | 12% | **50%** | -5% | 4% | 16% | 27% | 34% | **35%** | 18% | 34% | 46% | 52% | 55% | **22%** | 2% | 17% | 28% | 40% | 44% |
| 2000 | 39* | **39%** | 1% | 1% | 1% | 2% | 4% | **28%** | 0% | 0% | 2% | 4% | 5% | **18%** | 2% | 4% | 5% | 13% | 21% | **17%** | 1% | 9.8% | 23% | 39% | 48% | **20%** | 1% | -2% | -1% | 2% | 12% |
| 3000 | 129 | **30%** | 0% | 0% | 1% | 1% | 2% | **20%** | 0% | 0% | 0% | 0% | 1% | **15%** | 0% | 0% | 1% | 2% | 5% | **16%** | 0% | 0% | 0% | 6% | 16% | **16%** | -2% | -2% | -2% | -2% | 0% |
| 4000 | 287 | **18%** | 0% | 0% | 1% | 2% | 5% | **16%** | 0% | 0% | 0% | -1% | 0% | **12%** | 0% | 1% | 1% | 1% | 4% | **16%** | 0% | 0% | 0% | 0% | 1% | **11%** | 0% | 0% | 0% | 0% | 0% |
| 5000 | 753 | **15%** | 0% | 1% | 1% | 1% | 1% | **13%** | 0% | 0% | 0% | 0% | 1% | **11%** | 0% | 1% | 1% | 1% | 1% | **13%** | -1% | 0% | 1% | 0% | 1% | **10%** | 0% | -1% | -1% | -1% | 0% |
| 6000 | 1286 | **15%** | -1% | -1% | -1% | 0% | 0% | **11%** | 0% | 0% | 0% | 0% | 0% | **11%** | 0% | 0% | 0% | 0% | 0% | **11%** | 0% | 0% | 0% | 0% | 2% | **7%** | 0% | 0% | 0% | 0% | 0% |
| 7000 | 2020 | **12%** | 0% | 0% | 0% | 0% | 1% | **9%** | 0% | 1% | 1% | 1% | 1% | **7%** | 0% | 1% | 1% | 1% | 2% | **10%** | 1% | 0% | 1% | 1% | 1% | **7%** | 0% | 0% | 0% | 0% | -1% |
| 8000 | 2767 | **12%** | 0% | 0% | -1% | -1% | 0% | **7%** | 0% | 0% | 0% | 0% | 0% | **6%** | 0% | 0% | 0% | 0% | 1% | **9%** | 0% | 0% | 0% | 1% | 1% | **5%** | 0% | 0% | 0% | 0% | 0% |
| 9000 | 3630 | **10%** | 1% | 0% | -2% | -2% | -2% | **6%** | 0% | 0% | 0% | 0% | 0% | **5%** | 1% | 1% | 1% | 1% | 1% | **6%** | 0% | 0% | 0% | 0% | 2% | **5%** | 0% | 0% | 0% | 0% | 0% |
| 10000 | 4480 | **9%** | 0% | 0% | -1% | -1% | -1% | **5%** | 1% | 1% | 1% | 1% | 1% | **4%** | 0% | 0% | 0% | 1% | 2% | **4%** | 0% | 0% | 0% | 0% | 1% | **5%** | 0% | 0% | 0% | 0% | -1% |
| 15000 | 6707 | **2%** | 0% | 0% | 0% | 0% | 0% | **2%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | 0% | 0% | **1%** | 0% | 0% | 0% | 0% | 0% |

*There appears to be a typo in the reported value for Reach 2 in CBEC's (2010) Table 5. This acreage value should be greater than 67 acres, but less than 129 acres.

**Table 19-26. Percentage of years under baseline (base) conditions with average monthly San Joaquin River flows (above the Stanislaus confluence) greater than the specified flow, and the expected percent change under each of the unimpaired flows between 20% and 60%. Corresponding floodplain acreages are from Tuolumne River to the Stanislaus River (10 miles). Changes to frequency of occurrence which are greater than positive 10% are highlighted green, and changes to frequency of occurrence which are less than negative 10% are highlighted red (if applicable).**

| **San Joaquin River Reach 3** | | February | | | | | | March | | | | | | April | | | | | | May | | | | | | June | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow (cfs) | Floodplain Acreage | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% |
| 1000 | 8 | **99%** | 0% | 0% | 0% | 0% | 0% | **91%** | 1% | 2% | 6% | 6% | 7% | **83%** | 5% | 15% | 16% | 16% | 16% | **84%** | 7% | 13% | 15% | 16% | 16% | **40%** | 32% | 40% | 45% | 50% | 52% |
| 2000 | 23 | **59%** | -1% | -2% | -1% | 6% | 7% | **59%** | 1% | 5% | 5% | 16% | 23% | **61%** | -4% | 7% | 21% | 34% | 37% | **52%** | 16% | 33% | 39% | 45% | 45% | **26%** | 20% | 37% | 45% | 48% | 54% |
| 3000 | 29 | **46%** | 1% | 1% | 0% | 0% | -1% | **44%** | 0% | 0% | -1% | 5% | 9.8% | **40%** | 0% | 5% | 17% | 33% | 38% | **26%** | 17% | 38% | 52% | 61% | 66% | **24%** | 0% | 20% | 32% | 41% | 46% |
| 4000 | 40 | **37%** | 1% | 6% | 5% | 4% | 5% | **41%** | -2% | -2% | -5% | -5% | 1% | **29%** | 0% | 2% | 7% | 21% | 34% | **20%** | 1% | 27% | 43% | 57% | 65% | **21%** | 1% | 4% | 17% | 29% | 39% |
| 5000 | 100 | **29%** | 0% | 0% | 0% | 6% | 9% | **32%** | 0% | -2% | -5% | -5% | 0% | **24%** | 0% | 2% | 2% | 9% | 16% | **20%** | 0% | 5% | 26% | 40% | 55% | **18%** | 1% | 0% | 5% | 21% | 28% |
| 6000 | 213 | **28%** | 0% | -2% | -5% | -1% | 4% | **26%** | 0% | -4% | -5% | -6% | -6% | **17%** | 0% | 1% | 2% | 6% | 9.8% | **16%** | 1% | 4% | 7% | 32% | 44% | **15%** | 0% | 1% | 0% | 9.8% | 23% |
| 7000 | 286 | **22%** | -1% | -1% | -2% | -2% | 0% | **20%** | 0% | 0% | -2% | -1% | 0% | **15%** | 0% | 1% | 1% | 1% | 5% | **15%** | 1% | 2% | 4% | 15% | 35% | **15%** | -1% | -1% | -1% | 1% | 11% |
| 8000 | 400 | **18%** | 0% | -1% | -1% | 1% | 1% | **17%** | 0% | 0% | -1% | -2% | -1% | **13%** | 0% | 0% | 0% | 0% | 1% | **13%** | 0% | 1% | 4% | 6% | 24% | **12%** | 0% | 0% | -1% | 0% | 7% |
| 9000 | 574 | **16%** | 0% | 0% | 0% | 0% | 1% | **15%** | 0% | -1% | -1% | -2% | -2% | **11%** | 0% | 0% | 0% | 0% | 4% | **11%** | 1% | 1% | 1% | 5% | 9.8% | **12%** | 0% | -1% | -1% | -2% | 1% |
| 10000 | 780 | **15%** | 0% | -1% | -2% | -2% | -1% | **12%** | 0% | -1% | -1% | -1% | 0% | **11%** | 0% | 0% | 0% | 0% | 0% | **11%** | 1% | 1% | 1% | 2% | 7% | **10%** | 0% | -2% | -2% | -1% | 1% |
| 15000 | 1865 | **6%** | 0% | 0% | -1% | 0% | 0% | **6%** | 0% | 0% | 0% | 0% | 0% | **5%** | 0% | 0% | 0% | 0% | 0% | **6%** | 0% | 0% | 0% | 0% | 2% | **4%** | 0% | 0% | 0% | 1% | 1% |

**Table 19-27. Percentage of years under baseline (base) conditions with average monthly San Joaquin River flows at Vernalis greater than the specified flow, and the expected percent change under each of the unimpaired flows between 20% and 60%. Corresponding floodplain acreages are from Mossdale (Interstate-5 Bridge) to the confluence with the Stanislaus River (16 miles). Changes to frequency of occurrence which are greater than positive 10% are highlighted green, and changes to frequency of occurrence which are less than negative 10% are highlighted red (if applicable).**

| **San Joaquin River Reach 4** | | February | | | | | | March | | | | | | April | | | | | | May | | | | | | June | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow (cfs) | Floodplain Acreage | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% | **Base** | 20% | 30% | 40% | 50% | 60% |
| 1000 | 62 | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **100%** | 0% | 0% | 0% | 0% | 0% | **90%** | 6% | 9% | 9% | 9% | 9% |
| 2000 | 75 | **79%** | -5% | -2% | 2% | 4% | 6% | **80%** | -6% | 1% | 5% | 9% | 11% | **85%** | 2% | 12% | 13% | 13% | 13% | **85%** | 7% | 11% | 12% | 13% | 15% | **57%** | 11% | 18% | 24% | 27% | 33% |
| 3000 | 83 | **56%** | -1% | -2% | -5% | 2% | 6% | **63%** | -5% | 1% | 1% | 11% | 18% | **72%** | 0% | 9% | 13% | 23% | 26% | **71%** | 7% | 18% | 22% | 27% | 27% | **41%** | 13% | 22% | 30% | 33% | 38% |
| 4000 | 91 | **43%** | 5% | 6% | 5% | 4% | 2% | **45%** | 2% | 0% | 4% | 9.8% | 12% | **56%** | -2% | 6% | 17% | 24% | 32% | **52%** | 9.8% | 23% | 34% | 35% | 43% | **26%** | 4% | 28% | 35% | 40% | 46% |
| 5000 | 99 | **34%** | 1% | 9% | 7% | 9% | 9.8% | **43%** | -1% | -1% | 1% | 1% | 6% | **46%** | -5% | -1% | 6% | 22% | 30% | **45%** | 2% | 17% | 29% | 40% | 41% | **23%** | 1% | 9.8% | 28% | 37% | 43% |
| 6000 | 108 | **30%** | 0% | 1% | 7% | 9% | 11% | **39%** | -1% | -4% | -4% | -2% | 2% | **34%** | -4% | -1% | 6% | 21% | 29% | **23%** | 9.8% | 27% | 39% | 50% | 61% | **21%** | 0% | 2% | 12% | 28% | 37% |
| 7000 | 125 | **28%** | 0% | -1% | -2% | 6% | 9.8% | **34%** | 1% | -1% | -5% | -4% | -2% | **26%** | 1% | 2% | 4% | 12% | 27% | **21%** | 0% | 21% | 33% | 44% | 54% | **20%** | 0% | 0% | 5% | 20% | 32% |
| 8000 | 231 | **27%** | -1% | 0% | -2% | 0% | 5% | **29%** | 0% | -2% | -5% | -6% | 0% | **20%** | 2% | 5% | 4% | 9.8% | 17% | **20%** | 1% | 5% | 21% | 35% | 48% | **16%** | 0% | 0% | 2% | 12% | 26% |
| 9000 | 353 | **21%** | 0% | -1% | -1% | 0% | 2% | **18%** | 4% | 2% | 1% | 2% | 2% | **17%** | 0% | 0% | 1% | 4% | 9% | **17%** | 0% | 2% | 13% | 32% | 41% | **15%** | 0% | -1% | -1% | 9% | 16% |
| 10000 | 500 | **17%** | 0% | 0% | 0% | 1% | 2% | **18%** | 0% | 1% | -1% | 0% | 2% | **13%** | 1% | 0% | 1% | 4% | 6% | **13%** | 2% | 4% | 7% | 26% | 40% | **13%** | 0% | 0% | 0% | 2% | 11% |
| 15000 | 908 | **11%** | 0% | -2% | -2% | -1% | -1% | **9%** | 0% | 0% | 0% | 0% | 0% | **6%** | 0% | 0% | 1% | 1% | 2% | **9%** | 1% | 2% | 4% | 4% | 9% | **6%** | 0% | 1% | 1% | 1% | 2% |

## Stanislaus River Floodplain Evaluation Results

**Baseline:** Under existing conditions on the Stanislaus River, April and May experience floodplain inundation flows most often, with average monthly flows greater than 1,000 cfs (floodplain inundation threshold) occurring approximately 60% and 59% of the years, respectively. Each of the other months between February and June have a lower frequency of floodplain inundation, with February having the lowest frequency (10%) of monthly average flows over 1,000 cfs. Interestingly though, February also has the highest frequency (4%) of monthly average flow greater than 3,000 cfs (326 acres) (Table 19-22).

**20-60% Unimpaired Flow:** During March, only the 60% unimpaired flow provides an increase of 10% or more (12%) in the amount of years with monthly average flows which are greater than 1000 cfs. However, even the 60% unimpaired flow in March does not provide a significant increase in the amount of time that monthly average flows are greater than 1,250 cfs (19 acres). During the other months from February through June, the higher unimpaired flows provide greater increases compared to the lower unimpaired flows in the amount of time that monthly average flows are greater than the floodplain inundation threshold. May is the month with the largest increase in floodplain flows, with monthly average flows greater than 2,000 cfs (161 acres) occurring approximately 51% more often than baseline under the 60% unimpaired flow (Table 19-22).

## Tuolumne River Floodplain Evaluation Results

**Baseline:** Under existing conditions on the Tuolumne River, March and April experience floodplain inundation flows most often, with average monthly flows greater than 1,100 cfs (floodplain inundation threshold) occurring approximately 55% and 44% of the years respectively. Each of the other months between February and June have a lower frequency of floodplain inundation, with May and June having the lowest frequency (35% and 24% respectively) of monthly average flows greater than 1,100 cfs (Table 19-23).

**20-60% Unimpaired Flow:** During February and March, modeling does not indicate that the alternative unimpaired flows evaluated would produce significant floodplain benefits. During April through June, the higher unimpaired flows provide greater increases compared to the lower unimpaired flows in the amount of time that monthly average flows are greater than the floodplain inundation threshold. May is the month with the largest increase in floodplain flows, with monthly average flows greater than 1,500 cfs (152 acres) occurring approximately 78% more often than baseline under the 60% unimpaired flow (Table 19-23).

## Merced River Floodplain Evaluation Results

**Baseline:** Under existing conditions on the Merced River, the frequency of monthly average flows greater than 1,000 cfs (floodplain inundation threshold) occurs similarly during February through June ranging between 5% (April) and 29% (February) (Table 19-24).

**20-60% Unimpaired Flows:** The 20-60% unimpaired flows result in significant increases in the frequency of flows greater than 1,000 cfs during the months of April, May, and June, but do not increase the occurrence of these events during February or March. During April through June, the higher unimpaired flows provide greater increases compared to the lower unimpaired flows in the amount of time that monthly average flows are greater than the floodplain inundation threshold.

May is the month on the Merced River with the largest increase in floodplain flows, with monthly average flows greater than 1,000 cfs occurring 70% more often under the 60% unimpaired flow (Table 19-24).

## San Joaquin River Floodplain Evaluation Results

**Baseline:** Reaches 1 and 2 make up the section of the SJR between the Merced and Tuolumne Rivers. Under baseline flow conditions, floodplain inundation occurs most frequently during February and least frequently during June. Under existing channel configuration floodplain inundation occurs as low as 1,000 cfs (67 acres). Between 1,000 and 4,000 cfs there is a slow rate of increase in floodplain acreage with additional flow. Above 4,000 cfs (287 acres) the rate floodplain acreage increases rapidly (see Table 19-21). Under baseline conditions, monthly average flows greater than 4,000 cfs occur 18%, 16%, 12%, 16%, and 11% of the years during the 82-year period for February, March, April, May, and June respectively (Table 19-25).

The LSJR Reach 3 is located between the Tuolumne and the Stanislaus Rivers. Under existing channel configuration there is small amount of floodplain inundated at flows as low at 1000 cfs (8 acres). From 1,000 cfs to 7,000 cfs there are minimal gains to floodplain inundation with increasing flow. Above 7,000 cfs (286 acres) there is an increased rate of floodplain inundation as flows increase (see Table 19-21). Floodplain inundation under baseline conditions is similar from February to May, and then drops off in June. Monthly average flows greater than 1000 cfs occur 99%, 91%, 83%, 84%, 40% of the of the years during the 82-year period for February, March, April, May, and June respectively. Monthly average flows greater than 7,000 cfs occur 22%, 20%, 15%, 15%, and 15% of the years during the 82-year period for February, March, April, May, and June respectively (Table 19-26).

Reach 4 is located in the LSJR from the Stanislaus River confluence to Mossdale. In Reach 4, monthly average Vernalis flow greater than 7,000 cfs (125 acres) occur 28%, 34%, 26%, 21%, and 20% of the years during February, March, April, May, and June respectively. In general, each month from February through June has a similar pattern of monthly average flows that inundate floodplain, except that June has a lower frequency of lower flows. For example, a monthly average flow of 2,000 cfs (75 acres) occurs approximately 80% of the time during February through May, but only occurs 57% of years during June (Table 19-27).

**20-60% Unimpaired Flow:** Above the Tuolumne River in Reaches 1 and 2 significant floodplain improvements occur primarily under the 40%-60% unimpaired flows. These improvements in the frequency of floodplain inundation occur at flows between 1,000 cfs (67 acres) and 3,000 cfs (129 acres), and the largest floodplain improvements occur in May under the 40%-60% unimpaired flows. Monthly average flow events above 4,000 cfs (287 acres) do not increase substantially under any of the alternatives (Table 19-25).

Between the Stanislaus and Tuolumne Rivers (Reach 3), floodplain improvements from increased unimpaired flows primarily occur during April through June. The higher unimpaired flows produce larger increases in floodplain inundation compared to the lower unimpaired flows. During May, the 50% and 60% unimpaired flows increase floodplain inundation events greater than 7,000 cfs (286 acres) by 15% and 35% respectively (Table 19-26).

In Reach 4, significant improvements to the frequency of monthly average flows above 7,000 cfs (125 acres) occur under the 50% and 60% unimpaired flows in April, occur under the 30%-60% unimpaired flows in May, and occur under the 50% and 60% unimpaired flows in June. May is the month on the LSJR with the largest increase in floodplain flows, with monthly average flows greater than 7,000 cfs occurring 54% more often under the 60% alternative (Table 19-27).

## Summarized Floodplain Results

When considering floodplain results on different rivers and different times of the year, it becomes difficult to provide an overall picture of potential floodplain benefits. One way to summarize the floodplain benefits of the evaluated unimpaired flows is to consider a data output commonly referred to as acre-days (see USFWS 2014). This measurement is the number of acres inundated each day, and then summed over an identified time period. Table 19-28 provides a summary of the acre-days of floodplain inundation in the three tributaries that occur under baseline, and under different unimpaired flows during February through June. The table also shows the percentage increase achieved under each percent of unimpaired flow, relative to baseline. There is an overall 35 percent increase in floodplain inundation, from 39,292 acre-days to 53,208 acre-days at 40 percent of unimpaired flow. The percent increase in floodplain inundation is 16 percent and 74 percent, respectively, for 30 and 50 percent of unimpaired flow.

**Table 19-28. Annual average floodplain inundation in acre*days and percent increase during February through June for baseline and different unimpaired flow percentages.**

| Percent of Unimpaired Flow | Unit | Stanislaus | Tuolumne | Merced | Total |
|---|---|---|---|---|---|
| Baseline | Acre*Days | 4,881 | 27,668 | 6,742 | 39,292 |
| 20% UF | Acre*Days | 4,475 | 27,899 | 7,016 | 39,390 |
| | Percent Increase | -8% | 1% | 4% | 0% |
| 30% UF | Acre*Days | 5,618 | 31,882 | 7,895 | 45,395 |
| | Percent Increase | 15% | 15% | 17% | 16% |
| 40% UF | Acre*Days | 7,509 | 36,644 | 9,055 | 53,208 |
| | Percent Increase | 54% | 32% | 34% | 35% |
| 50% UF | Acre*Days | 11,805 | 44,426 | 12,055 | 68,287 |
| | Percent Increase | 142% | 61% | 79% | 74% |
| 60% UF | Acre*Days | 16,818 | 53,936 | 15,879 | 86,634 |
| | Percent Increase | 245% | 95% | 136% | 120% |

UF = unimpaired flow

A critically important time period for floodplain inundation, and also the time period that achieves the greatest benefit from the flow proposal, is the April through June period. Floodplain inundation does not change much during February and March because flows are relatively high during those months already under baseline. Table 19-29 provides a summary of acre-days of floodplain inundation that occur under baseline, and also for 20 to 60 percent of unimpaired flow, for the April through June period. The table also shows the percent increase achieved under each percent of unimpaired flow, relative to baseline. There is an overall 82 percent increase in floodplain inundation, from 21,034 acre-days to 38,352 acre-days at 40 percent of unimpaired flow in the three tributaries. The percent increase in floodplain inundation is 37 percent and 152 percent, respectively, for 30 and 50 percent of unimpaired flow.

**Table 19-29. Annual average floodplain inundation in acre*days and percent increase during April through June for baseline and different unimpaired flow percentages.**

| Percent of Unimpaired Flow | Unit | Stanislaus | Tuolumne | Merced | Total |
|---|---|---|---|---|---|
| Baseline | Acre*Days | 3,217 | 13,809 | 4,008 | 21,034 |
| 20% UF | Acre*Days | 2,627 | 14,676 | 4,153 | 21,456 |
| | Percent Increase | -18% | 6% | 4% | 2% |
| 30% UF | Acre*Days | 3,844 | 19,873 | 5,113 | 28,831 |
| | Percent Increase | 19% | 44% | 28% | 37% |
| 40% UF | Acre*Days | 5,716 | 26,046 | 6,589 | 38,352 |
| | Percent Increase | 78% | 89% | 64% | 82% |
| 50% UF | Acre*Days | 9,543 | 33,939 | 9,507 | 52,988 |
| | Percent Increase | 197% | 146% | 137% | 152% |
| 60% UF | Acre*Days | 13,909 | 41,689 | 13,016 | 68,615 |
| | Percent Increase | 332% | 202% | 225% | 226% |

UF = unimpaired flow

As is the case for potential temperature improvements, the benefits of floodplain inundation are greatest during dry and critically dry years. Table 19-30 shows floodplain inundation in the Tuolumne River for baseline and for each 10 percent increment of unimpaired flow from 20 to 60 percent for each water year type. Under baseline, there was no floodplain inundation in critically dry years, whereas under 40 percent unimpaired flow there are 4,172 acre-days of floodplain inundation from April through June. In dry years, floodplain inundation increases by a factor of 14 (1,390 percent), from 602 days to 8,964 acre-days of floodplain inundation. Improvements are similarly large for the Merced River, where there is no floodplain inundation under baseline conditions in below normal, dry, or critically dry years. Improvements are smaller in the Stanislaus River because flows are already relatively high in dry and critically dry years under baseline.

**Table 19-30. Average annual floodplain inundation in acre*days and percent increase during April through June for baseline and different unimpaired flow percentages for the Tuolumne River.**

| Percent of Unimpaired Flow | Unit | All Year Types | Wet | Above Normal | Below Normal | Dry | Critical |
|---|---|---|---|---|---|---|---|
| Baseline | Acre*Days | 13,809 | 41,553 | 7,501 | 555 | 602 | 0 |
| 20% UF | Acre*Days | 14,676 | 43,300 | 9,318 | 964 | 202 | 0 |
| | Percent Increase | 6% | 4% | 24% | 74% | -66% | NA |
| 30% UF | Acre*Days | 19,873 | 48,199 | 19,423 | 8,465 | 2,758 | 1,011 |
| | Percent Increase | 44% | 16% | 159% | 1424% | 358% | NA |
| 40% UF | Acre*Days | 26,046 | 50,334 | 30,383 | 19,862 | 8,974 | 4,172 |
| | Percent Increase | 89% | 21% | 305% | 3477% | 1390% | NA |
| 50% UF | Acre*Days | 33,939 | 56,322 | 41,223 | 31,160 | 16,617 | 9,411 |
| | Percent Increase | 146% | 36% | 450% | 5511% | 2658% | NA |
| 60% UF | Acre*Days | 41,689 | 63,025 | 50,896 | 40,833 | 24,441 | 15,187 |
| | Percent Increase | 202% | 52% | 579% | 7253% | 3957% | NA |

UF = unimpaired flow

Note: The percent increase could not be calculated for some river and year type combinations because there was 0 Acre*Days of floodplain under baseline. These value are replaced with NA.

As indicated by these summary tables and the previously discussed floodplain results tables, there is tremendous potential to increase floodplain habitat in these rivers under the proposed project.

## 19.3.4 Summary and Conclusions of Floodplain Inundation Evaluation

The results of this floodplain analysis indicate that providing more flow with a more natural regime during the February through June time period will significantly increase the amount of floodplain habitat which is available to native fish, and that higher unimpaired flows will produce greater benefit, in terms of floodplain frequency and magnitude (and presumably duration), compared to lower unimpaired flows or baseline conditions. In general, floodplain inundation will increase the most (compared to baseline) during the months of April, May, and June under the evaluated unimpaired flows.

In the last 2 decades, numerous studies have demonstrated that both aquatic and riparian ecosystems benefit from dynamic connectivity between rivers and their floodplains (see Jeffres et al. 2008). For example, riparian species benefit from nutrients mobilized by inundation of floodplain areas (Junk et al. 1989), while riverine species benefit by having access to the floodplain for foraging, spawning, and as a refuge from high velocities in the river during high flow events (Moyle et al. 2007).

Floodplain habitats in the Central Valley have been found to have a positive effect on growth of juvenile Central Valley salmonids (Sommer et al. 2001; Sommer et al. 2005; Jeffres et al. 2008), and larger and faster growth has been associated with increased survivorship in river and to adulthood (Bond et al 2008; Healey 1982; Fritts and Pearsons 2006; Mesick and Marston 2007a; Parker 1971; Unwin 1997; Ward et al 1989; Zabel and Williams 2002). Additionally, fish yields in watersheds generally increase when water surface area in floodplains is increased (USFWS 2014; Bayley 1991 as cited in Jeffres et al. 2008).

Implementation of the proposed project will produce substantial increases in floodplain habitat which is available to native fish and wildlife populations, and it is expected that there will be significant positive population responses by native salmonids, and other native fishes.

# 19.4 SalSim

## 19.4.1 Introduction of SalSim

To provide insight into potential management decisions being evaluated for this Bay-Delta Plan update, the State Water Board staff used a life-history population simulation model for fall-run Chinook salmon originating from the SJR and its upper three east-side salmon bearing tributaries (Stanislaus, Tuolumne, and Merced Rivers). This model is called SalSim and was developed by the CDFW, AD Consultants, and a variety of other modeling and fisheries experts (CDFW 2013a; CDFW 2014). The State Water Board used SalSim to explore and compare a variety of flow scenarios in order to assess the response of fall-run Chinook salmon production from the Stanislaus, Tuolumne, and Merced Rivers that may have occurred if these different flow scenarios were implemented in the past. It is important to understand that this model does not predict what is expected to occur in the future. Instead, the model backcasts how salmon populations may have been different in the past (1994-2010) if water management was different in the three east-side tributaries.

### Use of SalSim and Advisory for this Bay-Delta Plan Update

During the exploration and use of this model State Water Board staff discovered that the treatment of two of the most important salmon habitat attributes related to flow in the project area, water temperature and floodplain inundation, are not represented by the model in a manner that is consistent with current scientific information. Consequently, SalSim appears to underrepresent the benefit of habitat improvements related to floodplain and water temperature conditions during the spring time period that result from different flow scenarios which were evaluated for this project. Specifically, in SalSim, the downstream movement of juvenile salmon is slowed down when they pass inundated floodplains, which results in a later date and larger size of entry into the SJR and Delta, where a larger size improves survival. However, SalSim does not increase the growth rate of these fish when they are “on a floodplain”. Recent literature (see Jeffres et al. 2008) indicates that growth rates of juvenile salmon on a floodplain can be significantly greater than juvenile salmon rearing in the adjacent river channel. However, exactly how much faster salmon grow on a floodplain depends on many variables that are not completely understood in California, which may explain why SalSim does not contain a relationship between growth rates and floodplain use. By not having increased growth rates during floodplain use, SalSim likely underestimates the direct benefit of floodplain inundation to juvenile salmon survival. Additionally, negative temperature effects from warm water on juvenile salmon survival are under-sensitive during the spring time period in SalSim. For example, the density-independent mortality function (CDFW 2014) for juvenile salmon in SalSim calculates daily survival probabilities near 100% at daily maximum temperatures in excess of 40°C at flows of 550 cfs for salmon 65 mm in length. Temperatures above 30°C and certainly above 40°C are lethal to salmonids during exposure times of seconds or minutes (EPA 2003). Temperature modeling results presented in this chapter indicate that harmful and lethal temperatures can be dramatically reduced during the February through June time period for the proposed project. However, the SalSim model does not appear to apply the appropriate survival response to the reduction of harmful temperatures during the spring time period under some flow and temperature combinations and is likely underrepresenting the benefits of some of the scenarios evaluated. These observations suggest that SalSim functions should be updated to better respond to temperature and floodplain conditions.

These SalSim limitations were not unexpected. The developers of SalSim described in their documentation of SalSim (CDFW 2014) that their "ability to estimate average rates as a function of environmental variation, the key factors being local flow and temperature variables of the river system, is limited by the availability and accuracy of relevant existing empirical data".

Although SalSim's response to potential temperature and floodplain improvements appears to be conservative in nature, model runs by State Water Board staff were informative. Along with our separate temperature analyses, this model helped to evaluate the tradeoffs that are present in water management decisions. Specifically, the model enumerated tradeoffs between the needs of different life stages in the fall time period versus the spring time period. The use of this model informs some of the concepts behind the flow shifting paradigms that may occur through adaptive implementation.

## Executive Summary of SalSim

The following executive summary was provided in CDFW's (2014) SalSim documentation:

> "SalSim is a life-history population simulation model for fall-run Chinook salmon originating from the San Joaquin River (SJR) and its upper three east-side salmon bearing tributaries (Stanislaus, Tuolumne, and Merced Rivers). Additionally, SalSim includes functionality for simulating the SJR below Friant Dam. This functionality is currently inactive relative to salmon production due to salmon paucity, but can be activated when that part of the river system begins producing salmon. SalSim does model this portion of the river system's temperatures as a function of flow, storage and meteorological conditions.
>
> The primary objectives of SalSim are to provide a modeling tool that will:
>
> - Serve as a decision support tool for CDFW, regulators and water managers as they seek to restore fall-run Chinook salmon in the SJR Basin;
> - Be used to identify, establish, and evaluate instream flow levels (both in-tributary and mainstem) necessary to enhance habitat conditions for fall-run Chinook salmon;
> - Have broad scientific community acceptance;
> - Have broad management utility and confidence;
> - Be useable by a variety of interested users; and
> - Be fully transparent.
>
> SalSim is essentially three models functioning together as one overall model. The three sub-models include:
>
> - A water operations model that accounts for water movement into and out of the lower rim dam reservoirs on the mainstem SJR (Friant) and the principal east-side tributaries including the Stanislaus River (New Melones), the Tuolumne River (New Don Pedro), and the Merced River (New Exchequer).
> - A water temperature response model that predicts reservoir release temperatures as a function of reservoir storage, ambient air temperature and release patterns. The model predicts water

temperature responses for the lower reaches of each tributary and the entire mainstem of the SJR from Friant downstream to Mossdale.

- A salmon production model, which predicts salmon abundance beginning with the egg stage and extending through the entire salmon life cycle to adults returning inland to spawn 2 to 4 years later.

SalSim is intended as a user-friendly web-based application. Users can interactively perform simulation runs for different water management scenarios, view results on the screen (GUI output) and then download results for further analysis using third party software, such as, HEC-DSS (USACE Data System Storage) and Excel (via CSV output files).

SalSim can also use external data generated by other basin-wide operational and/or water temperature models such as CALSIM II and the San Joaquin River Basin-wide Water Temperature Model (a.k.a. HEC-5Q)".

## Model Use Advisory Issued by the Developers

The following model use advisory was provided in CDFW's (2014) SalSim documentation:

"The SalSim model development team includes this advisory in order to provide clear direction in the use of SalSim. There are two overarching concerns we address below to moderate model user's expectations. The first precaution in SalSim's use is that SalSim, as with all models that have some mechanistic components, is an idealization of the processes occurring at a particular spatial and temporal scale: in SalSim's case that scale pertains to estimating daily growth, mortality, and movement rates. Further, our ability to estimate average rates as a function of environmental variation, the key factors being local flow and temperature variables of the river system, is limited by the availability and accuracy of relevant existing empirical data. In our opinion, given the limitations of these data, SalSim represents best modeling practices and, hence, the best available science for modeling the impacts of localized temperature and flow effects on the outmigrating SJR fall-run Chinook salmon. If the model user wants to modify the system to see a resulting average change in salmon production, currently there is no better tool available to perform this task.

The second precaution in SalSim's use is that the parameters in SalSim are fitted using a "backcasting" approach and hence SalSim should not been seen as a model that is optimized for providing the most accurate possible forecasts. Rather, SalSim has been constructed as a tool to explore and compare scenario's and provide insights to answering "what if …?" questions. That is, SalSim allows the model user to change historical conditions, as represented in the model, in order to assess the response in the system that is most likely to occur. Put another way, SalSim should not be considered an accurate predictor of future salmon populations because, i) there are too many variables that cannot be reliably forecasted (i.e. future year ocean conditions and/or water year types, etc.) and ii) the underlying empirical data used to build SalSim has a considerable unexplained variability due to the absence of information on the availability of relevant factors (e.g. local availability of food for local populations), the use of laboratory rather than field data to estimate certain effects such as temperature effects on mortality and inherent variability itself in the measured environmental data (e.g. local flow is an average and cannot account for side-eddies and highly localized pools). That a full life cycle model has a high level of unexplained variability for an animal inhabiting such a diverse geographic life history spanning three ecosystems (i.e. inland, delta, and ocean) is to be expected.

SalSim model developers fully understand that it is important to bound model predictions to frame uncertainty in a formal way. This has not yet been developed for SalSim predictions due to time and funding limitations. This, along with formal model parameter sensitivity assessment to refine the variance-bias trade-off in identifying the appropriate number of variables to include in a simulation model, is planned for future model versions pending funding availability. Despite this shortcoming, the model developers firmly believe that SalSim is nonetheless the best available tool to inform SJR fall-run Chinook salmon management decision making with the understanding that the results are couched in terms of what would be expected on average even though extremes (i.e. higher than or lower than) might occur given the unexplained variability present in existing empirical data used to build SalSim. This type of situation where management decisions are made despite considerable uncertainties in the data is common in public health issues, such as analyses involving infectious diseases and vaccines, etc. Thus data uncertainty should not be used as an excuse not to use SalSim or to make management decisions.

It is worth noting that SalSim was not created in a vacuum. Rather, available empirical data combined with expert opinion and use of industry accepted (i.e. well established and proved) mathematical and statistical procedures and formulations coupled with formal peer review were used to build a state-of-the-art simulation model. SalSim predicts salmon population response given a suite of physical (abiotic) and biological (biotic) factors to visualize what would occur on average in the future if, and only if, the past were perfectly replicated in the future absent those changes the model user chooses to make.

Despite these model use precautions, SalSim developers are confident that the results arising from model runs represent on average what is most likely to happen if the defined environmental conditions that the model user chose had actually occurred. However, individual year nuances that are unforeseen cannot be accounted for in SalSim. Thus, it is important for model users to understand that SalSim results represent “on-average” conditions given the underlying likelihood survival probabilities occur that were developed per the empirical data available at the time of SalSim development.

A question arises in how to interpret various scenarios where the user conducts several runs making incremental changes in the system. It is not our intention that model runs be compared in terms of the specific number of salmon produced. Rather, various scenarios should be compared more broadly by looking at the percentage change in annual salmon production (foremost would be the percent change in adults and secondary would be the percent change in juveniles produced by each tributary, then total juveniles reaching the Delta, then entering the ocean). This analysis would be more of a qualitative evaluation versus a strictly quantitative comparison.

In summary, SalSim represents the best scientific tool available, gives both a qualitative and quantitative understanding of salmon life history and the underlying physical and biological systems influencing salmon production, and use of SalSim is substantially more reliable than making uninformed (i.e. uneducated) guesses about what would be expected to happen on average if the physical environment were changed from that which existed historically. This type of “backcasting” modeling is consistent with the philosophy employed by other widely used simulation models, such as CALSIM II, HEC-5Q, DSM2, to name a few. The idea is that by learning from the past we could better plan for the future.

Thus the State Board, and/or other management making decision bodies, are urged to use SalSim both to better inform present decision making and to inform decisions on how best to collect data in the future to get the most “bang for the buck” from the new information that is collected.”

## 19.4.2 Methods of State Water Board SalSim Evaluation

The State Water Board used SalSim to explore and compare a variety of flow scenarios in order to assess the response of fall-run Chinook salmon production from the Stanislaus, Tuolumne, and Merced Rivers that may have occurred if these different flow scenarios were implemented in the past. For this evaluation, total adult salmon production (defined below) was used as the primary comparative metric between each of the flow scenarios. To inform the iterative process of testing different scenarios other metrics such as egg production, egg survival, juveniles leaving each tributary, and juvenile survival were used to inform subsequent scenarios.

The following method subsections provide additional details regarding the inputs and outputs used for the State Water Board SalSim modeling runs and evaluation.

# Methods: Flow and Temperature Inputs to SalSim

Flow and temperature inputs used in the State Water Board's SalSim runs can be organized in two basic categories: 1) inputs to SalSim that came from modeling used in the SED evaluation, and 2) inputs generated specifically for SalSim flow shifting scenarios. The following subsections describe the differences in temperature and flow inputs used for these SalSim runs.

## (1) Inputs from flow and temperature modeling as used in the SED

### SED Flow Modeling

The State Water Board developed the WSE model to simulate the baseline and LSJR alternatives for water years 1922-2003 and to determine the effects on reservoir operations, water supply diversions, and river flow for each of the eastside tributaries (Stanislaus, Tuolumne, and Merced Rivers) and flow and salinity at Vernalis on the SJR. The scientific basis for the WSE model is described in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*, and the detailed methods and results for the LSJR alternatives are presented in Appendix F.1, *Hydrologic and Water Quality Modeling*. The WSE model was used to inform the SED to analyze project effects in accordance with CEQA requirements.

The WSE modeling runs which were used in the SED and in SalSim are referred to as unimpaired flow runs in the following SalSim sections, and are labeled SB20%UF for example for the 20% unimpaired flow run. This is to distinguish those scenarios from other scenarios where further consideration was given to temperature, flow, and storage to optimize adult salmon production. These additional modeling runs are referred to as flow shifting runs, and are described below in more detail.

### SED Temperature Modeling

To model effects on temperature in the LSJR and three eastside tributaries for the SED, the State Water Board used the San Joaquin River Basin-Wide Water Temperature and EC Model (shorthand used here is SJR HEC-5Q model or temperature model) developed by a group of consultants between 2003 and 2008 through a series of CALFED contracts that included peer review and refinement (CALFED 2009). The temperature model was most recently updated by the CDFW and released in June of 2013 (CDFW 2013b).

The temperature model uses the Hydrologic Water Quality Modeling System (HWMS-HEC5Q), a graphical user interface that employs HEC-5Q, the USACE HEC flow and water quality simulation model, to model reservoir and river temperatures subject to historical climate conditions and user defined operations. The temperature model was designed to provide a SJR Basin-wide evaluation of temperature response at 6-hour intervals for alternative conditions, such as operational changes, physical changes, and combinations of the two. The extent of the model includes the Merced, Tuolumne, and Stanislaus River systems from their LSJR confluences to the upstream end of their major reservoirs (i.e., McClure, Don Pedro, and New Melones, respectively). The upstream extent of the model on the LSJR is the Merced River confluence. The downstream extent of the model is the LSJR at Mossdale. The model simulates the reservoir stratification, release temperatures, and downstream river temperatures as a function of the inflow temperatures, reservoir geometry and outlets, flow, meteorology, and river geometry. Calibration data was used to accurately simulate temperatures for a range of reservoir operations, river flows, and meteorology.

The temperature model interfaces with CALSIM (see Appendix F.1, *Hydrologic and Water Quality Modeling*) or monthly data formatted similarly to CALSIM output. A pre-processing routine converts the monthly output to a format compatible with the SJR HEC-5Q model. This routine serves two purposes: 1) to allow the temperature model to perform a long-term simulation compatible with the period used in CALSIM II, and 2) to convert monthly output to daily values used in the temperature model.

Using the monthly output from the WSE model (see Appendix F.1), the "CALSIM to HEC-5Q" temperature model pre-processor was used by the State Water Board, and the temperature model was run to determine the river temperature effects of different flow scenarios within the Stanislaus, Tuolumne, Merced, and Lower San Joaquin Rivers. The temperature model was run for the period 1970 through 2003, a period with sufficient length and climatic variation to determine the effects of the LSJR alternatives on river temperatures.

The HEC-5Q modeling outputs that were used for the State Water Board's SED evaluation were used as SalSim inputs for the unimpaired flow runs.

## (2) Flow Modeling Modifications for the Purposes of SalSim

There are three additional flow and temperature modeling steps that were performed for the purpose of evaluating SalSim scenarios. First the WSE model was extended to run through 2010. Second, a scenario was evaluated where 25% of the February through June flow requirement water was shifted to other times of the year. Third, the temperature operations function in the temperature model (see CDFW 2013b: Appendix B, *System Operation for Temperature Control*) was used to set temperature and flow targets during all times of the year, and water from the February through June flow requirement could be used to try to meet these targets. For each of these modifications, all other constraints such as existing regulatory requirements, diversions, and end of year storage remained in effect as described in the WSE model. These three modeling steps are described below.

### Extending the WSE Model

As described above, the State Water Board's WSE model operates from 1922 to 2003. SalSim is designed to operate from 1994 to 2010. To make full use of SalSim, the WSE model period was extended through 2010. This was accomplished by using the historical reservoir inflows, and estimated monthly data for downstream local inflows, return flows, and water supply diversions, using CALSIM inputs from years with similar hydrology (Table 19-31; also see Chapter 21, *Drought Evaluation*). Output parameters, such as diversions and flows, were then calculated within the WSE model as described in Appendix F.1, *Hydrologic and Water Quality Modeling*.

**Table 19-31. Surrogate years that were used to extend the WSE model for the 2004 to 2010 time period**

| Water Year | Surrogate Year |
|---|---|
| 2004 | 1972 |
| 2005 | 1980 |
| 2006 | 1998 |
| 2007 | 1994 |
| 2008 | 1930 |
| 2009 | 1971 |
| 2010 | 1973 |

#### Shifting 25% of the February through June Flow Requirement

As described in the SED, the proposed project allows for adaptive implementation actions that could shift a portion of the required February through June unimpaired flows to other times of the year to prevent adverse effects to fisheries, including temperature. To test the effect of shifting part of the annual water requirement for LSJR Alternative 3 (40% unimpaired flow) to other times of the year, a SalSim run (called SB40%MaxFS) was completed for this report which shifted 25% of required unimpaired flow to the months of September through December. Of the water that was shifted, 15% was shifted to September, 20% was shifted to October, 25% was shifted to November, and 40% was shifted to December (to total 100% of the shifted water). All rivers and water year types were treated the same. Within each month the shifted flow was distributed evenly for each day. Surface water supply allocations were calculated in the WSE model based on start of October storage that did not include the shifted water. This flow shifting modeling scenario was only done for the 40% unimpaired flow alternative.

#### Shifting Based on Defined Temperature and Flow Targets

As discussed above, the temperature model has a temperature operations function (see CDFW 2013b: Appendix B, *System Operation for Temperature Control*) which has the capability of operating the reservoirs to try to meet downstream temperature and flow targets. A SalSim modeling run (called SB40%OPP) was made using inputs from a temperature operations run made in the temperature model. This temperature operations run was used to determine if further refined temperature and flow management scenarios, compared to the unimpaired flow SED runs, resulted in improved salmon production in SalSim. The 40% unimpaired flow SED run (LSJR Alternative 3), and the 40% temperature operation run, both used the same volumes of water annually for fish benefit purposes, which is equal to the percent of unimpaired flow objective (40%) during the February through June time period. The SED run primarily allocates the "fish benefits water" during the February through June time period as described in Appendix F.1, *Hydrologic and Water Quality Modeling*. On the other hand, the temperature operations run treats the "fish benefits water" as a bank account and allocates it to meet temperature targets and flow constraints throughout the entire year. Diversions and end of year storage remained the same between the 40% temperature operations run and the 40% unimpaired flow SED run. However, other assumptions like State Water Project and Central Valley Project exports, and flow entering the Stockton Deep Water Ship Channel, were recalculated according to the standard WSE model and SalSim procedures.

The temperature targets and the flow constraints used in the temperature operations run are shown in Attachment 2.

### Methods: SalSim Evaluation Criteria

For this evaluation, changes in annual SJR Basin (Stanislaus, Tuolumne, and Merced Rivers) total adult salmon production was used as the primary comparative metric. This metric includes annual SRJ Basin produced commercial and recreational harvest, annual SJR Basin produced salmon that stray out of basin as adults, and annual total SJR Basin produced escapement (hatchery and in-river). This metric does not include adult strays that come into the basin from other watersheds, because it is a set number in SalSim for each year that does not change based on the scenario. To inform the iterative process of testing different scenarios other metrics such as egg production, egg survival, juveniles leaving each tributary, and juvenile survival were used to inform subsequent scenarios.

## 19.4.3 Results of the SalSim Evaluation

The SalSim results for the unimpaired flow cases (as used in the SED analysis) and the two 40% flow shifting cases indicate that as percent of unimpaired flow is increased, annual average total adult salmon production would have also increased during the 1994 to 2010 time period (Figure 19-13, Figure 19-14, and Table 19-32).

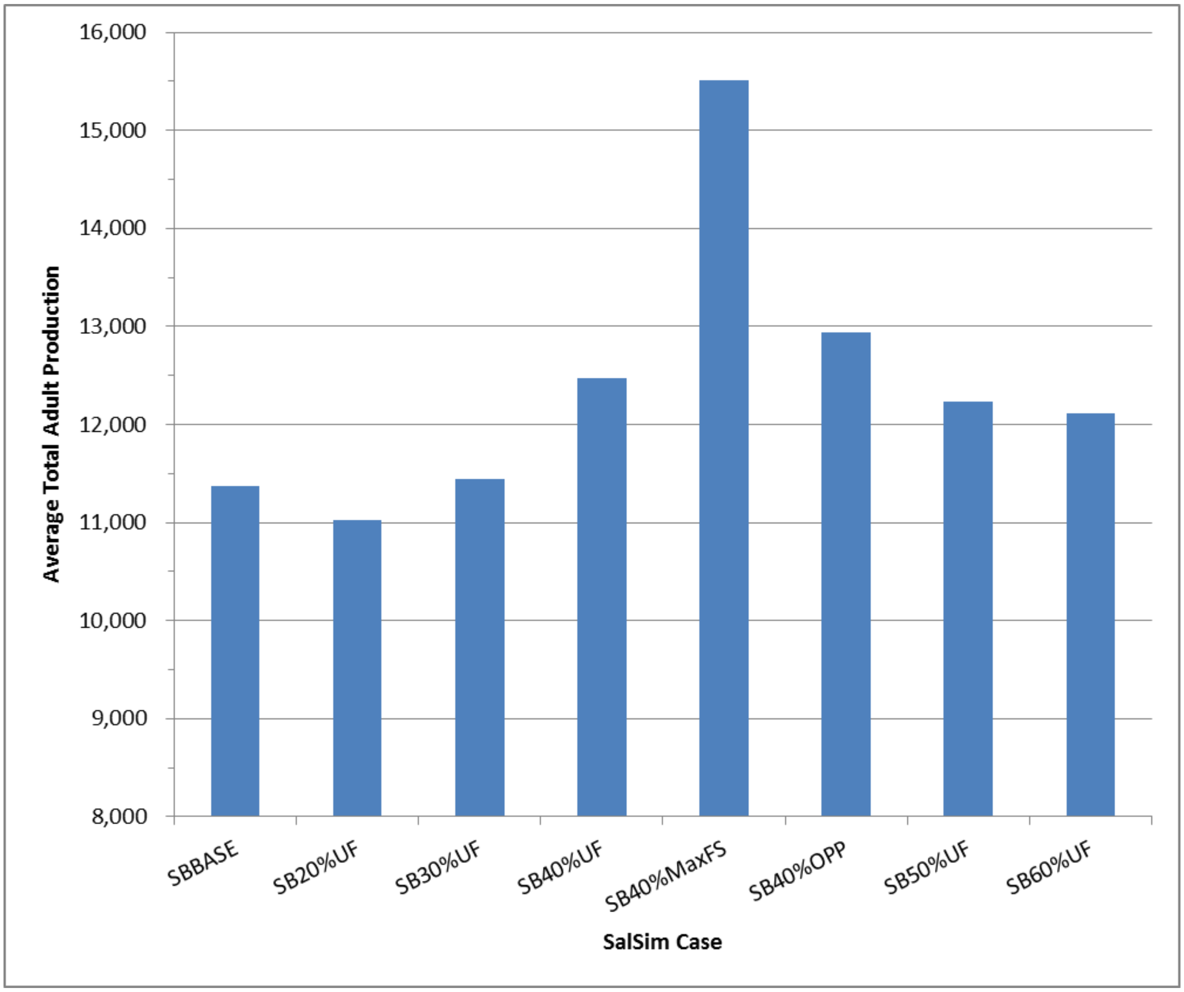


**Figure 19-13. SalSim average total adult fall-run Chinook salmon production per year from 1994 to 2010 resulting from different flow cases. These results are the combined results for the Stanislaus, Tuolumne, and Merced Rivers.**

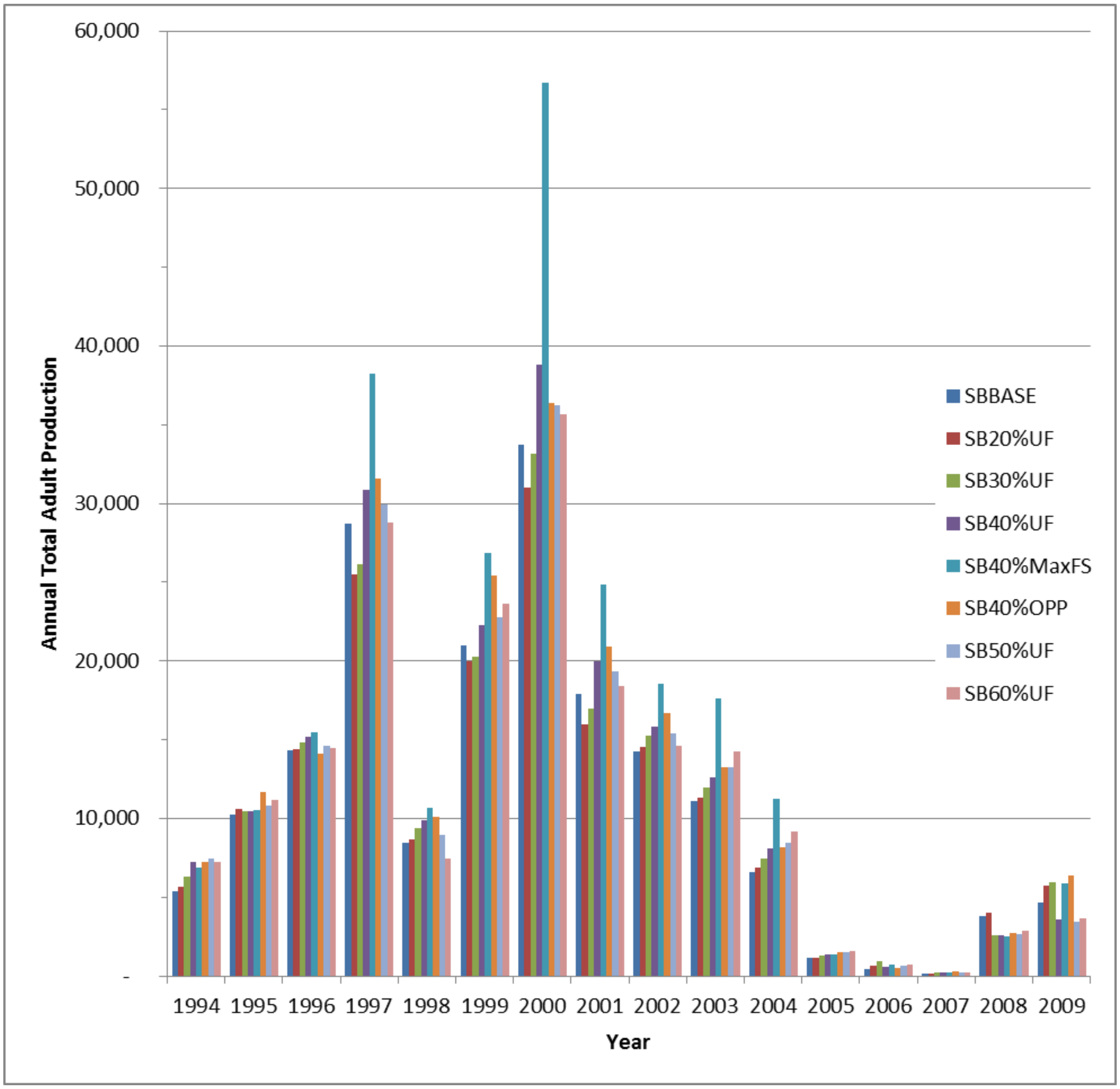


**Figure 19-14. SalSim annual total adult fall-run Chinook salmon production from 1994 to 2010 resulting from different flow cases. These results are the combined results for the Stanislaus, Tuolumne, and Merced Rivers.**

**Table 19-32. SalSim Annual Total Adult Fall-Run Chinook Salmon Production for Different Flow Cases. These results are the combined results for the Stanislaus, Tuolumne, and Merced Rivers, and are also illustrated in Figure 19-14.**

| SalSim Case | Total Adult Production by Year | | | | | | | | | | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | |
| SBBASE | 5,365 | 10,250 | 14,328 | 28,745 | 8,433 | 21,001 | 33,753 | 17,892 | 14,289 | 11,075 | 6,613 | 1,129 | 461 | 161 | 3,812 | 4,665 | **11,373** |
| SB20%UF | 5,696 | 10,571 | 14,407 | 25,499 | 8,685 | 19,983 | 30,996 | 16,007 | 14,507 | 11,349 | 6,850 | 1,173 | 680 | 169 | 4,008 | 5,755 | **11,021** |
| SB30%UF | 6,334 | 10,460 | 14,843 | 26,121 | 9,357 | 20,253 | 33,125 | 16,984 | 15,289 | 11,983 | 7,436 | 1,278 | 952 | 185 | 2,587 | 5,922 | **11,444** |
| SB40%UF | 7,213 | 10,484 | 15,170 | 30,888 | 9,872 | 22,289 | 38,824 | 19,996 | 15,801 | 12,613 | 8,072 | 1,392 | 579 | 216 | 2,594 | 3,611 | **12,476** |
| SB40%MaxFS | 6,843 | 10,540 | 15,474 | 38,226 | 10,704 | 26,833 | 56,691 | 24,875 | 18,557 | 17,604 | 11,252 | 1,332 | 693 | 194 | 2,499 | 5,870 | **15,512** |
| SB40%OPP | 7,212 | 11,664 | 14,106 | 31,598 | 10,122 | 25,432 | 36,359 | 20,923 | 16,689 | 13,248 | 8,198 | 1,479 | 489 | 323 | 2,696 | 6,399 | **12,934** |
| SB50%UF | 7,462 | 10,791 | 14,632 | 29,908 | 8,959 | 22,803 | 36,206 | 19,362 | 15,411 | 13,252 | 8,486 | 1,517 | 671 | 219 | 2,681 | 3,460 | **12,239** |
| SB60%UF | 7,229 | 11,162 | 14,441 | 28,770 | 7,473 | 23,601 | 35,632 | 18,404 | 14,633 | 14,258 | 9,158 | 1,575 | 723 | 204 | 2,834 | 3,677 | **12,111** |

The results of this SalSim evaluation indicate that improving flow conditions during the spring time period with consideration for the fall time period can produce increases in average annual total adult production from the three eastside SJR tributaries during the 1994 to 2010 modeling period. It is important to read the summary section below with respect to what the results mean during this time period. The increases in total adult production can be further improved with refined flow, reservoir storage, and temperature management as shown with the two flow shifting scenarios that were evaluated. It is expected that further refinement of flow, reservoir storage, and temperature management for the 50% and 60% cases would produce increases in total adult production that exceed those that resulted from the 40% flow cases.

## 19.4.4 Summary and Conclusions of the SalSim Evaluation

The use of SalSim has provided insight into what may have happened in the past if water was managed differently. It is important to understand the SalSim tool when considering what the results mean. Particularly, it is important to understand the limitations of SalSim, and it is important to understand the limitations of making optimized temperature and flow modeling runs and then inputting those flow and temperature results into SalSim.

### Limitations of SalSim

All models have limitations and uncertainty. Physically based models like temperature and flow models provide a much greater lever of certainty when compared to biological models like SalSim. Modeling living organisms which have complex behaviors, and experience multi-layered ecological interactions, is a difficult task. As complicated as biological modeling is, the SalSim model appears to generally represent expected patterns. However, SalSim is inherently limited in that it does not have perfect equations (as discussed above) to explain how each environmental variable affects growth, movement, survival, and reproduction of fall-run Chinook salmon. Additionally, it is important to understand that the first 4 years of adult production are priming years, meaning that the juvenile fish from brood year 1994 do not start returning as adults until 1996, 1997, and 1998 as 2-, 3-, and 4-year-old fish, respectively. Therefore, the 1994, 1995, 1996, and 1997 adult returns do not represent a complete comparative result between baseline and the flow cases that were evaluated. Furthermore, ocean crash years which are represented in SalSim affect total adult production from 2005 to 2009 (see CDFW's Table 24 and discussion in CDFW 2014), and appear to force adult production down to approximately the same very low number regardless of the flow case. Whether this forced crash is realistic or not is unclear, because it is possible that changes to the timing, health, and abundance of smolts entering the ocean during those years could have affected how many salmon made it through that bottleneck of poor conditions. It is also possible that improved Delta outflow may have altered bay and nearshore ocean conditions in a way that improved salmon survival. Consequently, looking at a 7-year time period (1998 through 2004) to evaluate improvements to adult salmon production may be a better output instead of looking at the full 16-year SalSim time period. When this 7-year time period is evaluated, average total adult production improvements are greater (compared to the full 16-year time period) for all of the flow cases evaluated except for the SB20%UF case which makes even less fish compared to baseline. For example, the total adult production increases by 4,139 adult fish per year on average when comparing the SB40%MaxFS case to the SBBASE case for the entire 16-year period, but increases by 7,637 adult fish per year on average when comparing these cases for the 7-year period. Because this 7-year time period is so short, it becomes difficult to make inferences about what the results mean in terms of what to expect from improved flow conditions in the long term. It is likely that the increases in adult fish production during this - year modeled time period represent an increasing trend in adult production and do not represent a new long term average of expected increases in adult production into the future.

## Limitation of Optimizing Modeling Runs

The program of implementation for this project allows flow shifting within the February through June time period and also allows for some shifting of water outside of this time period. As modeled, the unimpaired SED flow cases are a representation of a requirement for a certain percentage of unimpaired flow during February through June with a small amount of that water shifted to the fall. In some cases, a percentage of an unimpaired flow event for example, may not be ideal for the ecosystem. However, with flow shifting it is possible to bank water and create the full benefit of certain critical flow and temperature events. The flow shifting cases that were evaluated (SB40%MaxFS and SB40%OPP) represent some shifting and optimizing of flow, and both of these cases improved fish production compared to the non-optimized 40% case. Although these cases represent some optimization, it is likely that real-time optimization on a year-to-year, month-to-month, or day-to-day basis, as is possible with adaptive management, would provide even better results in terms of salmon production. However, optimizing flows and water temperatures in order to optimize SalSim cases, requires optimizing 16 years of flow and temperature on 3 different rivers which equates to a total of 48 years of optimization. This can include trying to time flow and temperature benefits to times and locations that match the timing and movement of fish during individual years. In a real-world management scenario, this type of real-time management can be informed by fish monitoring data like rotary screw traps and passage weirs. Optimizing long-term models on this time scale presents significant challenges; therefore rules that favor salmon on average were used to try to improve the non-optimized 40% case. In a real-world scenario, we expect using “on average” rules that are then informed and slightly modified by real-time information, will provide further improvement than what is represented by the modeling cases shown in this report.

## History as a Predictor of the Future

The effectiveness of restoring the natural flow regime in a watershed was demonstrated by Kiernan et al. (2012) in lower Putah Creek where a new flow regime was implemented that mimics the seasonal timing of natural increases and decreases in streamflow. Monitoring of several sites pre- and post- implementation of the new flow regime showed a change in the distribution of the native fish community (Kiernan et al. 2012). At the onset of the study, native fishes were constrained to habitat immediately (<1 km) below the diversion dam, and non-native species were numerically dominant at all downstream sampling sites. Following implementation of the new flow regime, native fish populations expanded and regained dominance across more than 20 km of lower Putah Creek. The authors (Kiernan et al. 2012) proposed that expansion of native fishes was facilitated by creation of favorable spawning and rearing conditions (e.g., elevated springtime flows), cooler water temperatures, maintenance of lotic (flowing) conditions over the length of the creek, and displacement of alien species by naturally occurring high-discharge events.

In addition to the Putah Creek example, at least two real-world examples exist of salmon populations in the Central Valley responding substantially well to flow and non-flow restoration actions. These examples are Clear Creek and Butte Creek. Both of these tributaries to the Sacramento River underwent flow and non-flow restoration beginning in the 1990s, which resulted in dramatic population increases of Chinook salmon. On Butte Creek, the spring-run Chinook salmon estimated yearly natural adult production increased from an average of 1,018 adults per year between 1967 and 1991, to an average of 9,713 adults per year between 1992 and 2011 (USFWS 2013a). This increase in adult abundance occurred after a series of projects were implemented including small dam removals, fish ladder installations, fish screen installations, implementation of 40 cfs of dedicated instream flow from October 1 to June 30, and other flow and temperature management actions to reduce mortality to over-summering adult spring-run Chinook salmon. On Clear Creek, estimated yearly natural production of fall-run Chinook salmon increased from an average of 3,576 adults per year between 1967 and 1991, to an average of 10,685 adults per year between 1992 and 2011 (USFWS 2013a). This increase in adult abundance on Clear Creek occurred after a series of restoration actions were implemented including setting minimum instream flow and temperature targets resulting in significant flow increases throughout each year (CVPIA 2013).

Prior to European influence in California, it is estimated that adult spring-run and fall-run Chinook salmon escapement in the SJR drainage totaled in the hundreds of thousands of fish annually as an estimated lower bound (Yoshiyama et al 1998). In the Tuolumne River, fall-run Chinook salmon escapement has declined from approximately 130,000 adult salmon per year during the 1940s (Mesick 2009) to less than 500 adult salmon per year several times during the last few decades. On the Stanislaus, Tuolumne, and Merced Rivers between 1967 and 1991 (well after significant habitat modifications) there was an estimated average yearly natural production of 38,388 adult fall-run Chinook salmon that returned to spawn each year (USFWS 2013a). During the 1992 to 2011 time period there was an estimated average yearly natural production of 18,703 adult fall-run Chinook salmon that returned to spawn each year on these three rivers combined (USFWS 2013a) indicating continued declines of salmon during the last few decades.

### Final SalSim Summary

With the projected temperature and floodplain benefits during the spring time period (as indicated by modeling results in the previous sections of this chapter), and with adaptive implementation, it is expected that there will be substantial increases in fall-run Chinook salmon abundance on these tributaries from unimpaired flows at or greater than 40%. The SalSim results support this expectation, and because of the apparent conservative nature of SalSim, the results are likely a lower bound of potential salmon production increases that could have occurred during the SalSim evaluation time period. Finally, it is important to consider that many other native fish and wildlife species are expected to benefit from improved flow conditions during the February through June time period including other imperiled Bay-Delta species such as steelhead, sturgeon, and splittail.

# 19.5 Final Discussion of Benefits Analysis

Scientific evidence indicates that reductions in flows and alterations to the flow regime in the SJR Basin, resulting from water development over the past several decades, have negatively impacted fish and wildlife beneficial uses (see Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*). The SJR Basin once supported large spring-run and fall-run (and possibly late fall-run) Chinook salmon populations; however, the basin now only supports fall-run Chinook salmon populations, and these populations are facing a high risk of extinction (Mesick 2009, 2010a, 2010b; Moyle 2002). Currently, the SJR Watershed accounts for approximately 5% of all fall-run Chinook salmon in the Central Valley, and a much smaller percentage of total salmon when winter-, spring-, and late fall-runs are included. The Stanislaus, Tuolumne, and Merced Rivers (individually or combined) have had larger reductions in the natural production of adult fall-run Chinook salmon than any of the other tributaries (or combination of three tributaries) to the Sacramento or San Joaquin Rivers when comparing the 1967-1991 and 1992-2011 time periods (USFWS 2013a). The existing low abundance and diversity of naturally spawning SJR Basin salmon and steelhead stocks increases the sensitivity of these stocks to natural disasters, long-term climate change, increasing human population, and other threats that could lead to extinction (Williamson and May 2005; Mesick 2009; Mesick 2010a; Mesick 2010b; Moyle et al. 2008; Lindley et al. 2009). One of the mechanisms of reducing extinction risk is to increase the number and distribution of viable populations within the historical range of the stocks, and to diversify population structures and life history attributes. For Central Valley fall-run Chinook salmon, Carlson and Satterthwaite (2011) suggested that the most effective means of achieving this would be to restore the SJR Basin populations.

One of the goals of the current Bay-Delta Plan update is to maintain flow conditions from the SJR Watershed to the Delta at Vernalis, sufficient to support and maintain the natural production of viable native SJR Watershed fish populations migrating through the Delta. The State Water Board proposes to use a percentage of unimpaired flow to restore a more natural flow regime during February through June on the Stanislaus, Tuolumne, and Merced Rivers to achieve this goal.

This chapter has presented biologically important and measurable benefits of providing higher and more variable flows during this time period using predicted effects to key evaluation, or "indicator species." For this analysis, the indicator species used were Central Valley fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley steelhead (*Oncorhynchus mykiss*). It is anticipated that habitat benefits relative to the indicator species will also provide habitat benefits to other native fish species, including other imperiled Bay-Delta species such as sturgeon and splittail. The results of the temperature, floodplain, and SalSim analysis presented in this chapter indicate that as the percentage of unimpaired flow is increased during the February through June time period, the flow related benefits to salmon and steelhead also increase. Further, as discussed in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*, there are likely to be many additional benefits (other than temperature and floodplain) that would result from improved flow conditions in these rivers. Improving flows that mimic the natural hydrographic conditions including related temperature and floodplain regimes to which native fish species are adapted, are expected to provide many juvenile salmonids with additional space, time, and food resources which are necessary for required growth, development, and survival. Extending spatial, temporal, and nutritional opportunities available to juvenile fall-run Chinook salmon and steelhead in the Stanislaus, Tuolumne, and Merced Rivers is expected to improve abundance, productivity, diversity, and spatial structure of the SJR Basin and Central Valley populations. Improving and maintaining these important population attributes should help buffer SJR Basin and Central Valley salmon and steelhead populations from catastrophic events and conditions in the future.

Although increasing flow and providing a more natural flow regime is expected to provide substantial and necessary benefits to native fishes; flow alone cannot solve the many issues that native fish populations face in the SJR Watershed. To reach the goal of achieving and maintaining viable populations of native fish, many other non-flow actions (see Program of Implementation as described in Appendix K, *Revised Water Quality Control Plan*) must be taken. For example, large scale habitat restoration should be completed. Additionally, California's coldwater fish species require cold water, and there should be considerable effort put forth to efficiently provide cold water downstream of California's reservoirs, and to provide migratory fish access to the cold water above these reservoirs. Improved coldwater management and infrastructure will improve California's native fish populations and may save water compared to the current coldwater management and dam infrastructure.

# 19.6 References Cited

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

Anadromous Fish Restoration Program (AFRP). 2005. *Recommended streamflow schedules to meet the AFRP doubling goal in the San Joaquin River Basin*. September 27.

Arthington, A. H., J. M. King, and J. H. O'Keffe. 1992. Development of an Holistic Approach for Assessing Environmental Flow Requirements of Riverine Ecosystems. Pages 69–76 in J. J. Pigram, and B. P. Hooper (editors). *Proceedings of an International Seminar and Workshop on Water Allocation for the Environment*. Centre for Water Policy Research: University of New England.

Arthington, A. H., R. E. Tharme, S. O. Brizga, B. J. Pusey, and M. J. Kennard. 2004. Environmental Flow Assessment with Emphasis on Holistic Methodologies. Pages 37–65 in R. Welcomme and T. Petr' (editors). *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II.* RAP Publication 2004/17. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. Available: http://www.fao.org/docrep/007/ad526e/ad526e07.htm

Baker, P. F., T. P. Speed, and F. K. Ligon. 1995. Estimating the influence of temperature on the survival of chinook salmon smolts (*Oncorhynchus tshawytscha*) migrating through the Sacramento-San Joaquin River Delta of California. *Canadian Journal of Fisheries and Aquatic Sciences* 52:855–863.

Barbour M. G., W. B. Billings. 1988. North American Terrestrial Vegetation. Cambridge, NY: University Press. As cited in J. J. Opperman, 2012. A Conceptual Model for Floodplains in the Sacramento-San Joaquine Delta. *San Francisco Estuary and Watershed Science* 10(3).

Bartholow, J., R. B. Hanna, L. Saito, D. Lieberman, and M. Horn. 2001. Simulated Limnological Effects of the Shasta Lake Temperature Control Device. *Environmental Management* 27(4):609–626.

Bayley, P. B. 1991. The flood pulse advantage and the restoration of river-floodplain systems. *Regulated Rivers: Research and Management* 6:75–86.

Bellmore, J. R., C. V. Baxter, K. Martens, and P. J. Connolly. 2013. The Floodplain Food Web Mosaic: A Study of its Importance to Salmon and Steelhead with Implications for their Recovery. *Ecological Applications* 23(1):189–207.

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

Bonada, N., S. Dole´dec, and B. Statzner. 2007. Taxonomic and biological trait differences of stream macroinvertebrate communities between mediterranean and temperate regions: implications for future climatic scenarios. Global Change Biology 13:1658–1671. In J. D. Kiernan, P. B. Moyle, and P. K. Crain. 2012. Restoring Native Fish Assemblages to a Regulated California Stream Using the Natural Flow Regime Concept. *Ecological Applications* 22(5):1472–1482.

Bond, M. H., S. A. Hayes, C. V. Hanson, and R. B. MacFarlane. 2008. Marine Survival of steelhead (*Oncorhynchus mykiss*) enhanced by a seasonally closed estuary. *Canadian Journal of Fisheries and Aquatic Sciences* 65:2242–2252.

Brandes, P. L., and J. S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In R. L. Brown (editor). Contributions to the biology of Central Valley salmonids. Volume 2. *California Department of Fish and Game Fish Bulletin* 179:39–136.

Brown, L. R., and M. L. Bauer. 2009. *Effects of Hydrologic Infrastructure on Flow Regimes of California's Central Valley Rivers: Implications for Fish Populations*. River Research and Applications. DOI: 10.1002/rra.1293.

Bunn, S. E., and A. H. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. *Environmental Management* 30(4):492–507.

Cain, J. R., J. Opperman, and M. Tompkins. 2010. *Testimony of John R. Cain, Dr. Jeff Opperman, and Dr. Mark Tompkins.* Sacramento and San Joaquin Flows, Floodplains, Other Stressors, and Adaptive Management.

CALFED. 2008. *Sacramento River Ecological Flows Study: Final Report*. Prepared by The Nature Conservancy, Stillwater Sciences, and ESSA Technologies. Prepared for CALFED Ecosystem Restoration Program, Sacramento, CA. 72 pp.

———. 2009. *San Joaquin River Basin Water Temperature Modeling and Analysis*. Prepared for CALFED ERP-06D-S20. Prepared by AD Consultants, Resource Management Associates, Inc. and Watercourse Engineering, Inc. Available: http://www.rmanet.com/CalFed_Sep09/%20SJRTempModelReport_09.pdf.

California Department of Fish and Game (CDFG). 2001. *Lower Tuolumne River Fall Run Chinook Salmon Escapement Survey 2001*. Reference ID 90770.

———. 2002. *Merced River Fall Chinook Salmon Escapement Survey.* Reference ID 90766.

———. 2005a*. California Department of Fish and Game Supplemental Comments and Recommendations on the Vernalis Flow and Salmon Doubling Objectives in the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin River Delta Estuary*.

———. 2005b. *San Joaquin River Fall-Run Chinook Salmon Population Model*. Final Draft. November 28.

———. 2010a. *Effects of Water Temperature on Anadromous Salmonids in the San Joaquin River Basin.*

———. 2010b. *Effects of Delta Inflow and Outflow on Several Native, Recreational, and Commercial Species.*

California Department of Fish and Wildlife (CDFW). 2013a*. SalSim: Salmon Simulator As Implemented for the San Joaquin River System*. User's Manual.

———. 2013b. *San Joaquin River Basin-Wide Water Temperature and EC Model*. June. Prepared for Department of Fish and Wildlife.

———. 2014. *SalSim: Salmon Simulator As Implemented for the San Joaquin River System*. SalSim-Documentation-2-20-14.

California Department of Water Resources (DWR). 1988. Water Temperature Effects on Chinook Salmon (Oncorhynchus tshawytscha), With Emphasis on the Sacramento River; A Literature Review. January 1988.

———. 2013. Technologies for Passing Fish at Large Dams.

California Natural Resource Agency (CNRA). 2010. *State Of The State's Wetlands: 10 Years Challenges and Progress.* 42 pp.

Carlisle, D. M., M. R. Meador, T. M. Short, C. M. Tate, M. E. Gurtz, W. L. Bryant, J. A. Falcone, and M. D. Woodside. 2013*. The quality of our Nation's waters - Ecological health in the Nation's streams, 1993-2005.* U.S. Geological Survey Circular 1391. 120 pp. Available: http://pubs.usgs.gov/circ/1391/.

Carlson, S. M, and W. H. Satterthwaite. 2011. Weakened Portfolio Effect in a Collapsed Salmon Population Complex. *Canadian Journal of Fisheries and Aquatic Sciences* 68:1579–1589.

Caywood, M. L. 1974. *Contributions to the life history of the Splittail* Pogonichthys macrolepidotus *(Ayres)*. Unpublished master's thesis, California State University, Sacramento.

Cbec. 2010*. San Joaquin Floodplain inundation mapping.* Memorandum. Cbec, Inc, Sacramento, CA. Page 24 in Appendix 4 of Comments pertaining to the "Scientific Basis for Developing Alternate San Joaquin River Delta Inflow Objectives" described in the State Water Resources Control Board's October 29, 2010, Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives. Prepared for the San Joaquin River Group Authority. December 6.

Clarke, W. C., and J. E. Shelbourn. 1985. Growth and Development of Seawater Adaptability by Juvenile Fall Chinook Salmon (*Oncorhynchus tshawytscha*) in Relation to Temperature. *Aquaculture* 45:21–31.

Cooperman M. S., S. G. Hinch, G. T. Crossin. 2010. Effects of experimental manipulations of salinity and maturation status on the physiological condition and mortality of homing adult sockeye salmon held in a laboratory. *Physiological and Biochemical Zoology* 83:459–472.

Cramer Fish Sciences (CFS). 2006. *Analyses of Rotary Screw Trap Sampling of Migrating Juvenile Chinook Salmon in the Stanislaus River, 1996-2006*. Brian Pyper and Casey Justice.

———. 2007a. *Upstream Fish Passage at a Resistance Board Weir Using Infrared and Digital Technology in the Lower Stanislaus River, California*. 2006-2007 Annual Data Report. Prepared for U.S. Fish and Wildlife Service.

———. 2007b. *Out-migrant Abundance Estimates and Coded Wire Tagging Pilot Study for Juvenile Chinook Salmon at Caswell Memorial State Park in the Lower Stanislaus River, California*. 2007 Annual Data Report.

Central Valley Project Improvement Act (CVPIA). 2013. *Draft CVPIA Fiscal Year 2014 Annual Work Plan*. April 28.

Ferguson, H. W. 1981. The effects of water temperature on the development of Proliferative kidney disease in rainbow trout, *Salmo gairdneri* Richardson. *Journal of Fish Diseases* 4(2):175–177.

FISHBIO. 2007. *Outmigrant Trapping of Juvenile Salmonids in the Lower Tuolumne River, 2006*. Last revised: March.

Fleenor, W., W. Bennett, P. B. Moyle, and J. Lund. 2010. *On Developing Prescriptions for Freshwater Flows to Sustain Desirable Fishes in the Sacramento-San Joaquin Delta*. Submitted to the State Water Resources Control Board Regarding Flow Criteria for the Delta Necessary to Protect Public Trust Resources. 43 pp.

Florida Administrative Code. 2010. *Rule 40D-8.041*. August 2.

Ford, T., and S. Kirihara. 2010*. Tuolumne River* Oncorhynchus mykiss *Monitoring Report*. Prepared by Turlock Irrigation District and Modesto Irrigation District, Turlock, CA and Modesto, CA, and Stillwater Sciences, Berkeley, CA. Prepared for Federal Energy Regulatory Commission, Washington, D.C.

Fritts, A. L., and T. N. Pearsons. 2006. Effects of Predation by Nonnative Smallmouth Bass on Native Salmonid Prey: the Role of Predator and Prey Size. *Transactions of the American Fisheries Society* 135:853–860.

Gasith, A., and V. H. Resh. 1999. Streams in Mediterranean climate regions: abiotic influences and biotic responses to predictable seasonal events. Annual Review of Ecology and Systematics 30:51–81. In J.D. Kiernan, , P.B. Moyle, and P. K. Crain. 2012. Restoring Native Fish Assemblages to a Regulated California Stream Using the Natural Flow Regime Concept. *Ecological Applications* 22(5): 1472–1482.

Gawlik, D. E. 2002. The effects of prey availability on the numerical response of wading birds. *Ecological Monographs* 72:329–346.

Gross M. R., R. M. Coleman, and R. M. McDowall. 1988. Aquatic productivity and the evolution of diadromous fish migration. *Science* 239:1291–1293.

Grosholz E., and E. Gallo. 2006. The influence of flood cycle and fish predation on invertebrate production on a restored California floodplain. *Hydrobiologia* 568:91–109.

Hallock, R. J., R. F. Elwell, and D. H. Fry Jr. 1970. *Migrations of adult king salmon* Oncorhynchus tshawytscha *in the San Joaquin Delta as demonstrated by the use of sonic tags*. The Resources Agency, Department of Fish and Game, CA. Fish Bulletin 151.

Healey, M. C. 1982. Timing and relative intensity of size-selective mortality of juvenile chum salmon during early sea life. Canadian Journal of Fisheries and Aquatic Sciences 39: 952–957. In United States Department of the Interior (DOI). 2010. *Exhibit 1: Comments regarding the California State Water Resources Control Board notice of public informational proceeding to develop Delta flow criteria for the Delta ecosystem necessary to protect public trust resources*. August.

Hirji, R., and R. Davis. 2009. *Environmental Flows in Water Resources Policies, Plans, and Projects: Findings and Recommendations*. The World Bank. 192 pp.

Jeffres, C. A., J. J. Opperman, and P. B. Moyle. 2008. Ephemeral Floodplain Habitats Provide Best Growth Conditions for Juvenile Chinook Salmon in a California River. *Environmental Biology of Fishes* 83: 449–458.

Junk, W. J., P. B., Bayley, and R. E. Sparks. 1989. The Flood Pulse Concept in River-Floodplain Systems. Special publication. *Canadian Journal of Fisheries and Aquatic Sciences* 106:110–127.

Katibah, E.F. 1984. A brief history of riparian forests in the Central Valley of California. In R. E. Warner, and K. M. Hendrix (editors). 1984. *California riparian system: ecology, conservation, and productive management.* Berkeley, CA: University of California Press. 23–28 pp.

Kiernan, J. D., P. B. Moyle, and P. K. Crain. 2012. Restoring Native Fish Assemblages to a Regulated California Stream Using the Natural Flow Regime Concept. *Ecological Applications* 22(5):1472–1482.

Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1981. Influences of Freshwater Inflow on Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin Estuary. In P. D. Cross, and D. L. Williams (editors). *Proceedings of the National Symposium on Freshwater Inflow to Estuaries*. 88–108 pp. U.S. Fish and Wildlife Service, FWS/OBS-81-04.

———. 1982. Life History of Fall-Run Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California. In V. S. Kennedy (editor), Estuarine comparisons, 393–411 pp. Academic Press, New York, NY.

Kjelson, M. A., and P. L. Brandes. 1989. The use of smolt survival estimates to quantify the effects of habitat changes on salmonid stocks in the Sacramento-San Joaquin Rivers, California. In C. D. Levings, L. B. Holtby, and M. A. Henderson (editors). Proceedings of the National Workshop on the Effects of Habitat Alteration on Salmonid Stocks. *Canadian Journal of Fisheries and Aquatic Sciences* 105:100–115.

Leitritz, E., and R. C. Lewis. 1976. *Trout and salmon culture*. California Department of Fish and Game. Fish Bulletin 164. 197 pp.

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

Lytle, D. A., and N. L. Poff. 2004. Adaptation to Natural Flow Regimes. *Trends in Ecology and Evolution* 19:94–100.

Marchetti, M. P., and P. B. Moyle. 2001. Effects of Flow Regime on Fish Assemblages in a Regulated California Stream. *Ecological Applications* 11:530–539.

Marine, K. P., and J. J. Cech Jr. 2004. Effects of High Water Temperature on Growth, Smoltification, and Predator Avoidance in Juvenile Sacramento River Chinook Salmon. *North American Journal of Fisheries Management* 24:198–210.

Matthews, W. J. 1998. Patterns in freshwater fish ecology. Chapman and Hall, New York, NY. InJ. D. Kiernan, P. B. Moyle, and P. K. Crain. 2012. Restoring Native Fish Assemblages to a Regulated

California Stream Using the Natural Flow Regime Concept. *Ecological Applications* 22(5):1472–1482.

Mazvimavi, D., E. Madamombe, and H. Makurira. 2007. Assessment of Environmental Flow Requirements for River Basin Planning in Zimbabwe. *Physics and Chemistry of the Earth* 32: 995–1006.

McBain and Trush. 2002. *San Joaquin River Restoration Study Background Report*. December. Prepared for Friant Water Users Authority, Lindsay, CA and Natural Resources Defense Council, San Francisco CA. Arcata, CA.

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

Mesick, C. 2001. *Factors that potentially limit the populations of fall-run Chinook salmon in the San Joaquin tributaries*. August 21. Presentation and report given to the Stanislaus Fish Group, Stockton, CA. Carl Mesick Consultants, El Dorado, CA.

———. 2009. *The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases*. September.

———. 2010a. *The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Merced River due to Insufficient Instream Flow Releases*. November.

———. 2010b. *Instream Flow Recommendations for the Stanislaus, Tuolumne, and Merced Rivers to Maintain the Viability of the Fall-Run Chinook Salmon Populations*.

———. 2012. Unpublished. *The effect of water diversions on the viability of the naturally-produced fall-run Chinook salmon populations in the Stanislaus, Tuolumne, and Merced Rivers, California.*

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

———. 2007b. *Provisional Draft: San Joaquin River Fall-run Chinook Salmon Age Cohort Reconstruction.*

Mesick, C. F., J. McLain, D. Marston, and T. Heyne. 2007. *Draft limiting factor analyses & recommended studies for fall-run Chinook salmon and rainbow trout in the Tuolumne River.* March. Report submitted to the Federal Energy Regulatory Commission.

Morinville, G. R., and J. B. Rasmussen. 2003. Early juvenile bioenergetic differences between anadromous and resident brook trout (*Salvelinus fontinalis*). *Canadian Journal of Fisheries and Aquatic Sciences* 60:401–410.

Mount J., W. Bennett, J. Durand, W. Fleenor, E. Hanak, J. Lund, and P. B. Moyle. 2012. *Aquatic Ecosystem Stressors in the Sacramento-San Joaquin Delta*. Public Policy Institute of California. 22 pp.

Moyle, P. B., and J. J. Cech, Jr. 2000. Fishes: an introduction to ichthyology. 4th edition. Prentice-Hall, Inc., Upper Saddle River. In C. A. Myrick, and J. J. Cech Jr. 2001. *Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations*. Bay-Delta Modeling Forum Technical Publication 01-1. 57 pp.

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

Moyle P. B., R. D. Baxter, T. R. Sommer, T. C. Foin, and S. A. Matern. 2004. *Biology and population dynamics of Sacramento splittail* (Pogonichthys macrolepidotus) *in the San Francisco Estuary: a review.* San Francisco Estuary and Watershed Science. Available: http://www.escholarship.org/uc/item/61r48686.

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

Moyle, P. B., J. A. Israel, and S. E. Purdy. 2008. *Salmon, Steelhead, and Trout in California. Status of an Emblematic Fauna*. Prepared for California Trout.

Moyle, P. B., J. G. Williams, and J. D. Kiernan. 2011. *Improving Environmental Flow Methods Used in California FERC Licensing*. California Energy Commission, PIER. CEC-500-XXXX-XXX

Myrick, C. A., and J. J. Cech Jr. 2001. *Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations*. Bay-Delta Modeling Forum Technical Publication 01-1. 57 pp.

Naiman, R. J., J. J. Latterell, N. E. Pettit, and J. D. Olden. 2008. Flow Variability and the Vitality of River Systems. *Comptes Rendus Geoscience* 340:629–643.

National Marine Fisheries Service (NMFS). 2009a. *Public Draft Recovery Plan for the Evolutionarily Significant units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead*. Sacramento Protected Resources Division. Appendix A.

———. 2009b. *Public Draft Recovery Plan for the Evolutionarily Significant units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead*. October. Sacramento Protected Resources Division.

———. 2009c. *Endangered Species Act Section 7 Consultation*. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. June.

National Resources Defense Council (NRDC). 2005. *The Science of Instream Flows: A Review of the Texas Instream Flow Program*. 162 pp.

Newman, K., and J. Rice. 1997. *Statistical model for survival of chinook salmon smolts outmigrating through the lower Sacramento-San Joaquin system*. Interagency Ecological Program Technical Report 59. California Department of Water Resources, Sacramento, CA.

Nichols, K., and J. S. Foott. 2002. *FY2001 Investigation Report: Health Monitoring and Natural Fall-run Chinook Salmon Juveniles in the San Joaquin River and Tributaries, April-June 2001*. U.S. Fish and Wildlife Service. California-Nevada Fish Health Center.

Nielsen, J. L., T. E. Lisle, and V. Ozaki. 1994. Thermally Stratified Pools and Their Use by Steelhead in Northern California Streams. *Transactions of the American Fisheries Society* 123:613–626.

Northcote, T. G. 1984. Mechanisms of fish migration in rivers. Pages 317–355 in J. D. McCleave, G. P. Arnold, J. J. Dodson. Mechanisms of migration in fishes. Plenum Press, NY. As cited in T. G. Northcote. 1997. Potamodromy in Salmonidae-living and moving in the fast lane. *North American Journal of Fisheries Management* 17:1029–1045.

Opperman, J. J. 2012. A Conceptual Model for Floodplains in the Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science* 10(3).

Orth, D. J., and O. E. Maughan. 1981. Evaluation of the "Montana Method" for Recommending Instream Flows in Oklahoma Streams*. Oklahoma Academy of Science* 61:62–66.

Parker, R. R. 1971. Size selective predation among juvenile salmonid fishes in a British Columbia inlet. *Journal of the Fisheries Research Board of Canada* 28(10):1503–1510.

Petts, G. E. 2009. Instream Flow Science for Sustainable River Management*. Journal of the American Water Resources Association* 45:1071–1086.

Poff, N. L., and J. V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. *Canadian Journal of Fisheries and Aquatic Sciences* 46:1805–1818.

Poff, N. L., J. K. Allan, M. B. Bain, J. R. Karr, K. L Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The Natural Flow Regime. *Bioscience* 47:769–784.

Poff, N. L., J. D. Olden, D. M. Pepin, and B. P. Bledsoe. 2006. Placing Global Stream Variability in Geographic and Geomorphic Contexts*. River Research and Applications* 22:149–166.

Poff, N. L., J. D. Olden, D. M. Merritt, and D. M. Pepin. 2007. Homogenization of Regional River Dynamics by Dams and Global Biodiversity Implications. *National Academy of Sciences* 104:5732–5737.

Power, M. E., A. Sun, M. Parker, W. E. Dietrich, and J. T. Wootton. 1995. Hydraulic Food-chain Models: An Approach to the Study of Food-web Dynamics in Large Rivers. *BioScience* 45:159–167.

Power, M. E., M. S. Parker, and W. E. Dietrich. 2008. Seasonal reassembly of a river food web: floods, droughts, and impacts of fish. Ecological Monographs 78:263–282. In J. D. Kiernan, P. B. Moyle, and P. K. Crain. 2012. Restoring Native Fish Assemblages to a Regulated California Stream Using the Natural Flow Regime Concept. *Ecological Applications* 22(5):1472–1482.

Reese, C. D., and B. C. Harvey. 2002. Temperature-Dependent Interactions between Juvenile Steelhead and Sacramento Pikeminnow in Laboratory Systems. *Transactions of the American Fisheries Society* 131:599–606.

Resh, V. H., A. V. Brown, A. P. Covich, M.E. Gurtz, H. W. Li, G. W. Minshall, S. R. Reice, A. L. Sheldon, J. B. Wallace, and R. Wissmar. 1988. The Role of Disturbance in Stream Ecology. *Journal of the North American Benthological Society* 7:433–455.

Richter, B. D., J. V. Baumgartner, J. Powell, and D. P. Braun. 1996. A Method for Assessing Hydrologic Alteration within Ecosystems. *Conservation Biology* 10:1163–1174.

Richter, B. D., R. Matthews, D. L. Harrison, and R. Wigington. 2003. Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity. *Ecological Applications* 13:206–224.

Richter, B. D., and G. A. Thomas. 2007. Restoring Environmental Flows by Modifying Dam Operations. *Ecology and Society* 12(1).

Rice, G. V. 1960. Use of coldwater holding facilities in conjunction with king salmon spawning operations at Nimbus Hatchery. Inland Fisheries Administrative Report Number 603. As cited in D. A. McCullough. 1999*. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids with Special Reference to Chinook Salmon*. 279 pp.

Seymour, A. H. 1956. *Effects of Temperature Upon Young Chinook Salmon*. Ph.D. thesis. University of Washiongton, Seattle.

Seymour, A. 1959. Effects of Temperature Upon the Formation of Vertebrae and Fin Rays in Young Chinook Salmon. *Transactions of the American Fisheries Society* 88(1):58–69.

Sheridan, M. A., W. V. Allen, and T. H. Kerstetter. 1983. Seasonal Variations in the Lipid Composition of Steelhead Trout, *Salmo Gairdneri* Richarson, associated with the Parr-Smolt Transformation. *Journal of Fish Biology* 23:125–134.

Sobczak W.V., J. E. Cloern, A. D. Jassby, and A. B. Muller-Solger. 2002. Bioavailability of organic matter in a highly disturbed estuary: the role of detrital and algal resources. *National Academies of Science* 99(12):8101–8105.

Sommer, T., R. Baxter, and B. Herbold. 1997. Resilience of splittail in the Sacramento–San Joaquin estuary. *Transactions of the American Fisheries Society* 126:961–976.

Sommer, T., M. L. Nobriga, W.C. Harrell, W. Batham, and W. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58:325–333.

Sommer, T., W. C. Harrell, A. M. Solger, B. Tom, and W. Kimmerer. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. *Aquatic Conservation–Marine and Freshwater Ecosystems* 14(3):247–261.

Sommer, T., W.C. Harrel, and M. L. Nobriga. 2005. Habitat Use and Stranding Risk of Juvenile Chinook Salmon on a Seasonal Floodplain. *North American Journal of Fisheries Management* 25:1493–1504.

Sparks, R. E. 1995. Need for Ecosystem Management of Large Rivers and Their Floodplains. *Bioscience* 45:168–182.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. *An Ecosystem Approach to Salmonid Conservation*. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. Available from the National Marine Fisheries Service, Portland, OR.

State Water Resources Control Board (State Water Board). 2010. *Development of Flow Criteria for the Sancramento-San Joaquin Delta Ecosystem*. August. Prepared pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009.

Sturrock, A. M., J. D. Wikert, T. Heyne, C. Mesick, A. E. Hubbard, T. M. Hinkelman, P. K. Weber, G. E. Whitman, J. J. Glessner, and R. C. Johnson. 2015. Reconstructing the Migratory Behavior and Long-Term Survivorship of Juvenile Chinook Salmon under Contrasting Hydrologic Regimes. *PLoS One* 10(5).

Tennant, D. L. 1976. Instream Flow Regimens for Fish, Wildlife, Recreation and Related Environmental Resources. *Fisheries* 1:6–10.

Tharme, R. E., and J.M. King. 1998. *Development of the Building Block Methodology for Instream Flow Assessments, and Supporting Research on the Effects of Different Magnitude Flows on Riverine Ecosystems*. Water Research Commission Report No. 576/1/98. 452 pp.

Tharme. R. E. 2003. A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers. *River Research and Applications* 19:397–441.

The Bay Institute (TBI). 1998. *From the Sierra to the sea: the ecological history of the San Francisco Bay–Delta watershed*. San Francisco, CA.

Torgersen, C. E., D. M. Price, W. L. Hiram, and B. A. McIntosh. 1999. Multiscale Thermal Refugia and Stream Habitat Associations of Chinook Salmon in Northeastern Oregon. *Ecological Application* 9(1):301–319.

Torgersen, C. E., J. L. Ebersole, and D. M. Keenan. 2012. *Primer for Identifying Cold-Water Refuges to Protect and Restore Thermal Diversity in Riverine Landscapes*. Prepared for Region 10, U.S. Environmental Protection Agency, Seattle, WA under EPA Interagency Agreement No. DW-14-95755001-0.

U.S. Army Corps of Engineers (USACE). 1987. *Distribution Restriction Statement*. Engineering and Design: Reservoir Water Quality Analysis. Engineer Manual 1110-2-1201.

U.S. Environmental Protection Agency (USEPA). 2001a. *Issue Paper 5. Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids*. Prepared as part of EPA Region 10 Temperature Water Quality Criteria Guidance Development Project.

———. 2001b. *Issue Paper 1. Salmonid Behavior and Water Temperature*. Prepared as part of EPA Region 10 Temperature Water Quality Criteria Guidance Development Project.

———. 2003. *USEPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards*. April. USEPA 910-B-03-002. 49 pp.

United States Fish and Wildlife Service (USFWS). 2008. *Flow-Overbank Inundation Relationship for Potential Fall-Run Chinook Salmon and Steelhead/Rainbow Trout Juvenile Outmigration Habitat in the Tuolumne River.* Sacramento, CA.

———. 2011. *Identification of the Instream Flow Requirements for Anadromous Fish in the Streams Within the Central Valley of California and Fisheries Investigations*. Annual Progress Report Fiscal Year 2011. Sacramento, CA.

———. 2012. *Identification of the Instream Flow Requirements for Anadromous Fish in the Streams Within the Central Valley of California and Fisheries Investigations*. Annual Progress Report Fiscal Year 2012. Sacramento, CA.

———. 2013a. *Central Valley Project Improvement Act Doubling Graphs*. January 1. Available: http://www.fws.gov/lodi/afrp/. Accessed: June 18, 2015.

———. 2013b. *Identification of the Instream Flow Requirements for Anadromous Fish in the Streams Within the Central Valley of California and Fisheries Investigations*. Annual Progress Report Fiscal Year 2013. Sacramento, CA.

———. 2014. *Identification of the Instream Flow Requirements for Anadromous Fish in the Streams Within the Central Valley of California and Fisheries Investigation*s. Annual Progress Report Fiscal Year 2014. Sacramento, CA.

Unwin, M. J. 1997. Fry-to-adult survival of natural and hatchery produced chinook salmon (*Oncorhynchus tshawytscha*) from a common origin. *Canadian Journal of Fisheries and Aquatic Sciences* 54:1246–1254.

Walker, K. F., F. Sheldon, and J. T. Puckridge. 1995. A Perspective on Dryland River Ecosystems. *Regulated Rivers* 11:85–104.

Wang, J. C. S. 1986. *Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories*.

Ward, B .R., P. A. Slaney, A. R. Facchin, and R. W. Land. 1989. Size-biased survival in steelhead trout (*Oncorhynchus mykiss*): back-calculated lengths from adults' scales compared to migrating smolts at the Keogh River, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 46(11).

Williams, J. G. 2006. Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. *San Francisco Estuary and Watershed Science* 4(3).

Williamson, K. S., and B. May. 2005. Homogenization of fall-run Chinook salmon gene pools in the Central Valley of California, USA. *North American Journal of Fisheries Management* 25(3):993–1009.

Yarnell, S. M., J. H. Viers, and J. F. Mount. 2010. Ecology and management of the spring snowmelt recession. BioScience 60:114–127. In J. D. Kiernan, P. B. Moyle, and P. K. Crain. 2012. Restoring Native Fish Assemblages to a Regulated California Stream Using the Natural Flow Regime Concept. *Ecological Applications* 22(5):1472–1482.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical abundance and decline of Chinook salmon in the Central Valley region of California. *North American Journal of Fisheries Management* 18:487–521.

Young, P. S., and J. J. Cech, Jr. 1996. Environmental Tolerances and Requirements of Splittail. *Transactions of the American Fisheries Society* 125:664–678.

Zabel, R. W., and J. G. Williams. 2002. Selective Mortality in Chinook Salmon: What is the Role of Human Disturbance? *Ecological Applications* 12(1):173–183.

Zeug, S. C., K. Sellheim, C. Watry, J. D. Wikert, J. Merz. 2014. Response of Juvenile Chinook Salmon to Managed Flow: Lessons Learned from a Population at the Southern Extent of Their Range in North America. *Fisheries Management and Ecology* 21:155–168.

Attachment 1 and 2

# Summarized Temperature Results and Temperature Targets and Flow Constraints Used in SalSim Optimization Run (SB40%OPP)

# Chapter 19
# **Attachment 1**

**Table 19-33. Summary of mean annual temperature benefits for the Stanislaus River from different February through June unimpaired flow (UF) percentages for all water years.**

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 1755 | 617 | 35% | 38% | 37% | 43% | 42% | 40% |
| AM | Oct | 64.4 | 1814 | 1473 | 81% | 91% | 90% | 93% | 93% | 92% |
| R | Oct | 55.4 | 1814 | 220 | 12% | 13% | 12% | 13% | 11% | 9% |
| R | Nov | 55.4 | 1755 | 662 | 38% | 41% | 39% | 40% | 38% | 35% |
| R | Dec | 55.4 | 1814 | 1741 | 96% | 99% | 99% | 99% | 99% | 99% |
| R | Jan | 55.4 | 1814 | 1810 | 100% | 100% | 100% | 100% | 100% | 100% |
| R | Feb | 55.4 | 1697 | 1530 | 90% | 91% | 91% | 92% | 93% | 94% |
| R | Mar | 55.4 | 1814 | 1104 | 61% | 63% | 67% | 70% | 75% | 78% |
| CR | Mar | 60.8 | 1814 | 1745 | 96% | 96% | 98% | 99% | 99% | 100% |
| CR | Apr | 60.8 | 1755 | 1585 | 90% | 90% | 92% | 95% | 96% | 97% |
| CR | May | 60.8 | 1814 | 1382 | 76% | 77% | 80% | 82% | 85% | 88% |
| S | Apr | 57.2 | 1755 | 1164 | 66% | 67% | 68% | 70% | 73% | 76% |
| S | May | 57.2 | 1814 | 747 | 41% | 39% | 42% | 45% | 52% | 58% |
| S | Jun | 57.2 | 1755 | 316 | 18% | 18% | 19% | 21% | 26% | 29% |
| SR | Jun | 64.4 | 1755 | 1116 | 64% | 63% | 65% | 68% | 73% | 76% |
| SR | Jul | 64.4 | 1814 | 529 | 29% | 29% | 32% | 33% | 34% | 35% |
| SR | Aug | 64.4 | 1814 | 488 | 27% | 29% | 27% | 26% | 25% | 24% |

**Table 19-34. Summary of mean annual temperature benefits for the Stanislaus River from different February through June unimpaired flow (UF) percentages for dry water years.**

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 1755 | 544 | 31% | 32% | 30% | 28% | 26% | 23% |
| AM | Oct | 64.4 | 1814 | 1691 | 93% | 93% | 93% | 95% | 94% | 94% |
| R | Oct | 55.4 | 1814 | 210 | 12% | 12% | 11% | 14% | 12% | 7% |
| R | Nov | 55.4 | 1755 | 841 | 48% | 48% | 48% | 48% | 46% | 41% |
| R | Dec | 55.4 | 1814 | 1814 | 100% | 100% | 100% | 100% | 100% | 100% |
| R | Jan | 55.4 | 1814 | 1814 | 100% | 100% | 100% | 100% | 100% | 100% |
| R | Feb | 55.4 | 1697 | 1547 | 91% | 85% | 86% | 87% | 89% | 92% |
| R | Mar | 55.4 | 1814 | 810 | 45% | 31% | 39% | 49% | 63% | 72% |
| CR | Mar | 60.8 | 1814 | 1706 | 94% | 88% | 97% | 98% | 100% | 100% |
| CR | Apr | 60.8 | 1755 | 1691 | 96% | 92% | 95% | 96% | 99% | 99% |
| CR | May | 60.8 | 1814 | 1464 | 81% | 78% | 73% | 75% | 84% | 92% |
| S | Apr | 57.2 | 1755 | 1053 | 60% | 56% | 56% | 56% | 63% | 69% |
| S | May | 57.2 | 1814 | 555 | 31% | 29% | 27% | 29% | 34% | 38% |
| S | Jun | 57.2 | 1755 | 147 | 8% | 8% | 8% | 9% | 10% | 11% |
| SR | Jun | 64.4 | 1755 | 768 | 44% | 41% | 40% | 41% | 47% | 52% |
| SR | Jul | 64.4 | 1814 | 322 | 18% | 18% | 17% | 17% | 17% | 17% |
| SR | Aug | 64.4 | 1814 | 376 | 21% | 21% | 19% | 18% | 18% | 16% |

**Table 35. Summary of mean annual temperature benefits for the Stanislaus River from different February through June unimpaired flow (UF) percentages for critically dry water years.**

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 1755 | 190 | 11% | 17% | 17% | 18% | 17% | 16% |
| AM | Oct | 64.4 | 1814 | 1261 | 70% | 86% | 85% | 89% | 88% | 87% |
| R | Oct | 55.4 | 1814 | 110 | 6% | 6% | 6% | 8% | 6% | 5% |
| R | Nov | 55.4 | 1755 | 420 | 24% | 27% | 24% | 28% | 24% | 21% |
| R | Dec | 55.4 | 1814 | 1645 | 91% | 98% | 98% | 99% | 99% | 99% |
| R | Jan | 55.4 | 1814 | 1814 | 100% | 100% | 100% | 100% | 100% | 100% |
| R | Feb | 55.4 | 1697 | 1445 | 85% | 84% | 83% | 83% | 85% | 86% |
| R | Mar | 55.4 | 1814 | 508 | 28% | 26% | 29% | 35% | 41% | 46% |
| CR | Mar | 60.8 | 1814 | 1690 | 93% | 92% | 94% | 96% | 98% | 99% |
| CR | Apr | 60.8 | 1755 | 1161 | 66% | 69% | 74% | 82% | 87% | 90% |
| CR | May | 60.8 | 1814 | 677 | 37% | 42% | 48% | 54% | 56% | 62% |
| S | Apr | 57.2 | 1755 | 490 | 28% | 30% | 34% | 36% | 39% | 42% |
| S | May | 57.2 | 1814 | 241 | 13% | 15% | 16% | 19% | 20% | 22% |
| S | Jun | 57.2 | 1755 | 57 | 3% | 4% | 4% | 5% | 4% | 5% |
| SR | Jun | 64.4 | 1755 | 427 | 24% | 27% | 30% | 33% | 36% | 42% |
| SR | Jul | 64.4 | 1814 | 227 | 12% | 15% | 15% | 15% | 14% | 15% |
| SR | Aug | 64.4 | 1814 | 186 | 10% | 15% | 15% | 14% | 13% | 13% |

## Table 36. Summary of mean annual temperature benefits for the Tuolumne River from different February through June unimpaired flow (UF) percentages for all water years.

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 1605 | 396 | 25% | 25% | 24% | 30% | 30% | 30% |
| AM | Oct | 64.4 | 1659 | 1012 | 61% | 61% | 60% | 64% | 63% | 63% |
| R | Oct | 55.4 | 1659 | 123 | 7% | 7% | 6% | 6% | 5% | 5% |
| R | Nov | 55.4 | 1605 | 576 | 36% | 36% | 35% | 35% | 32% | 31% |
| R | Dec | 55.4 | 1659 | 1598 | 96% | 97% | 97% | 96% | 95% | 95% |
| R | Jan | 55.4 | 1659 | 1640 | 99% | 99% | 99% | 99% | 99% | 99% |
| R | Feb | 55.4 | 1552 | 1194 | 77% | 79% | 81% | 83% | 85% | 87% |
| R | Mar | 55.4 | 1659 | 971 | 59% | 61% | 64% | 68% | 72% | 77% |
| CR | Mar | 60.8 | 1659 | 1366 | 82% | 88% | 91% | 95% | 97% | 98% |
| CR | Apr | 60.8 | 1605 | 1193 | 74% | 80% | 86% | 92% | 96% | 97% |
| CR | May | 60.8 | 1659 | 967 | 58% | 68% | 81% | 89% | 93% | 94% |
| S | Apr | 57.2 | 1605 | 911 | 57% | 60% | 65% | 71% | 77% | 82% |
| S | May | 57.2 | 1659 | 675 | 41% | 47% | 55% | 62% | 69% | 73% |
| S | Jun | 57.2 | 1605 | 375 | 23% | 29% | 34% | 37% | 42% | 45% |
| SR | Jun | 64.4 | 1605 | 747 | 47% | 62% | 72% | 79% | 84% | 86% |
| SR | Jul | 64.4 | 1659 | 519 | 31% | 33% | 31% | 37% | 37% | 35% |
| SR | Aug | 64.4 | 1659 | 321 | 19% | 19% | 19% | 20% | 20% | 19% |

## Table 37. Summary of mean annual temperature benefits for the Tuolumne River from different February through June unimpaired flow (UF) percentages for dry water years.

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 1605 | 197 | 12% | 12% | 12% | 12% | 12% | 12% |
| AM | Oct | 64.4 | 1659 | 1065 | 64% | 64% | 64% | 64% | 63% | 64% |
| R | Oct | 55.4 | 1659 | 141 | 8% | 8% | 7% | 6% | 5% | 6% |
| R | Nov | 55.4 | 1605 | 759 | 47% | 46% | 44% | 42% | 40% | 42% |
| R | Dec | 55.4 | 1659 | 1659 | 100% | 100% | 100% | 100% | 100% | 100% |
| R | Jan | 55.4 | 1659 | 1638 | 99% | 99% | 99% | 99% | 99% | 99% |
| R | Feb | 55.4 | 1552 | 1072 | 69% | 67% | 71% | 75% | 79% | 83% |
| R | Mar | 55.4 | 1659 | 618 | 37% | 39% | 39% | 47% | 57% | 64% |
| CR | Mar | 60.8 | 1659 | 1320 | 80% | 81% | 85% | 94% | 96% | 98% |
| CR | Apr | 60.8 | 1605 | 944 | 59% | 67% | 76% | 89% | 96% | 99% |
| CR | May | 60.8 | 1659 | 563 | 34% | 55% | 66% | 84% | 95% | 98% |
| S | Apr | 57.2 | 1605 | 534 | 33% | 38% | 48% | 61% | 70% | 77% |
| S | May | 57.2 | 1659 | 315 | 19% | 28% | 41% | 53% | 59% | 65% |
| S | Jun | 57.2 | 1605 | 69 | 4% | 9% | 15% | 19% | 23% | 27% |
| SR | Jun | 64.4 | 1605 | 222 | 14% | 29% | 44% | 55% | 68% | 74% |
| SR | Jul | 64.4 | 1659 | 148 | 9% | 10% | 11% | 12% | 13% | 14% |
| SR | Aug | 64.4 | 1659 | 163 | 10% | 9% | 9% | 9% | 9% | 9% |

## Table 38. Summary of mean annual temperature benefits for the Tuolumne River from different February through June unimpaired flow (UF) percentages for critically dry water years.

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 1605 | 149 | 9% | 10% | 10% | 10% | 10% | 10% |
| AM | Oct | 64.4 | 1659 | 831 | 50% | 50% | 49% | 53% | 53% | 52% |
| R | Oct | 55.4 | 1659 | 124 | 8% | 8% | 6% | 6% | 4% | 3% |
| R | Nov | 55.4 | 1605 | 532 | 33% | 34% | 34% | 35% | 30% | 25% |
| R | Dec | 55.4 | 1659 | 1639 | 99% | 99% | 99% | 99% | 98% | 95% |
| R | Jan | 55.4 | 1659 | 1659 | 100% | 100% | 100% | 100% | 100% | 99% |
| R | Feb | 55.4 | 1552 | 928 | 60% | 60% | 61% | 64% | 67% | 70% |
| R | Mar | 55.4 | 1659 | 226 | 14% | 18% | 27% | 34% | 41% | 47% |
| CR | Mar | 60.8 | 1659 | 1022 | 62% | 71% | 79% | 86% | 91% | 93% |
| CR | Apr | 60.8 | 1605 | 575 | 36% | 52% | 70% | 80% | 88% | 91% |
| CR | May | 60.8 | 1659 | 412 | 25% | 38% | 56% | 70% | 77% | 83% |
| S | Apr | 57.2 | 1605 | 288 | 18% | 26% | 38% | 48% | 58% | 67% |
| S | May | 57.2 | 1659 | 222 | 13% | 20% | 30% | 38% | 44% | 51% |
| S | Jun | 57.2 | 1605 | 61 | 4% | 9% | 12% | 16% | 18% | 20% |
| SR | Jun | 64.4 | 1605 | 179 | 11% | 28% | 40% | 49% | 58% | 63% |
| SR | Jul | 64.4 | 1659 | 98 | 6% | 7% | 8% | 9% | 9% | 10% |
| SR | Aug | 64.4 | 1659 | 104 | 6% | 7% | 7% | 7% | 7% | 6% |

## Table 39. Summary of mean annual temperature benefits for the Merced River from different February through June unimpaired flow (UF) percentages for all water years.

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 1566 | 210 | 13% | 14% | 13% | 14% | 14% | 12% |
| AM | Oct | 64.4 | 1618 | 783 | 48% | 55% | 54% | 58% | 57% | 55% |
| R | Oct | 55.4 | 1618 | 0 | 0% | 0% | 0% | 0% | 0% | 0% |
| R | Nov | 55.4 | 1566 | 192 | 12% | 14% | 13% | 14% | 14% | 12% |
| R | Dec | 55.4 | 1618 | 1337 | 83% | 88% | 88% | 88% | 87% | 86% |
| R | Jan | 55.4 | 1618 | 1522 | 94% | 94% | 94% | 94% | 94% | 94% |
| R | Feb | 55.4 | 1514 | 1082 | 71% | 69% | 70% | 72% | 73% | 75% |
| R | Mar | 55.4 | 1618 | 500 | 31% | 30% | 31% | 33% | 36% | 42% |
| CR | Mar | 60.8 | 1618 | 1271 | 79% | 78% | 80% | 84% | 87% | 89% |
| CR | Apr | 60.8 | 1566 | 610 | 39% | 40% | 53% | 60% | 69% | 76% |
| CR | May | 60.8 | 1618 | 380 | 23% | 31% | 41% | 47% | 55% | 61% |
| S | Apr | 57.2 | 1566 | 278 | 18% | 17% | 23% | 25% | 32% | 37% |
| S | May | 57.2 | 1618 | 190 | 12% | 14% | 17% | 18% | 24% | 28% |
| S | Jun | 57.2 | 1566 | 160 | 10% | 10% | 10% | 10% | 11% | 11% |
| SR | Jun | 64.4 | 1566 | 412 | 26% | 33% | 37% | 40% | 45% | 49% |
| SR | Jul | 64.4 | 1618 | 339 | 21% | 21% | 19% | 20% | 18% | 15% |
| SR | Aug | 64.4 | 1618 | 199 | 12% | 12% | 11% | 11% | 10% | 9% |

**Table 40. Summary of mean annual temperature benefits for the Merced River from different February through June unimpaired flow (UF) percentages for dry water years.**

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 1566 | 43 | 3% | 3% | 3% | 3% | 2% | 2% |
| AM | Oct | 64.4 | 1618 | 885 | 55% | 54% | 52% | 51% | 51% | 51% |
| R | Oct | 55.4 | 1618 | 0 | 0% | 0% | 0% | 0% | 0% | 0% |
| R | Nov | 55.4 | 1566 | 307 | 20% | 20% | 18% | 16% | 17% | 17% |
| R | Dec | 55.4 | 1618 | 1527 | 94% | 94% | 94% | 94% | 94% | 94% |
| R | Jan | 55.4 | 1618 | 1540 | 95% | 95% | 95% | 95% | 95% | 95% |
| R | Feb | 55.4 | 1514 | 849 | 56% | 56% | 56% | 56% | 59% | 60% |
| R | Mar | 55.4 | 1618 | 106 | 7% | 6% | 7% | 9% | 12% | 15% |
| CR | Mar | 60.8 | 1618 | 1128 | 70% | 69% | 73% | 80% | 83% | 86% |
| CR | Apr | 60.8 | 1566 | 241 | 15% | 23% | 35% | 47% | 61% | 68% |
| CR | May | 60.8 | 1618 | 82 | 5% | 14% | 19% | 23% | 30% | 36% |
| S | Apr | 57.2 | 1566 | 67 | 4% | 6% | 9% | 11% | 15% | 16% |
| S | May | 57.2 | 1618 | 45 | 3% | 3% | 5% | 7% | 8% | 10% |
| S | Jun | 57.2 | 1566 | 32 | 2% | 2% | 2% | 1% | 1% | 1% |
| SR | Jun | 64.4 | 1566 | 49 | 3% | 6% | 9% | 13% | 16% | 20% |
| SR | Jul | 64.4 | 1618 | 43 | 3% | 3% | 3% | 3% | 3% | 3% |
| SR | Aug | 64.4 | 1618 | 43 | 3% | 3% | 3% | 3% | 3% | 3% |

**Table 41. Summary of mean annual temperature benefits for the Merced River from different February through June unimpaired flow (UF) percentages for critically dry water years.**

| Life Stage | Month | USEPA Criteria (°F) | Maximum Compliance Possible (Mile-Days) | Total Compliance under Baseline (Mile-Days) | % of Maximum Compliance Achieved | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Baseline | 20% UF | 30% UF | 40% UF | 50% UF | 60% UF |
| AM | Sep | 64.4 | 1566 | 14 | 1% | 2% | 2% | 2% | 2% | 1% |
| AM | Oct | 64.4 | 1618 | 534 | 33% | 53% | 53% | 52% | 51% | 47% |
| R | Oct | 55.4 | 1618 | 0 | 0% | 0% | 0% | 0% | 0% | 0% |
| R | Nov | 55.4 | 1566 | 91 | 6% | 10% | 10% | 14% | 13% | 9% |
| R | Dec | 55.4 | 1618 | 1207 | 75% | 92% | 91% | 91% | 91% | 88% |
| R | Jan | 55.4 | 1618 | 1539 | 95% | 95% | 95% | 95% | 95% | 94% |
| R | Feb | 55.4 | 1514 | 787 | 52% | 48% | 48% | 49% | 51% | 53% |
| R | Mar | 55.4 | 1618 | 93 | 6% | 3% | 4% | 5% | 6% | 12% |
| CR | Mar | 60.8 | 1618 | 1091 | 67% | 62% | 65% | 70% | 75% | 79% |
| CR | Apr | 60.8 | 1566 | 140 | 9% | 13% | 20% | 27% | 34% | 46% |
| CR | May | 60.8 | 1618 | 46 | 3% | 7% | 10% | 14% | 16% | 19% |
| S | Apr | 57.2 | 1566 | 39 | 3% | 3% | 4% | 5% | 7% | 10% |
| S | May | 57.2 | 1618 | 24 | 1% | 1% | 2% | 3% | 3% | 4% |
| S | Jun | 57.2 | 1566 | 3 | 0% | 0% | 0% | 0% | 0% | 0% |
| SR | Jun | 64.4 | 1566 | 39 | 2% | 5% | 7% | 9% | 11% | 12% |
| SR | Jul | 64.4 | 1618 | 37 | 2% | 3% | 3% | 3% | 2% | 2% |
| SR | Aug | 64.4 | 1618 | 22 | 1% | 2% | 2% | 2% | 2% | 1% |

# Chapter 19
# Attachment 2

**Temperature and flow targets by water year type for the Stanislaus River temperature operation SalSim run.**

| Stanislaus | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature Control - Wet Year | | | | | | Flow Control - Wet Year | | | | | | | surplus(+)/Deficit(-) Control Factors | | | | |
| Date | Julian Day | Temp Target | RM | Selected Temp | | Date | Julian Day | Min_Q | Max_Q | Selected flow | | | Date | Julian Day | +Q_out | -Q_out | |
| from | from | F | (in-river) | (0=Base, 1=Target) | | from | from | cfs | cfs | (0=Base, 1=Alt) | | | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No | |
| 1-Jan | 1 | 53.60 | 33.30 | 1 | | 1-Jan | 1 | 400.00 | 800.00 | 1 | | | 1-Jan | 1 | 1.00 | 1.00 | |
| 1-Feb | 32 | 53.60 | 33.30 | 1 | | 1-Feb | 32 | 400.00 | 800.00 | 1 | | | 1-Feb | 32 | 1.00 | 1.00 | |
| 1-Mar | 60 | 53.60 | 33.30 | 1 | | 1-Mar | 60 | 800.00 | 1200.00 | 1 | | | 1-Mar | 60 | 1.00 | 1.00 | |
| 1-Apr | 91 | 53.60 | 33.30 | 1 | | 1-Apr | 91 | 800.00 | 1500.00 | 1 | | | 1-Apr | 91 | 1.00 | 1.00 | |
| 1-May | 121 | 53.60 | 33.30 | 1 | | 1-May | 121 | 1500.00 | 2500.00 | 1 | | | 1-May | 121 | 1.00 | 1.00 | |
| 1-Jun | 152 | 53.60 | 33.30 | 1 | | 1-Jun | 152 | 2000.00 | 4000.00 | 1 | | | 1-Jun | 152 | 1.00 | 1.00 | |
| 30-Jun | 181 | 53.60 | 33.30 | 1 | | 30-Jun | 181 | 2000.00 | 4000.00 | 1 | | | 30-Jun | 181 | 1.00 | 1.00 | |
| 1-Jul | 182 | 64.00 | 45.00 | 1 | | 1-Jul | 182 | 200.00 | 400.00 | 1 | | | 1-Jul | 182 | 1.00 | 1.00 | |
| 10-Oct | 283 | 64.00 | 45.00 | 1 | | 10-Oct | 283 | 200.00 | 400.00 | 1 | | | 10-Oct | 283 | 1.00 | 1.00 | |
| 11-Oct | 284 | 53.60 | 33.30 | 1 | | 11-Oct | 284 | 750.00 | 2000.00 | 1 | | | 11-Oct | 284 | 1.00 | 1.00 | |
| 31-Oct | 304 | 53.60 | 33.30 | 1 | | 31-Oct | 304 | 750.00 | 2000.00 | 1 | | | 31-Oct | 304 | 1.00 | 1.00 | |
| 1-Nov | 305 | 53.60 | 33.30 | 1 | | 1-Nov | 305 | 400.00 | 1000.00 | 1 | | | 1-Nov | 305 | 1.00 | 1.00 | |
| 1-Dec | 335 | 53.60 | 33.30 | 1 | | 1-Dec | 335 | 400.00 | 600.00 | 1 | | | 1-Dec | 335 | 1.00 | 1.00 | |
| 31-Dec | 365 | 53.60 | 33.30 | 1 | | 31-Dec | 365 | 400.00 | 600.00 | 1 | | | 31-Dec | 365 | 1.00 | 1.00 | |

**Stanislaus**

| Temperature Control - Above Normal Year | | | | | Flow Control - Above Normal Year | | | | | surplus(+)/Deficit(-) Control Factors | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Julian Day | Temp Target | RM | Selected Temp | Date | Julian Day | Min_Q | Max_Q | Selected flow | Date | Julian Day | +Q_out | -Q_out |
| from | from | F | (in-river) | (0=Base, 1=Target) | from | from | cfs | cfs | (0=Base, 1=Alt) | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 53.60 | 33.30 | 1 | 1-Jan | 1 | 400.00 | 600.00 | 1 | 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 53.60 | 33.30 | 1 | 1-Feb | 32 | 400.00 | 600.00 | 1 | 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 53.60 | 33.30 | 1 | 1-Mar | 60 | 600.00 | 1000.00 | 1 | 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 53.60 | 33.30 | 1 | 1-Apr | 91 | 800.00 | 1250.00 | 1 | 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 53.60 | 33.30 | 1 | 1-May | 121 | 1000.00 | 2000.00 | 1 | 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 53.60 | 33.30 | 1 | 1-Jun | 152 | 1500.00 | 3500.00 | 1 | 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 53.60 | 33.30 | 1 | 30-Jun | 181 | 1500.00 | 3500.00 | 1 | 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 64.00 | 45.00 | 1 | 1-Jul | 182 | 200.00 | 400.00 | 1 | 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 64.00 | 45.00 | 1 | 10-Oct | 283 | 200.00 | 400.00 | 1 | 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 53.60 | 33.30 | 1 | 11-Oct | 284 | 500.00 | 1500.00 | 1 | 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 53.60 | 33.30 | 1 | 31-Oct | 304 | 500.00 | 1500.00 | 1 | 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 53.60 | 33.30 | 1 | 1-Nov | 305 | 400.00 | 750.00 | 1 | 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 53.60 | 33.30 | 1 | 1-Dec | 335 | 400.00 | 600.00 | 1 | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 33.30 | 1 | 31-Dec | 365 | 400.00 | 600.00 | 1 | 31-Dec | 365 | 1.00 | 1.00 |

**Stanislaus**

| Temperature Control - Below Normal Year | | | | |
|---|---|---|---|---|
| Date | Julian Day | Temp Target | RM | Selected Temp |
| from | from | F | (in-river) | (0=Base, 1=Target) |
| 1-Jan | 1 | 53.60 | 33.30 | 1 |
| 1-Feb | 32 | 53.60 | 33.30 | 1 |
| 1-Mar | 60 | 53.60 | 33.30 | 1 |
| 1-Apr | 91 | 53.60 | 33.30 | 1 |
| 1-May | 121 | 53.60 | 33.30 | 1 |
| 1-Jun | 152 | 53.60 | 33.30 | 1 |
| 30-Jun | 181 | 53.60 | 33.30 | 1 |
| 1-Jul | 182 | 64.00 | 48.00 | 1 |
| 10-Oct | 283 | 64.00 | 48.00 | 1 |
| 11-Oct | 284 | 53.60 | 33.30 | 1 |
| 31-Oct | 304 | 53.60 | 33.30 | 1 |
| 1-Nov | 305 | 53.60 | 33.30 | 1 |
| 1-Dec | 335 | 53.60 | 33.30 | 1 |
| 31-Dec | 365 | 53.60 | 33.30 | 1 |

| Flow Control - Below Normal Year | | | | |
|---|---|---|---|---|
| Date | Julian Day | Min_Q | Max_Q | Selected flow |
| from | from | cfs | cfs | (0=Base, 1=Alt) |
| 1-Jan | 1 | 300.00 | 500.00 | 1 |
| 1-Feb | 32 | 300.00 | 500.00 | 1 |
| 1-Mar | 60 | 400.00 | 800.00 | 1 |
| 1-Apr | 91 | 600.00 | 1000.00 | 1 |
| 1-May | 121 | 800.00 | 1500.00 | 1 |
| 1-Jun | 152 | 1250.00 | 2500.00 | 1 |
| 30-Jun | 181 | 1250.00 | 2500.00 | 1 |
| 1-Jul | 182 | 200.00 | 300.00 | 1 |
| 10-Oct | 283 | 200.00 | 300.00 | 1 |
| 11-Oct | 284 | 500.00 | 1250.00 | 1 |
| 31-Oct | 304 | 500.00 | 1250.00 | 1 |
| 1-Nov | 305 | 300.00 | 750.00 | 1 |
| 1-Dec | 335 | 300.00 | 500.00 | 1 |
| 31-Dec | 365 | 300.00 | 500.00 | 1 |

| surplus(+)/Deficit(-) Control Factors | | | |
|---|---|---|---|
| Date | Julian Day | +Q_out | -Q_out |
| from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 1.00 | 1.00 |

**Stanislaus**

**Temperature Control - Dry Year**

| Date from | Julian Day from | Temp Target F | RM (in-river) | Selected Temp (0=Base, 1=Target) |
|---|---|---|---|---|
| 1-Jan | 1 | 53.60 | 39.40 | 1 |
| 1-Feb | 32 | 53.60 | 39.40 | 1 |
| 1-Mar | 60 | 53.60 | 39.40 | 1 |
| 1-Apr | 91 | 53.60 | 39.40 | 1 |
| 1-May | 121 | 53.60 | 39.40 | 1 |
| 1-Jun | 152 | 53.60 | 39.40 | 1 |
| 30-Jun | 181 | 53.60 | 39.40 | 1 |
| 1-Jul | 182 | 64.00 | 50.60 | 1 |
| 10-Oct | 283 | 64.00 | 50.60 | 1 |
| 11-Oct | 284 | 53.60 | 39.40 | 1 |
| 31-Oct | 304 | 53.60 | 39.40 | 1 |
| 1-Nov | 305 | 53.60 | 39.40 | 1 |
| 1-Dec | 335 | 53.60 | 39.40 | 1 |
| 31-Dec | 365 | 53.60 | 39.40 | 1 |

**Flow Control - Dry Year**

| Date from | Julian Day from | Min_Q cfs | Max_Q cfs | Selected flow (0=Base, 1=Alt) |
|---|---|---|---|---|
| 1-Jan | 1 | 200.00 | 400.00 | 1 |
| 1-Feb | 32 | 200.00 | 400.00 | 1 |
| 1-Mar | 60 | 400.00 | 600.00 | 1 |
| 1-Apr | 91 | 600.00 | 750.00 | 1 |
| 1-May | 121 | 800.00 | 1250.00 | 1 |
| 1-Jun | 152 | 1000.00 | 2000.00 | 1 |
| 30-Jun | 181 | 1000.00 | 2000.00 | 1 |
| 1-Jul | 182 | 200.00 | 300.00 | 1 |
| 10-Oct | 283 | 200.00 | 300.00 | 1 |
| 11-Oct | 284 | 500.00 | 1000.00 | 1 |
| 31-Oct | 304 | 500.00 | 1000.00 | 1 |
| 1-Nov | 305 | 200.00 | 500.00 | 1 |
| 1-Dec | 335 | 200.00 | 400.00 | 1 |
| 31-Dec | 365 | 200.00 | 400.00 | 1 |

**surplus(+)/Deficit(-) Control Factors**

| Date from | Julian Day from | +Q_out 1.00=yes 0.00=No | -Q_out 1.00=yes 0.00=No |
|---|---|---|---|
| 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 1.00 | 1.00 |

**Stanislaus**

| Temperature Control - Critical Year | | | | | Flow Control - Critical Year | | | | | surplus(+)/Deficit(-) Control Factors | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Julian Day | Temp Target | RM | Selected Temp | Date | Julian Day | Min_Q | Max_Q | Selected flow | Date | Julian Day | +Q_out | -Q_out |
| from | from | F | (in-river) | (0=Base, 1=Target) | from | from | cfs | cfs | (0=Base, 1=Alt) | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 53.60 | 39.40 | 1 | 1-Jan | 1 | 200.00 | 400.00 | 1 | 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 53.60 | 39.40 | 1 | 1-Feb | 32 | 200.00 | 400.00 | 1 | 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 53.60 | 39.40 | 1 | 1-Mar | 60 | 300.00 | 500.00 | 1 | 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 53.60 | 39.40 | 1 | 1-Apr | 91 | 500.00 | 750.00 | 1 | 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 53.60 | 39.40 | 1 | 1-May | 121 | 750.00 | 1000.00 | 1 | 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 53.60 | 39.40 | 1 | 1-Jun | 152 | 750.00 | 1500.00 | 1 | 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 53.60 | 39.40 | 1 | 30-Jun | 181 | 750.00 | 1500.00 | 1 | 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 64.00 | 50.60 | 1 | 1-Jul | 182 | 200.00 | 300.00 | 1 | 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 64.00 | 50.60 | 1 | 10-Oct | 283 | 200.00 | 300.00 | 1 | 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 53.60 | 39.40 | 1 | 11-Oct | 284 | 500.00 | 800.00 | 1 | 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 53.60 | 39.40 | 1 | 31-Oct | 304 | 500.00 | 800.00 | 1 | 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 53.60 | 39.40 | 1 | 1-Nov | 305 | 200.00 | 500.00 | 1 | 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 53.60 | 39.40 | 1 | 1-Dec | 335 | 200.00 | 400.00 | 1 | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 39.40 | 1 | 31-Dec | 365 | 200.00 | 400.00 | 1 | 31-Dec | 365 | 1.00 | 1.00 |

**Temperature and flow targets by water year type for the Tuolumne River temperature operation SalSim run.**

**Tuolumne**

| Temperature Control - Wet Year | | | | |
|---|---|---|---|---|
| Date from | Julian Day from | Temp Target F | RM (in-river) | Selected Temp (0=Base, 1=Target) |
| 1-Jan | 1 | 53.60 | 27.60 | 1 |
| 1-Feb | 32 | 53.60 | 27.60 | 1 |
| 1-Mar | 60 | 53.60 | 27.60 | 1 |
| 1-Apr | 91 | 53.60 | 27.60 | 1 |
| 1-May | 121 | 53.60 | 27.60 | 1 |
| 1-Jun | 152 | 53.60 | 27.60 | 1 |
| 30-Jun | 181 | 53.60 | 27.60 | 1 |
| 1-Jul | 182 | 64.00 | 43.60 | 1 |
| 10-Oct | 283 | 64.00 | 43.60 | 1 |
| 11-Oct | 284 | 53.60 | 43.60 | 1 |
| 31-Oct | 304 | 53.60 | 27.60 | 1 |
| 1-Nov | 305 | 53.60 | 27.60 | 1 |
| 1-Dec | 335 | 53.60 | 27.60 | 1 |
| 31-Dec | 365 | 53.60 | 27.60 | 1 |

| Flow Control - Wet Year | | | | |
|---|---|---|---|---|
| Date from | Julian Day from | Min_Q cfs | Max_Q cfs | Selected flow (0=Base, 1=Alt) |
| 1-Jan | 1 | 400.00 | 1000.00 | 1 |
| 1-Feb | 32 | 400.00 | 1000.00 | 1 |
| 1-Mar | 60 | 800.00 | 2000.00 | 1 |
| 1-Apr | 91 | 1000.00 | 2500.00 | 1 |
| 1-May | 121 | 2000.00 | 3000.00 | 1 |
| 1-Jun | 152 | 2500.00 | 4000.00 | 1 |
| 30-Jun | 181 | 2500.00 | 4000.00 | 1 |
| 1-Jul | 182 | 400.00 | 600.00 | 1 |
| 10-Oct | 283 | 400.00 | 600.00 | 1 |
| 11-Oct | 284 | 500.00 | 2000.00 | 1 |
| 31-Oct | 304 | 500.00 | 2000.00 | 1 |
| 1-Nov | 305 | 400.00 | 1000.00 | 1 |
| 1-Dec | 335 | 400.00 | 1000.00 | 1 |
| 31-Dec | 365 | 400.00 | 1000.00 | 1 |

| surplus(+)/Deficit(-) Control Factors | | | |
|---|---|---|---|
| Date from | Julian Day from | +Q_out 1.00=yes 0.00=No | -Q_out 1.00=yes 0.00=No |
| 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 1.00 | 1.00 |

**Tuolumne**

| Temperature Control - Above Normal Year | | | | | | Flow Control - Above Normal Year | | | | | | surplus(+)/Deficit(-) Control Factors | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Julian Day | Temp Target | RM | Selected Temp | | Date | Julian Day | Min_Q | Max_Q | Selected flow | | Date | Julian Day | +Q_out | -Q_out |
| from | from | F | (in-river) | (0=Base, 1=Target) | | from | from | cfs | cfs | (0=Base, 1=Alt) | | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 53.60 | 27.60 | 1 | | 1-Jan | 1 | 300.00 | 500.00 | 1 | | 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 53.60 | 27.60 | 1 | | 1-Feb | 32 | 300.00 | 500.00 | 1 | | 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 53.60 | 27.60 | 1 | | 1-Mar | 60 | 500.00 | 1500.00 | 1 | | 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 53.60 | 27.60 | 1 | | 1-Apr | 91 | 750.00 | 2000.00 | 1 | | 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 53.60 | 27.60 | 1 | | 1-May | 121 | 1500.00 | 2500.00 | 1 | | 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 53.60 | 27.60 | 1 | | 1-Jun | 152 | 2000.00 | 3000.00 | 1 | | 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 53.60 | 27.60 | 1 | | 30-Jun | 181 | 2000.00 | 3000.00 | 1 | | 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 64.00 | 43.60 | 1 | | 1-Jul | 182 | 200.00 | 400.00 | 1 | | 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 64.00 | 43.60 | 1 | | 10-Oct | 283 | 200.00 | 400.00 | 1 | | 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 53.60 | 27.60 | 1 | | 11-Oct | 284 | 500.00 | 1750.00 | 1 | | 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 53.60 | 27.60 | 1 | | 31-Oct | 304 | 500.00 | 1750.00 | 1 | | 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 53.60 | 27.60 | 1 | | 1-Nov | 305 | 500.00 | 750.00 | 1 | | 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 53.60 | 27.60 | 1 | | 1-Dec | 335 | 300.00 | 500.00 | 1 | | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 27.60 | 1 | | 31-Dec | 365 | 300.00 | 500.00 | 1 | | 31-Dec | 365 | 1.00 | 1.00 |

**Tuolumne**

| Temperature Control - Below Normal Year | | | | | Flow Control - Below Normal Year | | | | | surplus(+)/Deficit(-) Control Factors | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Julian Day | Temp Target | RM | Selected Temp | Date | Julian Day | Min_Q | Max_Q | Selected flow | Date | Julian Day | +Q_out | -Q_out |
| from | from | F | (in-river) | (0=Base, 1=Target) | from | from | cfs | cfs | (0=Base, 1=Alt) | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 53.60 | 27.60 | 1 | 1-Jan | 1 | 200.00 | 400.00 | 1 | 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 53.60 | 27.60 | 1 | 1-Feb | 32 | 200.00 | 400.00 | 1 | 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 53.60 | 27.60 | 1 | 1-Mar | 60 | 400.00 | 1250.00 | 1 | 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 53.60 | 27.60 | 1 | 1-Apr | 91 | 600.00 | 1500.00 | 1 | 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 53.60 | 27.60 | 1 | 1-May | 121 | 800.00 | 2000.00 | 1 | 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 53.60 | 27.60 | 1 | 1-Jun | 152 | 1000.00 | 2500.00 | 1 | 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 53.60 | 27.60 | 1 | 30-Jun | 181 | 1000.00 | 2500.00 | 1 | 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 64.00 | 43.60 | 1 | 1-Jul | 182 | 100.00 | 300.00 | 1 | 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 64.00 | 43.60 | 1 | 10-Oct | 283 | 100.00 | 300.00 | 1 | 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 53.60 | 27.60 | 1 | 11-Oct | 284 | 500.00 | 1500.00 | 1 | 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 53.60 | 27.60 | 1 | 31-Oct | 304 | 500.00 | 1500.00 | 1 | 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 53.60 | 27.60 | 1 | 1-Nov | 305 | 200.00 | 500.00 | 1 | 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 53.60 | 27.60 | 1 | 1-Dec | 335 | 200.00 | 400.00 | 1 | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 27.60 | 1 | 31-Dec | 365 | 200.00 | 400.00 | 1 | 31-Dec | 365 | 1.00 | 1.00 |

**Tuolumne**

| Temperature Control - Dry Year | | | | | | Flow Control - Dry Year | | | | | | surplus(+)/Deficit(-) Control Factors | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Julian Day | Temp Target | RM | Selected Temp | | Date | Julian Day | Min_Q | Max_Q | Selected flow | | Date | Julian Day | +Q_out | -Q_out |
| from | from | F | (in-river) | (0=Base, 1=Target) | | from | from | cfs | cfs | (0=Base, 1=Alt) | | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 53.60 | 35.60 | 1 | | 1-Jan | 1 | 200.00 | 400.00 | 1 | | 1-Jan | 1 | 1.00 | 0.00 |
| 1-Feb | 32 | 53.60 | 35.60 | 1 | | 1-Feb | 32 | 200.00 | 400.00 | 1 | | 1-Feb | 32 | 1.00 | 0.00 |
| 1-Mar | 60 | 53.60 | 35.60 | 1 | | 1-Mar | 60 | 400.00 | 1000.00 | 1 | | 1-Mar | 60 | 0.00 | 1.00 |
| 1-Apr | 91 | 53.60 | 35.60 | 1 | | 1-Apr | 91 | 600.00 | 1250.00 | 1 | | 1-Apr | 91 | 0.00 | 1.00 |
| 1-May | 121 | 53.60 | 35.60 | 1 | | 1-May | 121 | 800.00 | 1500.00 | 1 | | 1-May | 121 | 1.00 | 0.00 |
| 1-Jun | 152 | 53.60 | 35.60 | 1 | | 1-Jun | 152 | 1000.00 | 2000.00 | 1 | | 1-Jun | 152 | 1.00 | 0.00 |
| 30-Jun | 181 | 53.60 | 35.60 | 1 | | 30-Jun | 181 | 1000.00 | 2000.00 | 1 | | 30-Jun | 181 | 1.00 | 0.00 |
| 1-Jul | 182 | 64.00 | 43.60 | 1 | | 1-Jul | 182 | 100.00 | 300.00 | 1 | | 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 64.00 | 43.60 | 1 | | 10-Oct | 283 | 100.00 | 300.00 | 1 | | 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 53.60 | 35.60 | 1 | | 11-Oct | 284 | 500.00 | 1250.00 | 1 | | 11-Oct | 284 | 1.00 | 0.00 |
| 31-Oct | 304 | 53.60 | 35.60 | 1 | | 31-Oct | 304 | 500.00 | 1250.00 | 1 | | 31-Oct | 304 | 1.00 | 0.00 |
| 1-Nov | 305 | 53.60 | 35.60 | 1 | | 1-Nov | 305 | 200.00 | 500.00 | 1 | | 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 53.60 | 35.60 | 1 | | 1-Dec | 335 | 200.00 | 400.00 | 1 | | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 35.60 | 1 | | 31-Dec | 365 | 200.00 | 400.00 | 1 | | 31-Dec | 365 | 1.00 | 1.00 |

| Tuolumne | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature Control - Critical Year | | | | | Flow Control - Critical Year | | | | | surplus(+)/Deficit(-) Control Factors | | | |
| Date | Julian Day | Temp Target | RM | Selected Temp | Date | Julian Day | Min_Q | Max_Q | Selected flow | Date | Julian Day | +Q_out | -Q_out |
| from | from | F | (in-river) | (0=Base, 1=Target) | from | from | cfs | cfs | (0=Base, 1=Alt) | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 52.00 | 35.60 | 1 | 1-Jan | 1 | 200.00 | 400.00 | 1 | 1-Jan | 1 | 1.00 | 0.00 |
| 1-Feb | 32 | 52.00 | 35.60 | 1 | 1-Feb | 32 | 200.00 | 400.00 | 1 | 1-Feb | 32 | 1.00 | 0.00 |
| 1-Mar | 60 | 61.00 | 35.60 | 1 | 1-Mar | 60 | 400.00 | 800.00 | 1 | 1-Mar | 60 | 0.00 | 1.00 |
| 1-Apr | 91 | 61.00 | 35.60 | 1 | 1-Apr | 91 | 600.00 | 1250.00 | 1 | 1-Apr | 91 | 0.00 | 1.00 |
| 1-May | 121 | 61.00 | 35.60 | 1 | 1-May | 121 | 800.00 | 1500.00 | 1 | 1-May | 121 | 1.00 | 0.00 |
| 1-Jun | 152 | 61.00 | 35.60 | 1 | 1-Jun | 152 | 1000.00 | 1750.00 | 1 | 1-Jun | 152 | 1.00 | 0.00 |
| 30-Jun | 181 | 59.00 | 35.60 | 1 | 30-Jun | 181 | 1000.00 | 1750.00 | 1 | 30-Jun | 181 | 1.00 | 0.00 |
| 1-Jul | 182 | 59.00 | 49.20 | 1 | 1-Jul | 182 | 100.00 | 200.00 | 1 | 1-Jul | 182 | 1.00 | 0.00 |
| 10-Oct | 283 | 64.00 | 49.20 | 1 | 10-Oct | 283 | 100.00 | 200.00 | 1 | 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 64.00 | 35.60 | 1 | 11-Oct | 284 | 500.00 | 1000.00 | 1 | 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 53.60 | 35.60 | 1 | 31-Oct | 304 | 500.00 | 1000.00 | 1 | 31-Oct | 304 | 1.00 | 0.00 |
| 1-Nov | 305 | 53.60 | 35.60 | 1 | 1-Nov | 305 | 200.00 | 500.00 | 1 | 1-Nov | 305 | 1.00 | 0.00 |
| 1-Dec | 335 | 53.60 | 35.60 | 1 | 1-Dec | 335 | 200.00 | 400.00 | 1 | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 35.60 | 1 | 31-Dec | 365 | 200.00 | 400.00 | 1 | 31-Dec | 365 | 1.00 | 1.00 |

**Temperature and flow targets by water year type for the Merced River temperature operation SalSim run.**

| Merced River | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature Control - Wet Year | | | | | Flow Control - Wet Year | | | | | surplus(+)/Deficit(-) Control Factors | | | | |
| Date | Julian Day | Temp Target | RM | Selected Temp | Date | Julian Day | Min_Q | Max_Q | Selected flow | Date | Julian Day | +Q_out | -Q_out |
| from | from | F | (in-river) | (0=Base, 1=Target) | from | from | cfs | cfs | (0=Base, 1=Alt) | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 40.00 | 45.00 | 1 | 1-Jan | 1 | 400.00 | 800.00 | 1 | 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 40.00 | 45.00 | 1 | 1-Feb | 32 | 400.00 | 800.00 | 1 | 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 53.60 | 27.07 | 1 | 1-Mar | 60 | 800.00 | 1200.00 | 1 | 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 53.60 | 27.07 | 1 | 1-Apr | 91 | 800.00 | 1500.00 | 1 | 1-Apr | 91 | 1.00 | 1.00 |
| -May | 121 | 61.00 | 27.07 | 1 | 1-May | 121 | 1500.00 | 2500.00 | 1 | 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 61.00 | 27.07 | 1 | 1-Jun | 152 | 2000.00 | 4000.00 | 1 | 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 61.00 | 27.07 | 1 | 30-Jun | 181 | 2000.00 | 4000.00 | 1 | 30-Jun | 181 | 1.00 | 0.00 |
| 1-Jul | 182 | 64.00 | 27.07 | 1 | 1-Jul | 182 | 200.00 | 400.00 | 1 | 1-Jul | 182 | 1.00 | 0.00 |
| 10-Oct | 283 | 64.00 | 42.30 | 1 | 10-Oct | 283 | 200.00 | 400.00 | 1 | 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 53.60 | 42.30 | 1 | 11-Oct | 284 | 750.00 | 1500.00 | 1 | 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 53.60 | 27.07 | 1 | 31-Oct | 304 | 750.00 | 1500.00 | 1 | 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 53.60 | 27.07 | 1 | 1-Nov | 305 | 400.00 | 800.00 | 1 | 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 53.60 | 27.07 | 1 | 1-Dec | 335 | 400.00 | 500.00 | 1 | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 27.07 | 1 | 31-Dec | 365 | 400.00 | 500.00 | 1 | 31-Dec | 365 | 1.00 | 1.00 |

| Merced River | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature Control - Above Normal Year** | | | | | **Flow Control - Above Normal Year** | | | | | **surplus(+)/Deficit(-) Control Factors** | | | |
| **Date** | **Julian Day** | **Temp Target** | **RM** | **Selected Temp** | **Date** | **Julian Day** | **Min_Q** | **Max_Q** | **Selected flow** | **Date** | **Julian Day** | **+Q_out** | **-Q_out** |
| **from** | **from** | **F** | **(in-river)** | **(0=Base, 1=Target)** | **from** | **from** | **cfs** | **cfs** | **(0=Base, 1=Alt)** | **from** | **from** | **1.00=yes 0.00=No** | **1.00=yes 0.00=No** |
| 1-Jan | 1 | 40.00 | 45.00 | 1 | 1-Jan | 1 | 200.00 | 400.00 | 1 | 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 40.00 | 45.00 | 1 | 1-Feb | 32 | 200.00 | 400.00 | 1 | 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 53.60 | 42.10 | 1 | 1-Mar | 60 | 600.00 | 1000.00 | 1 | 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 53.60 | 42.10 | 1 | 1-Apr | 91 | 600.00 | 1250.00 | 1 | 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 61.00 | 42.10 | 1 | 1-May | 121 | 1000.00 | 2000.00 | 1 | 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 61.00 | 42.10 | 1 | 1-Jun | 152 | 1000.00 | 2500.00 | 1 | 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 61.00 | 42.10 | 1 | 30-Jun | 181 | 1500.00 | 2500.00 | 1 | 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 64.00 | 46.70 | 1 | 1-Jul | 182 | 100.00 | 300.00 | 1 | 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 64.00 | 46.70 | 1 | 10-Oct | 283 | 100.00 | 300.00 | 1 | 10-Oct | 283 | 0.00 | 1.00 |
| 11-Oct | 284 | 53.60 | 42.10 | 1 | 11-Oct | 284 | 750.00 | 1250.00 | 1 | 11-Oct | 284 | 0.00 | 1.00 |
| 31-Oct | 304 | 53.60 | 42.10 | 1 | 31-Oct | 304 | 750.00 | 1250.00 | 1 | 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 53.60 | 42.10 | 1 | 1-Nov | 305 | 200.00 | 500.00 | 1 | 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 53.60 | 42.10 | 1 | 1-Dec | 335 | 200.00 | 400.00 | 1 | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 42.10 | 1 | 31-Dec | 365 | 200.00 | 400.00 | 1 | 31-Dec | 365 | 1.00 | 1.00 |

**Merced River**

| Temperature Control - Below Normal Year | | | | | Flow Control - Below Normal Year | | | | | surplus(+)/Deficit(-) Control Factors | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Julian Day | Temp Target | RM | Selected Temp | Date | Julian Day | Min_Q | Max_Q | Selected flow | Date | Julian Day | +Q_out | -Q_out |
| from | from | F | (in-river) | (0=Base, 1=Target) | from | from | cfs | cfs | (0=Base, 1=Alt) | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 52.00 | 45.00 | 1 | 1-Jan | 1 | 200.00 | 350.00 | 1 | 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 52.00 | 45.00 | 1 | 1-Feb | 32 | 200.00 | 350.00 | 1 | 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 53.60 | 42.10 | 1 | 1-Mar | 60 | 400.00 | 800.00 | 1 | 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 53.60 | 42.10 | 1 | 1-Apr | 91 | 500.00 | 1000.00 | 1 | 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 61.00 | 42.10 | 1 | 1-May | 121 | 750.00 | 1500.00 | 1 | 1-May | 121 | 1.00 | 1.00 |
| 1-Jun | 152 | 61.00 | 42.10 | 1 | 1-Jun | 152 | 1000.00 | 2000.00 | 1 | 1-Jun | 152 | 1.00 | 1.00 |
| 30-Jun | 181 | 61.00 | 42.10 | 1 | 30-Jun | 181 | 1000.00 | 2000.00 | 1 | 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 64.00 | 46.70 | 1 | 1-Jul | 182 | 100.00 | 300.00 | 1 | 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 64.00 | 46.70 | 1 | 10-Oct | 283 | 100.00 | 300.00 | 1 | 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 53.60 | 42.10 | 1 | 11-Oct | 284 | 500.00 | 1000.00 | 1 | 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 53.60 | 42.10 | 1 | 31-Oct | 304 | 500.00 | 1000.00 | 1 | 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 53.60 | 42.10 | 1 | 1-Nov | 305 | 200.00 | 500.00 | 1 | 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 53.60 | 42.10 | 1 | 1-Dec | 335 | 200.00 | 350.00 | 1 | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 42.10 | 1 | 31-Dec | 365 | 200.00 | 350.00 | 1 | 31-Dec | 365 | 1.00 | 1.00 |

**Merced River**

| Temperature Control - Dry Year | | | | | Flow Control - Dry Year | | | | | surplus(+)/Deficit(-) Control Factors | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Julian Day | Temp Target | RM | Selected Temp | Date | Julian Day | Min_Q | Max_Q | Selected flow | Date | Julian Day | +Q_out | -Q_out |
| from | from | F | (in-river) | (0=Base, 1=Target) | from | from | cfs | cfs | (0=Base, 1=Alt) | from | from | 1.00=yes 0.00=No | 1.00=yes 0.00=No |
| 1-Jan | 1 | 52.00 | 45.00 | 1 | 1-Jan | 1 | 200.00 | 300.00 | 1 | 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 52.00 | 45.00 | 1 | 1-Feb | 32 | 200.00 | 300.00 | 1 | 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 56.00 | 42.10 | 1 | 1-Mar | 60 | 300.00 | 500.00 | 1 | 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 56.00 | 42.10 | 1 | 1-Apr | 91 | 500.00 | 800.00 | 1 | 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 61.00 | 42.10 | 1 | 1-May | 121 | 750.00 | 1000.00 | 1 | 1-May | 121 | 1.00 | 0.00 |
| 1-Jun | 152 | 61.00 | 42.10 | 1 | 1-Jun | 152 | 750.00 | 1500.00 | 1 | 1-Jun | 152 | 1.00 | 0.00 |
| 30-Jun | 181 | 61.00 | 42.10 | 1 | 30-Jun | 181 | 750.00 | 1500.00 | 1 | 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 64.00 | 46.70 | 1 | 1-Jul | 182 | 100.00 | 200.00 | 1 | 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 64.00 | 46.70 | 1 | 10-Oct | 283 | 100.00 | 200.00 | 1 | 10-Oct | 283 | 0.00 | 1.00 |
| 11-Oct | 284 | 53.60 | 42.10 | 1 | 11-Oct | 284 | 200.00 | 500.00 | 1 | 11-Oct | 284 | 0.00 | 1.00 |
| 31-Oct | 304 | 53.60 | 42.10 | 1 | 31-Oct | 304 | 200.00 | 500.00 | 1 | 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 53.60 | 42.10 | 1 | 1-Nov | 305 | 200.00 | 400.00 | 1 | 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 53.60 | 42.10 | 1 | 1-Dec | 335 | 200.00 | 300.00 | 1 | 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 53.60 | 42.10 | 1 | 31-Dec | 365 | 200.00 | 300.00 | 1 | 31-Dec | 365 | 1.00 | 1.00 |

## Merced River

**Temperature Control - Critical Year**

| Date from | Julian Day from | Temp Target F | RM (in-river) | Selected Temp (0=Base, 1=Target) |
|---|---|---|---|---|
| 1-Jan | 1 | 52.00 | 45.00 | 1 |
| 1-Feb | 32 | 52.00 | 45.00 | 1 |
| 1-Mar | 60 | 56.00 | 42.10 | 1 |
| 1-Apr | 91 | 56.00 | 42.10 | 1 |
| 1-May | 121 | 61.00 | 42.10 | 1 |
| 1-Jun | 152 | 61.00 | 42.10 | 1 |
| 30-Jun | 181 | 61.00 | 42.10 | 1 |
| 1-Jul | 182 | 64.00 | 46.70 | 1 |
| 10-Oct | 283 | 64.00 | 46.70 | 1 |
| 11-Oct | 284 | 53.60 | 42.10 | 1 |
| 31-Oct | 304 | 53.60 | 42.10 | 1 |
| 1-Nov | 305 | 53.60 | 42.10 | 1 |
| 1-Dec | 335 | 53.60 | 42.10 | 1 |
| 31-Dec | 365 | 53.60 | 42.10 | 1 |

**Flow Control - Critical Year**

| Date from | Julian Day from | Min_Q cfs | Max_Q cfs | Selected flow (0=Base, 1=Alt) |
|---|---|---|---|---|
| 1-Jan | 1 | 200.00 | 300.00 | 1 |
| 1-Feb | 32 | 200.00 | 300.00 | 1 |
| 1-Mar | 60 | 300.00 | 400.00 | 1 |
| 1-Apr | 91 | 400.00 | 600.00 | 1 |
| 1-May | 121 | 500.00 | 800.00 | 1 |
| 1-Jun | 152 | 700.00 | 1000.00 | 1 |
| 30-Jun | 181 | 700.00 | 1000.00 | 1 |
| 1-Jul | 182 | 100.00 | 200.00 | 1 |
| 10-Oct | 283 | 100.00 | 200.00 | 1 |
| 11-Oct | 284 | 200.00 | 400.00 | 1 |
| 31-Oct | 304 | 200.00 | 400.00 | 1 |
| 1-Nov | 305 | 200.00 | 300.00 | 1 |
| 1-Dec | 335 | 200.00 | 300.00 | 1 |
| 31-Dec | 365 | 200.00 | 300.00 | 1 |

**surplus(+)/Deficit(-) Control Factors**

| Date from | Julian Day from | +Q_out 1.00=yes 0.00=No | -Q_out 1.00=yes 0.00=No |
|---|---|---|---|
| 1-Jan | 1 | 1.00 | 1.00 |
| 1-Feb | 32 | 1.00 | 1.00 |
| 1-Mar | 60 | 1.00 | 1.00 |
| 1-Apr | 91 | 1.00 | 1.00 |
| 1-May | 121 | 1.00 | 0.00 |
| 1-Jun | 152 | 1.00 | 0.00 |
| 30-Jun | 181 | 1.00 | 1.00 |
| 1-Jul | 182 | 1.00 | 1.00 |
| 10-Oct | 283 | 1.00 | 1.00 |
| 11-Oct | 284 | 1.00 | 1.00 |
| 31-Oct | 304 | 1.00 | 1.00 |
| 1-Nov | 305 | 1.00 | 1.00 |
| 1-Dec | 335 | 1.00 | 1.00 |
| 31-Dec | 365 | 1.00 | 1.00 |