Appendix E

Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program

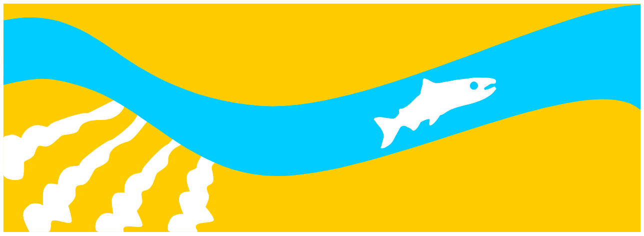
Draft
Program Environmental Impact Statement/Report

SAN JOAQUIN RIVER
RESTORATION PROGRAM

Draft
April 2011

Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program

SAN JOAQUIN RIVER
RESTORATION PROGRAM



November 2010

Executive Summary

In 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit challenging the renewal of long-term water service contracts between the United States and California's Central Valley Project Friant Division contractors. After more than 18 years of litigation, the lawsuit, known as *NRDC et al. v. Kirk Rodgers et al.*, reached a Stipulation of Settlement (Settlement). The Settling Parties, including NRDC, Friant Water Users Authority, and the U.S. Departments of the Interior and Commerce, agreed on the terms and conditions of the Settlement, which was subsequently approved on October 23, 2006.

The Settlement establishes two primary goals:

- **Restoration Goal –** To restore and maintain fish populations in "good condition" in the mainstem San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.

- **Water Management Goal –** To reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

The Settlement establishes a framework for accomplishing the Restoration and Water Management goals that will require environmental review, design, and construction of projects over a multiple-year period. To achieve the Restoration Goal, the Settlement calls for a combination of channel and structural modifications along the San Joaquin River below Friant Dam, releases of water from Friant Dam to the confluence of the Merced River, and the reintroduction of Chinook salmon, *Oncorhynchus tshawytscha*.

In response to the Settlement, the implementing agencies, consisting of the U.S. Department of Interior, Bureau of Reclamation (Reclamation) and U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), California Department of Fish and Game (DFG), and California Department of Water Resources (DWR) organized a Program Management Team and associated Work Groups to begin work implementing the Settlement. For additional information related to the Implementing Agency approach, the reader is referred to the Program Management Plan available on the San Joaquin River Restoration Program (SJRRP) Web site, www.restoresjr.net.

Related to the Settlement, President Obama signed the San Joaquin River Restoration Act (Act) on March 30, 2009, giving the Department of Interior full authority to implement the SJRRP. The SJRRP will implement the Settlement and Act.

Fisheries Management Plan

The Fisheries Management Work Group (FMWG), composed of representatives from Reclamation, USFWS, NMFS, DFG, DWR, and consultants, was tasked with developing the Fisheries Management Plan (FMP) as a first step in the Restoration Goal planning process. The FMWG immediately began work in early 2007 researching fisheries management planning approaches in other systems. Conceptual models for spring- and fall-run Chinook salmon were developed, forming the basis of the FMP, which was completed in a collaborative process. In addition, numerous Technical Feedback meetings were open to the public to discuss the development and technical assumptions of the FMP.

Adaptive Management Approach

This FMP is a first step in the Restoration Goal planning process and lays out a structured approach to adaptively manage the reintroduction of Chinook salmon and other fishes. This FMP is not intended to be an implementation plan for program-level or site-specific-level projects. The FMP provides a roadmap to adaptively manage efforts to restore and maintain naturally reproducing and self-sustaining populations of Chinook salmon and other fish in the San Joaquin River between Friant Dam and the confluence with the Merced River (Restoration Area). It addresses the SJRRP on a program-level and refers to how the Settlement will be implemented programmatically from a fisheries perspective. The FMP will be revised as needed, reflecting changes in implementation strategy as a result of the Adaptive Management Approach, described later in this FMP.

Given the uncertainty associated with reintroduction of Chinook salmon and native fish to the San Joaquin River, and the complexity of the SJRRP, an adaptive management program is needed to ensure the SJRRP can be flexible, adjusting as new information becomes available. The responses of reestablished Chinook salmon and other fishes to physical factors such as temperature, streamflow, climate change, and the impacts of various limiting factors are unknown. Adaptive management is an approach allowing decision makers to take advantage of a variety of strategies and techniques that are adjusted, refined, and/or modified based on an improved understanding of system dynamics.

The FMP is organized in sections according to the Adaptive Management Approach as applied to the SJRRP. This organization serves as a planning and procedural tool for managers and technical specialists of the SJRRP. The FMP is divided into six key sections, with each section/chapter representing a discrete component of the Adaptive Management Approach. These sections are:

1. Environmental Conditions: Defining the Problem
2. Fish Management Goals and Objectives
3. Conceptual and Quantitative Models
4. Develop and Route Actions

5. Program Monitoring and Evaluation
6. SJRRP Assessment Evaluation and Adaptation

Environmental Conditions: Defining the Problem

Because of alterations to the system, the San Joaquin River no longer supports fall-run or spring-run Chinook salmon. A substantial amount of information is known concerning the problems that must be remedied to reestablish Chinook salmon and other fishes in the San Joaquin River. The FMP summarizes known information about existing conditions, helping define the problems that need to be addressed to reestablish Chinook salmon and other fishes in the San Joaquin River. Information regarding existing habitat, water quality, recreational use, fish populations, and climate change is summarized.

Fish Management Goals and Objectives

Overarching population and habitat goals are necessary to provide a comprehensive vision to restore fish populations and appropriate habitat in the Restoration Area. The goals described were used to form specific objectives, which are intended to be realistic and measurable so the program will have a quantitative means of evaluating program success. Fish management goals are separated into two categories – population goals and habitat goals. Three of the population goals presented in the FMP are based on Restoration Administrator recommendations. A fourth goal for Chinook salmon, which was based on principles of population genetics, and a fifth goal, which addressed other native fishes, were developed. Six habitat goals were established for the Restoration Area focusing on improved streamflow conditions and the establishment of suitable habitat.

The goals were used to establish realistic and measurable population and habitat objectives that will be used to evaluate overall program success. The recommended objectives should be treated as preliminary recommendations, recognizing that the objectives will very likely be revised as more is learned about the conditions and capacities of the system. The fish management goals and objectives are described further in Chapter 3.

Conceptual and Quantitative Modeling

Before the development of the FMP, conceptual models for spring-run and fall-run Chinook salmon were developed by the FMWG to lay the foundation for the FMP. Conceptual models provide the explicit link between goals and restoration actions. Conceptual models are simple depictions of how parts of the ecosystem are believed to work and how they might respond to restoration actions. These models are explicit representations of scientists' and resource managers' understanding of system functions. Conceptual models are used to develop restoration actions that have a high likelihood of achieving an objective while providing information to increase understanding of ecosystem function and, in some instances, to resolve conflicts among alternative hypotheses about the ecosystem.

The absence of Chinook salmon populations in the San Joaquin River provides considerable uncertainty in their planning. Therefore, quantitative models provide structured analyses enabling adaptive management of the SJRRP. Specifically, selected fisheries quantitative model(s) would assist in the following tasks:

- Refining population goals
- Planning habitat restoration and flow management actions
- Developing expected fish survival rates attributable to different restoration activities
- Identifying and prioritizing limiting factors that will require restoration or other actions
- Adaptive management planning through identifying key uncertainties and data needs, and developing testable hypotheses

Ecosystem Diagnosis and Treatment (EDT) was the first modeling approach selected for use in the SJRRP because it provides a framework that views Chinook salmon as the diagnostic species for the ecosystem. The EDT framework was designed so that analyses made at different spatial scales (i.e., from tributary watersheds to successively larger watersheds) can be related and linked. Biological performance is a central feature of the framework and is defined in terms of three elements: life history diversity, productivity, and capacity. These elements of performance are characteristics of the ecosystem that describe persistence, abundance, and distribution potential of a population. The analytical model uses environmental information and draws conclusions about the ecosystem.

Develop and Route Actions

Once limiting factors are identified in the conceptual models, potential solutions (i.e., actions) to ameliorate the limiting factors needed to be developed and assessed in a transparent structured analysis. In many cases, there may be more than one potential action that could reduce the effects of a limiting factor. As new information becomes available, the relative importance of limiting factors may change, resulting in the development of new actions or the removal of actions. In the Adaptive Management Approach, the potential actions include Settlement actions and additional actions considered as a means to meet particular fisheries goals.

Potential actions for limiting factors were developed based on Settlement requirements, pre-Settlement background information, actions commonly applied in the Central Valley, and additional actions identified in scientific literature. Actions were developed and sorted by the FMWG into adaptive management categories via the action routing process described in Chapter 5.

Potential actions developed to reduce the effects of limiting factors are routed through a decision tree. Action routing results in recommendations to conduct a targeted study, small-scale implementation, or full implementation depending on evaluation factors (e.g., worth, risk, reversibility). For example, inadequate streamflow is a limiting factor addressed by the Settlement flow schedule action. The Settlement flow schedule was routed through the decision tree and resulted in full implementation being recommended for that action.

The specific process of action routing began with limiting factor analyses in the conceptual models. Potential actions were developed and routed through a decision matrix. Objectives were developed to ameliorate limiting factors affecting particular life stages and reaches. Data needs and monitoring of actions were included to highlight what data were needed to evaluate the actions and how it would be monitored to obtain that data. Data needs are expected to yield additional information to better inform a management action and may be necessary before recommendations can be made to implement an action. Monitoring allows for assessing hypotheses, especially actions associated with moderate to high uncertainty. Potential triggers and adaptive responses address how results from monitoring actions will be used to determine alterations of actions or the development of new actions.

A total of 19 objectives was developed to ameliorate limiting factors and a total of 61 separate actions were routed through the decision process. Note, some potential actions are routed multiple times; however, they are routed under different limiting factors and may have different goals and objectives. The recommended adaptive management category is included for each action.

Program Monitoring and Evaluation

Monitoring is a critical component of the adaptive management process and will be used to assess the performance of the SJRRP. The monitoring framework includes program-level monitoring, monitoring for population objectives, and monitoring for physical-habitat parameters, and will enable the collection of information required by management to make operational decisions. Specific protocols and details of a real-time program will be detailed in a future publication.

Program-level monitoring is designed to measure the overall success of the program in meeting the objectives established in the Goals and Objectives section. Program-level monitoring is generally at the fisheries population level, and consists of measuring elements such as escapement levels, viability values, and genetic fitness. The population and habitat objectives identified for the SJRRP are listed and potential monitoring methods are provided under each objective.

SJRRP Assessment, Evaluation, and Adaptation

An assessment, evaluation, and adaptation process is described to revise management actions as new knowledge is acquired and scientific understanding improves. New knowledge must appropriately affect the governance and management of the SJRRP, enabling change in management actions and implementation. For example, new water temperature information from either modeling or quantitative studies could change the emphasis on the spatial extent of floodplain construction for juvenile Chinook salmon. This new information could change the physical habitat goals for Chinook salmon and other fishes. Changes in the goals can lead to revised objectives and a new suite of actions designed to achieve those objectives.

Both policy and technical expertise are needed to achieve successful integration of new knowledge into the management of the SJRRP. The results of such integration can affect the SJRRPs goals, objectives, models, actions, and monitoring. Such continual assimilation of new information requires internal and external processes, operating at multiple time scales. A description of the process that will be used to assess, evaluate, and adapt the SJRRP to new information is included.

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Abbreviations and Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
Act	San Joaquin River Restoration Act
AFSP	Anadromous Fish Screen Program
Basin Plan	Water Quality Control Plan for the Sacramento River Basin and the San Joaquin River Basin
B-IBI	Benthic index of biotic integrity
BMI	Benthic macroinvertebrate
CALFED	CALFED Bay-Delta Program
cfs	cubic feet per second
cm	centimeters
cm/s	centimeters per second
CVP	Central Valley Project
CVWB	Central Valley Water Board
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
DMC	Delta-Mendota Canal
DNA	deoxyribonucleic acid
DO	dissolved oxygen
DPS	district population segment
DWR	California Department of Water Resources
EDT	Ecosystem Diagnosis and Treatment
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FD	Friant Division
FL	fork length
FMWG	Fisheries Management Work Group
FMP	Fisheries Management Plan
FR	Federal Register
FWUA	Friant Water Users Authority
g	grams
g/day	grams per day

H_A	assessing hypotheses
IBM	Individual based model
IPCC	Intergovernmental Panel on Climate Change
m^2	square meters
mg/L	milligrams per liter
mg N/L	milligrams nitrogen per liter
mm	millimeter
NMFS	National Marine Fisheries Service
NOD	Notice of Determination
NRDC	Natural Resources Defense Council
PEIS/R	Program Environmental Impact Statement/Environmental Impact Report
PIT	passive integrated transponder
PMP	Program Management Plan
ppt	parts-per-thousand
PTA	Patient-Template Analysis
RA	Restoration Administrator
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
Restoration Area	San Joaquin River from Friant Dam to the confluence with the Merced River
RM	river mile
RNA	ribonucleic acid
ROD	Record of Decision
SAG	Science Advisory Group
Secretary	Secretary of the U.S. Department of Interior
Settlement	Stipulations of the Settlement Agreement
SJR5Q	water temperature model
SJRRP	San Joaquin River Restoration Program
SR	State Route
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
TCD	temperature control device
TM	Technical Memoranda
USFWS	U.S. Fish and Wildlife Service
VSP	Viable Salmonid Population

Chapter 1 Introduction

In 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit challenging the renewal of long-term water service contracts between the United States and the Central Valley Project (CVP) Friant Division (FD) contractors. After more than 18 years of litigation, the lawsuit, known as *NRDC et al. v. Kirk Rodgers et al.*, reached a Stipulation of Settlement (Settlement) on September 13, 2006. The Settling Parties, including NRDC, Friant Water Users Authority (FWUA), and the U.S. Departments of the Interior (Interior) and Commerce, agreed on the terms and conditions of the Settlement, which was subsequently approved by the U.S. Eastern District Court of California on October 23, 2006. The Settlement establishes two primary goals:

- **Restoration Goal –** To restore and maintain fish populations in "good condition" in the mainstem San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.

- **Water Management Goal –** To reduce or avoid adverse water supply impacts to all of the FD long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

Photo: USFWS

The Settlement establishes a framework for accomplishing the Restoration and Water Management goals that will require environmental review, design, and construction of projects over a multiple-year period. To achieve the Restoration Goal, the Settlement calls for a combination of channel and structural modifications along the San Joaquin River below Friant Dam, releases of water from Friant Dam to the confluence of the Merced River, and the reintroduction of Chinook salmon (*Oncorhynchus tshawytscha)*. To achieve the Water Management Goal, the Settlement calls for the downstream recapture of Restoration Flows to replace reductions in water supplies to FD long-term contractors resulting from the release of the Restoration Flows, establishes a Recovered Water Account, and allows the delivery of surplus water supplies to FD long-term contractors during wet hydrologic conditions.

President Obama signed the San Joaquin River Restoration Act (Act) on March 30, 2009, giving the Interior full authority to implement the Settlement. The implementing agencies form the San Joaquin River Restoration Program (SJRRP) and will implement the

Settlement and Act. Consistent with the National Environmental Policy Act and the California Environmental Quality Act, a Program Environmental Impact Statement/Environmental Impact Report (PEIS/R) is currently being prepared for the SJRRP. The PEIS/R considers the planned program as a whole, and thereby will assemble and analyze the range of direct, indirect, and cumulative impacts associated with the entire program rather than presenting detailed analyses of individual projects and actions within the SJRRP. With this approach, more detailed site-specific environmental documents for specific projects will be prepared in the future as project details are developed.

For additional information regarding the Settlement, the Act, and the SJRRP, the reader is referred to the Implementing Agencies guidance document known as the Program Management Plan (PMP) available on the SJRRP Web site, www.restoresjr.net.

1.1 Fisheries Management Plan Scope

This Fisheries Management Plan (FMP) is a first step in the Restoration Goal planning process and lays out a structured approach to adaptively manage the reintroduction of Chinook salmon and reestablishment of other fishes. This FMP is not intended to be an implementation plan for program-level or site-specific-level projects. The FMP provides a roadmap to adaptively manage efforts to restore and maintain naturally reproducing and self-sustaining populations of Chinook salmon and other fishes in the San Joaquin River between Friant Dam and the confluence with the Merced River (Restoration Area). It addresses the SJRRP on a program level and refers to how the Settlement will be implemented programmatically from a fisheries perspective. The FMP will be revised as needed, reflecting changes in implementation strategy as a result of the Adaptive Management Approach, described later in this FMP.

The FMP is not intended to be inconsistent with, or alter the Settlement in any way. However, if inconsistencies exist, the Settlement will be the controlling document. A combined PEIS/R and a Record of Decision/Notice of Determination (ROD/NOD) will document the environmental review process and the final decisions made by the Implementing Agencies. Whereas the FMP identifies the fisheries management of the SJRRP on a program level, associated implementation plan(s) will address the site-specific implementation and will be issued subsequent to the ROD/NOD.

1.2 Fisheries Management Planning Process

After the completion of the PMP in May 2007, which included a draft FMP outline, a Fisheries Management Work Group (FMWG), composed of representatives from U.S. Department of the Interior, Bureau of Reclamation (Reclamation), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), California Department of Fish and Game (DFG), California Department of Water Resources (DWR), and consultants, was organized to begin preparing the FMP.

The FMP was completed in a collaborative process. In addition, numerous Technical Feedback meetings were open to the public to discuss the development and technical assumptions of the FMP. These meetings provided a forum for public input on the development of the FMP and facilitated development of the FMP to create an open and transparent public process.

Important components in the FMP development were review and coordination from various external and internal sources and effective coordination with stakeholders and other programs operating in the Restoration Area. In addition, the FMP is based on the Adaptive Management Approach specifically developed for the SJRRP. Given the uncertainty associated with restoration of Chinook salmon and native fish populations to the San Joaquin River, and the complexity of the SJRRP, an adaptive management program is needed to ensure the SJRRP can be flexible, adjusting as new information becomes available.

Enabling the power of scientific problem solving into management actions through an adaptive management process has been previously described (Walters 1986, Bormann et al 1993, Scientific Panel for Sustainable Forest Practices in Clayoquot Sound 1995, Healey 2001, Instream Flow Council 2004). Adaptive management is an approach allowing decision makers to take advantage of a variety of strategies and techniques that are adjusted, refined, and/or modified based on an improved understanding of system dynamics. SJRRP restoration actions are restricted to the Restoration Area, thus limiting the application of adaptive management on an ecosystem-wide basis. Thorough monitoring and evaluation of adaptive management actions are critical to successful learning and resolution of scientific uncertainties. Results of monitoring and evaluation will be used to redefine problems, reexamine goals, and/or refine conceptual and quantitative models, to ensure efficient learning and adaptation of management techniques.

By using adaptive management, the SSJRP will respond and change the implementation and management strategy as new knowledge is gained. This Adaptive Management Approach will allow the FMWG to: (1) maximize the likelihood of success of actions, (2) increase learning opportunities, (3) identify data needs and reduce uncertainties, (4) use the best available information to provide technical support and increase the confidence in future decisions and recommendations, and (5) prioritize management actions.

There is an increasing need to embrace a strategic approach to landscape conservation due to rapidly changing threats to fish and wildlife resources (National Ecological Assessment Team 2006). Strategic habitat conservation is a structured, science-driven approach for making efficient, transparent decisions that incorporates an adaptive management approach. The principles of strategic habitat conservation planning were critically important in constructing the FMP. The U.S. Department of Interior Adaptive Management Guidelines (Williams et al. 2007) and the recent Independent Review of the Central Valley Project Improvement Act's Fisheries Program (Cummins et al. 2008) were also important in detailing the components of an effective adaptive management process and were used as a guide in building the FMP. In addition, numerous CALFED

Bay-Delta Program (CALFED) peer-reviewed and draft documents illustrating important processes and concepts associated with adaptive management, such as the 2001 Strategic Plan for Ecosystem Restoration (CALFED 2001), were also used in building this FMP. The draft Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan (Terraqua, Inc. 2004) also incorporated many of the CALFED adaptive management principles and was an important resource. The Adaptive Management Approach used in this FMP, is broken into discrete stages. It is illustrated in Figure 1-1, and includes descriptions of the major decision points represented by boxes.

The FMWG also would like to acknowledge the significant work in the form of recommendations developed by the Restoration Administration (RA). These recommendations have helped the FMWG in developing many sections of the FMP, particularly the numeric population goals. These recommendations include topics such as spring-run stock selection and population targets (Meade 2007), fall-run population targets (Meade 2008), and monitoring and evaluations during the Interim Flow period (Meade 2009).

1.3 Fisheries Management Plan Organization

The FMP is organized in sections according to the Adaptive Management Approach as applied to the SJRRP (Figure 1-1). This organization serves as a planning and procedural tool for SJRRP managers and technical specialists. Although the FMP is a stand-alone document, it is also a component of the PEIS/R for the SJRRP. Concurrent to the development of the FMP, Technical Appendices and SJRRP Technical Memoranda (TM) were developed that include more detail intended to support the PEIS/R. They also provide background information for the FMP.

Readers interested in learning more about the SJRRP and related actions including historic details of the San Joaquin River are encouraged to read the Settlement, PEIS/R, and other background documents on the public Web site, www.restoresjr.net.

The FMP is divided into six key sections, with each section/chapter representing a discrete component of the Adaptive Management Approach (as shown in Figure 1-1). For example, the existing conditions, which define the problem in the Restoration Area are described in Chapter 2, and are represented by the upper left box entitled “Define Problem.” The development of fish management goals, including fish and habitat, is discussed in Chapter 3. Chapter 4 describes the conceptual and quantitative models developed specifically for the SJRRP. Chapter 5 describes the development and routing of potential SJRRP actions as well as the preliminary management decisions in the FMP. Chapter 6 describes program planning. Monitoring and evaluation methods are described in Chapter 7. Chapter 8 describes how the FMP will assess and evaluate the SJRRP on a long-term basis. Chapter 9 provides the references used to support and develop this FMP. Additional information supporting the FMP is provided in Exhibits A through F.

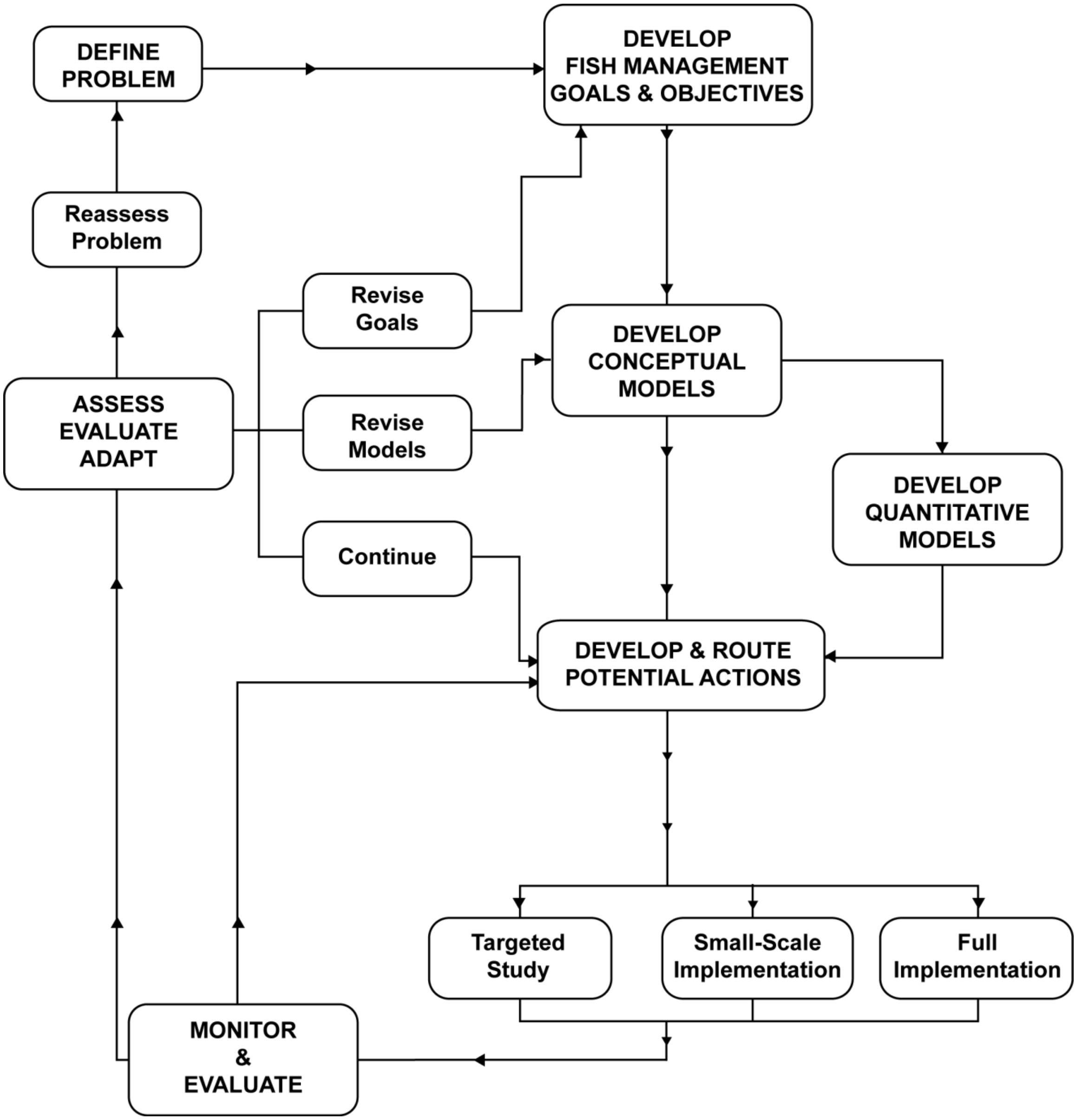

Figure 1-1.
San Joaquin River Restoration Fisheries Management Plan
Adaptive Management Approach

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Chapter 2 Environmental Conditions: Defining the Problem

Fall- and spring-run Chinook salmon were extirpated from the San Joaquin River following the completion of Friant Dam and resultant dewatering of the river 60 years ago. The last documented run of spring-run Chinook salmon in the upper San Joaquin River Basin, consisting of only 36 individuals, was observed in 1950 (Warner 1991). Since the 1950s, the remaining Chinook salmon in the San Joaquin Basin consist only of fall-run Chinook salmon populations found in major tributaries to the lower San Joaquin River. A substantial amount of information is known concerning the problems that must be remedied to reestablish Chinook salmon and other fishes in the Restoration Area (Jones and Stokes 2002, Stillwater Sciences 2003, Kondolf 2005, Moyle 2005, Meade 2007, Meade 2008). Exhibit A (*Conceptual Models of Stressors and Limiting Factors for San Joaquin River Chinook Salmon*) describes the life-history requirements and environmental factors most likely to affect the abundance of spring-run and fall-run Chinook salmon, as well as potential stressors and limiting factors for Chinook salmon in the San Joaquin River. These stressors and limiting factors define the problem and provide a foundation for the development of Restoration Goals, and the potential management actions described in later chapters.

Figure 2-1 identifies the first step in the Adaptive Management Approach as defining the problem. The following summarizes existing habitat and fisheries conditions in the Restoration Area (San Joaquin River from Friant Dam to the confluence of the Merced River). Additional details describing the existing conditions for fisheries in the Study Area, which is the San Joaquin River upstream from Friant Dam, Restoration Area, San Joaquin River downstream from the Merced River confluence, Sacramento-San Joaquin Delta (Delta), and the San Francisco Bay, can be found in Exhibit A and in Chapter 5 of the PEIS/R. A brief discussion of climate change is included below as the impacts of climate change are part of past and existing environmental conditions, and will continue to be a factor in restoration planning.

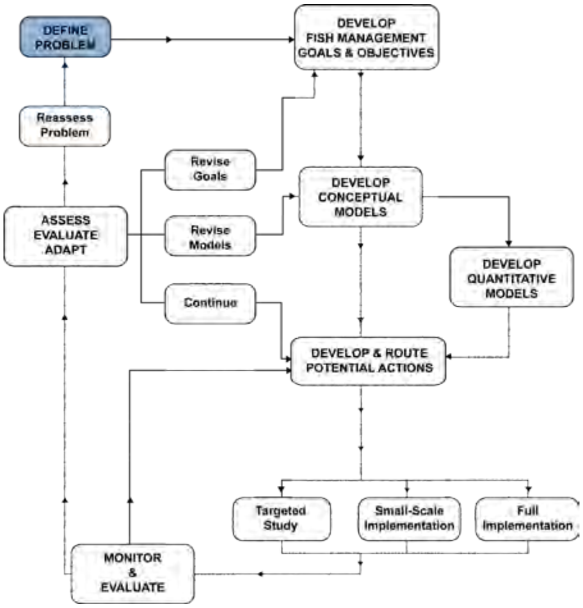

**Figure 2-1.
Fisheries Management Plan Adaptive Management Approach – Defining the Problem**

2.1 Restoration Area Characteristics

The Restoration Area, approximately 153 miles long, extends from Friant Dam at the upstream end near the town of Friant, downstream to the confluence of the Merced River, and includes an extensive flood control bypass system (bypass system) (Figure 2-2). The Restoration Area has been significantly altered by changes in land and water use over the past century.

Figure 2-2.
San Joaquin River Restoration Area and the Defined River Reaches

Five river reaches have been defined to address the great variation in river characteristics throughout the Restoration Area (Table 2-1). The reaches are differentiated by their geomorphology and resulting channel morphology, and by the infrastructure along the river. Hence, flow characteristics, geomorphology, and channel morphology are similar within each of the reaches.

Table 2-1.
Reach Specific Restoration Area Conditions

Reach	Substrate	Geomorphology	Water Present/ Source	Land Use	Vegetation	Other Impacts
1A	Gravel	Incised	Yes/ Friant	Gravel mining/ Agriculture	Invasive woody spp.	Sediment limited
1B	Gravel	Narrow/ levees	Yes/ Friant	Gravel mining/ Agriculture	Narrow riparian zone; Invasive woody spp.	Sediment limited
2A	Sand	Narrow/ levees	No/ Intermittent/ Delta Mendota Canal	Agriculture	Sparse; grassland; non-native	Seepage loss; ground water overdrafting; backwater effects
2B	Sand	Sandy channel/ levees	No/ Intermittent/ Mendota pool (DMC)	Agriculture	Narrow riparian zone; native	Limited conveyance; perennial
3	Sand	Narrow/ canals	Yes/ DMC	Agriculture / urban	Narrow riparian zone	Flow diverted to Arroyo canal
4A	Sand	Narrow canals	No	Agriculture	Sparse	Lowest ratio of vegetation to river in the entire Restoration Area
4B1	Sand	Poorly defined	No/ water by passed	Agriculture	Dense vegetation	Dry for >40 years except Ag water return
4B2	Sand	Wider floodplains	Yes	Agriculture	Vast area natural vegetation	Agriculture water returns
5	Sand	Side channels/ levees/ floodplain	Yes	Public ownership/ wildlife habitat	Large expanses of grassland and woody riparian veg.	Extensive bypass system

Key:
\> = greater than
DMC = Delta Mendota Canal


Below Friant Dam. Photo: USFWS, San Joaquin River Restoration Program

Reach 1 begins at Friant Dam and continues approximately 37 miles downstream to Gravelly Ford. This reach conveys continuous flows through an incised, gravel-bedded channel. Reach 1 typically has a moderate slope, and is confined by periodic bluffs and terraces. The reach is divided into two subreaches: 1A and 1B. Reach 1A, which extends down to State Route (SR) 99, supports continuous riparian vegetation except where the channel has been disrupted by gravel mining and other development. Invasive woody species are common in Reach 1A (Moise and Hendrickson 2002). Reach 1B continues from SR 99 to Gravelly Ford where it is more narrowly confined by levees. Woody riparian species occur mainly in narrow strips immediately adjacent to the river channel in Reach 1B. Reach 1 has been extensively mined for instream gravel and is sediment limited. Gravel mining and agriculture are the primary land uses in Reach 1B.

Reach 2 starts at Gravelly Ford, extends downstream to Mendota Dam, and is a meandering, low-gradient channel. During most months of the year, the Reach 2 channel is dry with the exception of flood release conditions from Gravelly Ford to Mendota Dam. Mendota Pool is formed by the Mendota Dam at the confluence of the San Joaquin River and Fresno Slough. The primary source of water to the Mendota Pool is conveyed from the Delta through the Delta-Mendota Canal (DMC).


Chowchilla Bypass. Photo: USFWS, San Joaquin River Restoration Program

Reach 2 is subdivided at the Chowchilla Bypass Bifurcation Structure into two subreaches, Reach 2A and Reach 2B, which have confining levees protecting adjacent agricultural land. Reach 2A and Reach 2B are intermittent and sand-bedded. Reach 2A is subject to extensive seepage losses and accumulates sand due to backwater effects of the Chowchilla Bypass Bifurcation Structure and the low gradient of the reach. Riparian vegetation in Reach 2A is sparse or absent due to the usually dry conditions of the river and groundwater overdrafting (McBain and Trush 2002). Reach 2A vegetation has abundant grassland/pasture and large stands of nonnative plants (Moise and Hendrickson 2002). Reach 2B has a sandy channel with limited conveyance capacity and a thin strip of riparian vegetation, primarily native species, which borders the channel. A portion of Reach 2B is perennial because of the backwater of Mendota Pool.

Reach 3 extends from Mendota Dam at the upstream end to Sack Dam at the downstream end and receives continuous flows from the DMC. At Sack Dam, flow releases are diverted into the Arroyo Canal. The river is confined by local dikes and canals on both banks. The sandy channel meanders through a predominantly agricultural area, except where the City of Firebaugh borders the river's west bank. The river at this location has a low stage but is perennial and supports a narrow riparian corridor along the edge of the river channel.

River Channel Below Sack Dam. Photo: USFWS, San Joaquin River Restoration Program

Reach 4, located between Sack Dam and the confluence with Bear Creek and the Eastside Bypass, is sand-bedded and usually dewatered because of the diversion at Sack Dam. The upstream portion of Reach 4 is bounded by canals and local dikes down to the confluence with the Mariposa Bypass at the San Luis National Wildlife Refuge. Levees that begin at the Mariposa Bypass continue downstream on both banks (McBain and Trush 2002). Reach 4 is subdivided into three distinct subreaches: 4A, 4B1, and 4B2.

Reach 4. Photo: USFWS, San Joaquin River Restoration Program

Reach 4A, from Sack Dam to the Sand Slough Control Structure, is confined within a narrow channel. This subreach is dry in most months with negligible flows that are diverted at Sack Dam. The floodplain of Reach 4A is broad, with levees set back from the active channel. The subreach is sparsely vegetated, with a thin and discontinuous band of vegetation along the channel margin. This subreach has the fewest functioning stream habitat types and the lowest ratio of natural vegetation per river mile in the Restoration Area.

Sand Slough Control Structure. Photo: USFWS, San Joaquin Restoration Program

Reach 4B1 extends from the Sand Slough Control Structure to the confluence with the Mariposa Bypass. All flows reaching the Sand Slough Control Structure are diverted to the bypass system. Because of this, Reach 4B has been perennially dry for more than 40 years, except when agricultural return flows are put through the channel, leaving standing water in many locations. As a result, the Reach 4B1 channel is poorly defined with dense vegetation and other fill material. The riparian corridor upstream from the Mariposa Bypass is narrow, but nearly unbroken.

Reach 4B2 begins at the confluence of the Mariposa Bypass, where flood flows in the bypass system rejoin the mainstem of the San Joaquin River, and extend to the confluence of the Eastside Bypass. Reach 4B2 contains wider floodplains than upstream reaches and vast areas of natural vegetation.

Reach 5 extends from the confluence of the Eastside Bypass downstream to the Merced River confluence. Reach 5 is perennial because it receives varying amounts of agricultural return flows from Mud and Salt sloughs. Reach 5 is more sinuous than other reaches and contains oxbows, side channels, and remnant channels (McBain and Trush 2002). Reach 5 is bounded on the west by levees downstream to the Salt Slough confluence and on the right bank to the Merced River confluence. Reach 5 has a broad floodplain; however, levees generally dissociate the floodplain from the mainstem San Joaquin River (McBain and Trush 2002). Less agricultural land conversion has occurred in Reach 5, with a majority of the land held in public ownership and managed for wildlife habitat.

Reach 5. Photo: USFWS, San Joaquin River Restoration Program

The natural habitat surrounding Reach 5 includes large expanses of grassland with woody riparian vegetation in the floodplain. Remnant riparian tree groves are concentrated on the margins of mostly dry secondary channels and depressions or in remnant oxbows. The mainstem has a patchy riparian canopy, consisting of large individual trees or clumps of valley oak (*Quercas lobata*) or willow (*Salix sp*) with herbaceous or shrub understory (McBain and Trush 2002).

The bypass system consists of a series of dams, bifurcation structures, flood channels, levees, and portions of the main river channel. The bypass system is managed to maintain flood-conveyance capacity. Descriptions of primary components of the bypass system follow.

- Fresno Slough, also known as James Bypass, conveys flood flows regulated by Pine Flat Dam from the Kings River system in the Tulare Basin to Mendota Pool.

- The Chowchilla Bifurcation Structure, at the head of Reach 2B, regulates the flow split between the San Joaquin River and the Chowchilla Bypass. The Chowchilla Bypass extends to the confluence of Ash Slough, and is approximately 22 miles long, leveed, and 600 to 700 feet wide. Sand deposits are dredged from the bypass, as needed, and vegetation is periodically removed from the channel.

- The Eastside Bypass bypasses 32.5 miles of river and extends from the confluence of Ash Slough and Chowchilla Bypass to the confluence with the San Joaquin River at the head of Reach 5 and is subdivided into three reaches. Eastside Bypass Reach 1 extends from Ash Slough to the Sand Slough Bypass confluence and receives flows from the Chowchilla River at River Mile (RM) 136. Eastside Bypass Reach 2 extends from Sand Slough Bypass to the head of the Mariposa Bypass at RM 147.2. Eastside Bypass Reach 3 extends from the head of the Mariposa Bypass to the head of Reach 5, at RM 168.5 and receives flows from Deadman, Owens, and Bear creeks.

  Upland vegetation at the Eastside Bypass consists of grassland and ruderal vegetation. In the Grasslands Wildlife Management Area, riparian trees and shrubs have a patchy distribution along the banks of the Eastside Bypass. The lower Eastside Bypass has some side channels and sloughs that support remnant patches of riparian vegetation.

2.2 Fish

Typical of Central Valley rivers and a semiarid climate, the natural or “unimpaired” flow regime of the San Joaquin River historically provided large annual and seasonal variation in the magnitude, timing, duration, and frequency of streamflows. Variability in streamflows provided conditions that helped sustain multiple life-history strategies for Chinook salmon and other native fishes.

Fish communities in the San Joaquin River Basin have changed markedly in the last 150 years. Native fish assemblages were adapted to widely fluctuating riverine conditions, ranging from large winter and spring floods to low summer flows, and had migratory access to upstream habitats. These environmental conditions resulted in a broad diversity of fish species, including anadromous species. Fishes that may have historically occurred, as well as those that currently inhabit the Restoration Area are listed in Table 2-2.

Table 2-2.
Fish Species with Possible Historic and Current Presence in the Restoration Area

Species	Scientific Name	Assemblage[1]	Native (N) or Introduced (I)	Current Presence[2]
Spring-run Chinook salmon	*Oncorhynchus tshawytscha*	A	N	No
Fall-run Chinook salmon	*O. tshawytscha*	A	N	Periodic
Rainbow trout/ steelhead	*O.mykiss*	RT	N	Yes
Pacific lamprey	*Lampetra tridentata*	A/PHS	N	Yes
River lamprey	*Lampetra ayersi*	A/PHS	N	Unknown
Kern brook lamprey	*Lampetra hubbsi*	RT/PHS	N	Yes
Western brook lamprey	*Lampetra richardsoni*	PHS	N	Unknown
White sturgeon	*Acipenser transmontanus*	A	N	Yes[3]
Green sturgeon	*Acipenser medirostris*	A	N	No
Hitch	*Lavinia exilicauda*	DB	N	Yes
California roach	*Lavinia symmetricus*	CR/RT/PHS	N	Yes
Sacramento blackfish	*Orthodon microlepidotus*	DB	N	Yes
Sacramento splittail	*Pogonichthys macrolepidotus*	DB	N	Yes
Hardhead	*Mylopharodon conocephalus*	PHS	N	Yes
Sacramento pikeminnow	*Ptychocheilus grandis*	PHS	N	Yes
Sacramento sucker	*Catostomus occidentalis*	PHS/RT/CR	N	Yes
Threespine stickleback	*Gasterosteus aculeatus*	RT/PHS	N	Yes
Prickly sculpin	*Cottus asper*	RT	N	Yes
Riffle sculpin	*Cottus gulosus*	RT	N	Yes
Sacramento perch	*Archoplites interruptus*	DB	N	Extirpated
Tule perch	*Hysterocarpus traski*	PHS/DB	N	Yes
Threadfin shad	*Dorosoma petenense*		I	Yes
Common carp	*Cyprinus carpio*		I	Yes
Fathead minnow	*Pimephales promelas*		I	Yes
Red shiner	*Cyprinella lutrensis*		I	Yes
Bullhead catfish	*Ameiurus nebulosus*		I	Yes[4]
Black catfish	*Ameiurus melas*		I	Yes[4]
White catfish	*Ameiurus catus*		I	Yes
Striped bass	*Morone saxatilis*		I	Yes
Black crappie	*Pomoxis nigromaculatus*		I	Yes
Bluegill sunfish	*Lepomis macrochirus*		I	Yes
Green sunfish	*Lepomis cyanellus*		I	Yes
Largemouth bass	*Micropterus salmoides*		I	Yes
Redear sunfish	*Lepomis microlophus*		I	Yes
Spotted bass	*Micropterus punctulatus*		I	Yes
White crappie	*Pomoxis annularis*		I	Yes

Notes:

[1] Based on Moyle (2002) for native species only: A = anadromous, CR = California roach assemblage, RT = rainbow trout assemblage, PHS = pikeminnow-hardhead-sucker assemblage, DB = deep-bodied fishes assemblage

[2] DFG 2007a

[3] DFG Report Card Data, 2009

[4] Reclamation 2003

Three of the Central Valley stream native fish assemblages defined by Moyle (2002) are used in the FMP to describe current and historical fish populations in the San Joaquin River. These fish assemblages are described below.

In the Restoration Area, the rainbow trout assemblage includes native and hatchery rainbow trout (*O. mykiss*), sculpin (*Cottus sp.*), Sacramento sucker (*Catostomus occidentalis*), Kern brook lamprey (*Lampetra hubbsi*), and threespine stickleback (*Gasterosteus aculeatus*). Their habitat is described as high-gradient, cool water streams. Historically, this assemblage likely occurred upstream from Friant Dam; however, the presence of Friant Dam has created environmental conditions suitable for the rainbow trout assemblage in Reach 1. Native fish species recently captured by DFG (2007a) in Reach 1 included rainbow trout, Sacramento sucker, and sculpin species.

The pikeminnow-hardhead-sucker assemblage in the San Joaquin River includes Sacramento pikeminnow (*Ptycochelis grandis*), hardhead (*Mylopharadon conocephalus*), Sacramento sucker, California roach (*Lavinia symmetricus)*, and tule perch (*Hysterocarpus traski*). Their habitat is described as wide, shallow riffles and deep pools with warm summer water temperatures. Within the Restoration Area, the pikeminnow-hardhead-sucker assemblage can be found in Reaches 2 through 5 (DFG 2007a).

In the San Joaquin River, the deep-bodied fish assemblage includes hitch (*Lavinia exilicanda*), Sacramento blackfish (*Orthodon microlepidotus*), and Sacramento splittail (*Pogonichthys macrolepidoptus*). Their habitat is characterized by warm-water oxbows, inundated floodplains, sloughs, stagnant backwaters and shallow tule beds and deep pools or long stretches of slow-moving water. Fishes in the deep-bodied fish assemblages are largely dependent on shallow floodplains for successful spawning. Under suitable conditions such as adequate flow and water temperatures, this assemblage can be found in Reaches 2 through 5. Sacramento perch (*Archoplites interruptus*) were historically present, but are now considered extirpated from the Restoration Area.

These assemblages are naturally separated by elevation. However, local variations in stream gradient, water temperature, and other important habitat features commonly blur the distinctions between these fish assemblages. This results in deviation from generalized distribution patterns and overlap of species from one assemblage to another. Nevertheless, the assemblages provide a helpful description of San Joaquin River fish communities and highlight the influence of habitat features on their structure and distribution.

Two other general categories used in this FMP, though not assemblages as described by Moyle (2002), include anadromous fish and nonnative fish. These fish may co-occur with the above assemblages.

Brief species distributions and life-history characteristics of some key native species are included below and are described in greater detail in the Fisheries Technical Appendix of the PEIS/R. In addition, Exhibit C summarizes spawning habitat characteristics of Chinook salmon and other fishes.

2.2.1 Chinook Salmon

Chinook salmon in the Central Valley have four genetically distinct runs differentiated by the timing of spawning migration, stage of sexual maturity when entering freshwater, and timing of juvenile or smolt outmigration (Moyle et al. 1989). In the San Joaquin River, spring-run Chinook salmon historically spawned as far upstream as the present site of Mammoth Pool Reservoir (RM 322), where their upstream migration was historically blocked by a natural velocity barrier (P. Bartholomew, pers. comm., as cited in Yoshiyama et al. 1996). Fall-run Chinook salmon generally spawned lower in the watershed than spring-run Chinook salmon (DFG 1957). The San Joaquin River historically supported large runs of spring-run Chinook salmon; DFG (1990, as cited in Yoshiyama et al. 1996) suggested that this run was one of the largest Chinook salmon runs on any river on the Pacific Coast, with an annual escapement averaging 200,000 to 500,000 adult spawners (DFG 1990, as cited Yoshiyama et al. 1996). Construction of Friant Dam began in 1939 and was completed in 1942, which blocked access to upstream habitat. Nevertheless, runs of 30,000 to 56,000 spring-run Chinook salmon were reported in the years after Friant Dam was constructed, with salmon holding in the pools and spawning in riffles downstream from the dam. Friant Dam began filling in 1944, and in the late 1940s began to divert increasing amounts of water into canals to support agriculture. Flows into the mainstem San Joaquin River were reduced to a point that the river ran dry in the vicinity of Gravelly Ford. By 1950, the entire run of spring-run Chinook salmon was extirpated from the San Joaquin River (Fry 1961). Although the San Joaquin River also supported a fall-run Chinook salmon run, they historically composed a smaller portion of the river's salmon runs (Moyle 2002). By the 1920s, reduced autumn flows in the mainstem San Joaquin River nearly eliminated the fall-run, although a small run did persist.

It is also likely a population of late fall-run Chinook salmon was present historically in the San Joaquin River Basin although appreciable numbers are currently only present in the Sacramento River Basin (Williams 2006). Fall-run and late fall-run are considered one Evolutionarily Significant Unit (ESU) by NMFS (64 Federal Register (FR) 50394, September 16, 1999). They are, however, genetically distinct and exhibit differences in timing of key life-history attributes (Moyle 2002).

The life-history strategies and requirements of spring-run and late fall-run Chinook salmon are summarized below and described in more detail in Exhibit A and in Chapter 5 of the PEIS/R. Fall-run Chinook salmon are currently the most abundant race of salmon in California (Mills et al. 1997). Fall-run Chinook salmon historically spawned in the mainstem San Joaquin River upstream from the Merced River confluence and in the mainstem channels of

Salmon Lifecycle. Figure: USFWS, Anadromous Fish Restoration Program

the major tributaries (Yoshiyama et al. 1996). Currently, however, they are limited to the Merced, Stanislaus, and Tuolumne rivers where they spawn and rear downstream from mainstem dams. DFG has operated a barrier (Hills Ferry Barrier) at the confluence of the Merced River with the San Joaquin River since the early 1990s to prevent adult fall-run Chinook salmon from migrating further up the San Joaquin River into warmer temperatures and unsuitable habitat.

Spring-run Chinook salmon migrate upstream from March through June, and hold in deep pools until they are ready to spawn. Fall-run Chinook salmon adults migrate into fresh water between September and December. Adult late fall-run Chinook salmon migrate into freshwater from October through April, with peak migration in December or January.

Spring-run Chinook salmon historically spawned in the San Joaquin River upstream from the town of Friant from late August to October, peaking in September and October (Clark 1943). Fall-run Chinook salmon in the San Joaquin tributaries typically spawn from October through December, peaking in early to mid-November. Late fall-run Chinook salmon spawn from January to early April, peaking in January (Williams 2006).

All adult Chinook salmon die after spawning, and their carcasses provide significant benefits to stream and riparian ecosystems. The carcasses provide nutrients to numerous invertebrates, birds, mammals, and freshwater biota (Bilby et al. 1998, Helfield and Naiman 2001, Hocking and Reimchen 2002). Evidence of marine-derived nitrogen from salmon carcasses has also been detected in riparian vegetation as well as agricultural crops adjacent to salmon producing streams (Helfield and Naiman 2001, Merz and Moyle 2006).

Egg incubation generally lasts between 40 to 90 days at water temperatures of 43 to 54 degrees Fahrenheit (°F) (6 to 12 degrees Celsius (°C)) (Vernier 1969, Bams 1970, Heming 1982, Bjornn and Reiser 1991). Alevins remain in the gravel for 2 to 3 weeks after hatching and absorb their yolk sac before emerging from the gravels into the water column from November to March (Fisher 1994, Ward and McReynolds 2001). Late fall-run Chinook salmon eggs incubate through April to June.

The length of time spent rearing in freshwater varies greatly among juvenile spring-run Chinook salmon. Spring-run Chinook salmon may disperse downstream as fry soon after emergence, early in their first summer, in the fall as flows increase, or as yearlings after overwintering in freshwater (Healey 1991). Even in rivers such as the Sacramento River where many juveniles rear until they are yearlings, some juveniles likely migrate downstream throughout the year (Nicholas and Hankin 1989). Fall-run Chinook salmon fry


Juvenile Chinook Salmon. Photo: USFWS, Delta Juvenile Fish Monitoring Program

typically disperse downstream from early January through mid-March, whereas smolts primarily migrate between late March and mid-June in the Central Valley (Brandes and McLain 2001). Late fall-run Chinook salmon juveniles typically rear in the stream through the summer before beginning their emigration in the fall or winter (Fisher 1994).

Juvenile salmonids rear on seasonally inundated floodplains when available. Sommer et al. (2001) found higher growth and survival rates of Chinook salmon juveniles reared on the Yolo Bypass compared with those in the mainstem Sacramento River. Jeffres et al. (2008) observed similar results on the Cosumnes River floodplain. Drifting invertebrates, the primary prey of juvenile salmonids, were more abundant on the inundated Yolo Bypass floodplain than in the adjacent Sacramento River (Sommer et al. 2001).

Smoltification is the physiological process that increases salinity tolerance and preference, endocrine activity, and gill Na^+-K^+ ATPase activity. It usually begins when the juveniles reach between 3 and 4 inches (76 to 102 millimeters) fork length (FL); however, some fish delay smoltification until they are about 12 months old (yearlings) when they reach 4 to 9 inches (102 to 229 millimeters) FL (Exhibit A). Environmental factors, such as streamflow, water temperature, photoperiod, lunar phase, and pollution, can affect the onset of smoltification (Rich and Loudermilk 1991).

2.2.2 Other Fishes

This section describes the distribution and life-history requirements of other fishes that could occur in the Restoration Area following implementation of the SJRRP, including Central Valley steelhead.

Rainbow Trout/Steelhead

Historical rainbow trout/steelhead distribution in the upper San Joaquin River is unknown; however, in rivers where they still occur, they are normally more widely distributed than Chinook salmon (Voight and Gale 1998, as cited in McEwan 2001, Yoshiyama et al. 1996), and are typically tributary spawners.

Rainbow trout/Steelhead. Photo: Doug Killam, DFG

O. mykiss has two classifications: steelhead refer to the anadromous form, while rainbow trout refer to the nonanadromous form. The anadromous distinct population segment (DPS) of *O. mykiss* was listed under the Federal Endangered Species Act (ESA) by NMFS (63 FR 13347, March 19, 1998 and 71 FR 834, January 5, 2006).

In the Central Valley, adult steelhead migrate upstream beginning in June, peaking in September, and continuing through February or March (Hallock et al. 1961, Bailey 1954, McEwan and Jackson 1996). Spawning occurs primarily from January through March, but may begin as early as late December and may extend through April (Hallock et al. 1961, as cited in McEwan and Jackson 1996). Although most steelhead die after spawning, some adults are capable of returning to the ocean and migrating back upstream to spawn in subsequent years.

Eggs hatch after 20 to 100 days, depending on water temperature (Shapovalov and Taft 1954, Barnhart 1991). Steelhead rear in freshwater before outmigrating to the ocean as smolts. The length of time juveniles spend in freshwater appears to be related to growth rate (Peven et al. 1994). In warmer areas, where feeding and growth are possible throughout the winter, steelhead may require a shorter period in freshwater before smolting (Roelofs 1985).

Most steelhead spend 1 to 3 years in the ocean, with smaller smolts tending to remain in salt water for a longer period than larger smolts (Chapman 1958, Behnke 1992). Larger smolts have been observed to experience higher ocean survival rates (Ward and Slaney 1988).

Pacific Lamprey

Pacific Lamprey. Photo: Juan Cervantes ©

Pacific lamprey (*Lampetra tridentate*) are anadromous fish that have Pacific coast distributions and have been found in the San Joaquin River (DFG 2007a). Pacific lamprey adults begin upstream migration between January and September, and may spend up to a year in freshwater until they are ready to spawn in late winter or spring. Upstream migration seems to take place largely in response to high flows, and adults can move substantial distances unless blocked by major barriers. Hatching occurs in approximately 17 days at 57°F (14°C) and, after spending an approximately equal period in redd gravels (Meeuwig et al. 2005), ammocoetes (larvae) emerge and drift downstream to depositional areas where they burrow into fine substrates and filter feed on organic materials (Moore and Mallatt 1980). Ammocoetes remain in freshwater for 5 to 7 years before undergoing a metamorphosis into an eyed, smolt-like form (Moore and Mallatt 1980, Moyle 2002). At this time, individuals migrate to the ocean between fall and spring, typically during high-flow events, to feed parasitically on a variety of marine fishes (Van de Wetering 1998, Moyle 2002). Pacific lampreys remain in the ocean for approximately 18 to 40 months before returning to freshwater as immature adults (Kan 1975, Beamish 1980). Unlike anadromous salmonids, recent evidence suggests anadromous lampreys do not necessarily home to their natal streams (Bergstedt and Seelye 1995; Goodman et al. 2008). Pacific lampreys die soon after spawning, though there is some anecdotal evidence that this is not always the case (Moyle 2002, Michael 1980).

Kern Brook Lamprey

Kern brook lamprey are endemic to the eastern portion of the San Joaquin Valley, and were first collected in the Friant-Kern Canal. They have subsequently been found in the lower Merced, Kaweah, Kings, and San Joaquin rivers. They are generally found in silty backwaters of rivers stemming from the Sierra foothills. The nonpredatory, resident Kern brook lamprey has not been extensively studied, but it presumably has a similar life history and habitat requirements to the western brook lamprey (*Lampetra richardsoni*) and other brook lamprey species. Like other lampreys, the Kern brook lamprey is thought to spawn in the spring and die soon thereafter (Moyle 2002). After eggs hatch they remain in gravel redds until their yolk sacs are absorbed. At this time, larvae emerge and drift downstream into low-velocity, depositional rearing areas where they feed by filtering organic matter from the substrate. After reaching approximately 4 to 6 inches (102 to 152 millimeter (mm)), ammocoetes undergo metamorphosis into eyed adults (Moyle 2002). As with other brook lamprey species, adults do not eat and may even shrink following metamorphosis (USFWS 2004). Adults prefer riffles containing small gravel for spawning, and cobble for cover (Moyle 2002).

Hitch


Hitch. Photo: Peter Moyle, UC Davis

Hitch are endemic to the Sacramento-San Joaquin River Basin. There are three subspecies within this species found in the Clear Lake, Pajaro, and Salinas watersheds, and Sacramento-San Joaquin Watershed (Lee et al. 1980). Hitch occupy warm, low-elevation lakes, sloughs, and slow-moving stretches of rivers, and clear, low-gradient streams. Among native fishes, hitch have the highest temperature tolerances in the Central Valley. They can withstand water temperatures up to 100°F (38°C), although they prefer temperatures of 81 to 84°F (27 to 29°C). Hitch also have moderate salinity tolerances, and can be found in environments with salinities up to 9 parts per thousand (ppt) (Moyle 2002). Hitch require clean, smaller gravel and temperatures of 57 to 64°F (14 to 18°C) to spawn. When larvae and small juveniles move into shallow areas to shoal, they require vegetative refugia to avoid predators. Larger fish are often found in deep pools containing an abundance of aquatic and terrestrial cover (Moyle 2002).

Mass spawning migrations typically occur when flows increase during spring, raising water levels in rivers, sloughs, ponds, reservoirs, watershed ditches, and riffles of lake tributaries. Females lay eggs that sink into gravel interstices. Hatching occurs in 3 to 7 days at 59 to 72°F (15 to 22°C) and larvae take another 3 to 4 days to emerge. As they grow, they move into perennial water bodies where they will shoal for several months in association with aquatic vegetation or other complex vegetation before moving into open water. Hitch are omnivorous and feed in open waters on filamentous algae, aquatic and terrestrial insects, zooplankton, aquatic insect pupae and larvae, and small planktonic crustaceans (Moyle 2002).

Sacramento Blackfish


Sacramento blackfish. Photo: Peter Moyle, UC Davis

Sacramento blackfish are endemic to low-elevation portions of major tributaries of the Sacramento and San Joaquin rivers. Although they were abundant in the sizeable lakes of the historical San Joaquin Valley, they are currently common only in sloughs and oxbow lakes of the Delta. Sacramento blackfish are most abundant in warm, turbid, and often highly modified habitats.

They are found in locations ranging from deep turbid pools with clay bottoms to warm, shallow and seasonally highly alkaline. Blackfish have a remarkable ability to adapt to extreme environments such as high temperatures and low dissolved oxygen (DO) (Cech et al 1979, Campagna and Cech 1981). Although optimal temperatures range from 72 to 82°F (22 to 28°C), adults can frequently be found in waters exceeding 86°F (30°C). Their ability to tolerate extreme conditions affords them survival during periods of drought or low flows (Moyle 2002).

Spawning occurs in shallow areas with dense aquatic vegetation between May and July when water temperatures range between 54 and 75°F (12 to 24°C). Eggs attach to substrate in aquatic vegetation, and larvae are frequently found in similar shallow areas. Juvenile blackfish are often found in large schools within shallow areas associated with cover, and feed on planktonic algae and zooplankton (Moyle 2002).

Sacramento Splittail

Sacramento splittail are endemic to the Sacramento and San Joaquin rivers, Delta, and San Francisco Bay. In the San Joaquin River, they have been documented as far upstream as the town of Friant (Rutter 1908). In recent wet years, splittail have been found as far upstream as Salt Slough (Saiki 1984, Brown and Moyle 1993, Baxter 1999, Baxter 2000) where the presence of both adults and juveniles indicated successful spawning.

Sacramento splittail. Photo: USFWS, Delta Juvenile Fish Monitoring Program

Adult splittail move upstream in late November through late January, foraging in flooded areas along the main rivers, bypasses, and tidal freshwater marsh areas before spawning (Moyle et al. 2004). Feeding in flooded riparian areas before spawning may contribute to spawning success and survival of adults after spawning (Moyle et al. 2001). Splittail appear to concentrate their reproductive effort in wet years when potential success is greatly enhanced by the availability of inundated floodplain habitat (Meng and Moyle 1995, Sommer et al. 1997). Splittail are fractional spawners, with individuals spawning over several months (Wang 1995).

Eggs begin to hatch in 3 to 7 days, depending on temperature (Bailey et al. 2000). After hatching, the swim bladder inflates and larvae begin active swimming and feeding (Moyle 2002). Most larval splittail remain in flooded riparian areas for 10 to 14 days, most likely feeding in submerged vegetation before moving into deeper water as they become stronger swimmers (Wang 1986, Sommer et al. 1997). Most juveniles move downstream in response to flow pulses into shallow, productive bay and estuarine waters from April to August (Meng and Moyle 1995, Moyle 2002). Floodplain habitat offers high-quality food and production, and low predator densities to increase juvenile growth and survival.

Non-breeding splittail are found in temperatures up to 75°F (24°C) (Young and Cech 1996). Juveniles and adults have optimal growth at 68°F (20°C), with physiological distress above 84°F (29°C) (Young and Cech 1995). Splittail have a high tolerance for variable environmental conditions (Young and Cech 1996), and are generally opportunistic feeders. Prey includes mysid shrimp, clams, and some terrestrial invertebrates.

Hardhead

Hardhead are endemic to larger low- and mid-elevation streams of the Sacramento-San Joaquin river basins. Hardhead are widely distributed in foothill streams and may be found in a few reservoirs on the San Joaquin River upstream from Millerton Lake. Hardhead prefer water temperatures above 68°F (20°C) with optimal temperatures between 75 and 82°F (24 to 28°C). Their distribution is limited to well-oxygenated streams and the surface water of impoundments. They are often found in clear, deep pools greater than 31.5 inches (800 mm) and runs with slower water velocities. Larvae and post-larvae may occupy river edges or flooded habitat before seeking deeper low-velocity habitat as they increase in size (Moyle 2002).

Hardhead spawn between April and August. Females lay eggs on gravel in riffles, runs, or the heads of pools. The early life history of hardhead is not well known. Juveniles may feed on insects from the surface, whereas adults are benthivores occupying deep pools. Prey items may include insect larvae, snails, algae, aquatic plants, crayfish, and other large invertebrates (Moyle 2002).

Sacramento Pikeminnow

Sacramento pikeminnow are endemic to the Sacramento-San Joaquin River Basin. Sacramento pikeminnow prefer rivers in low- to mid-elevation areas with clear water, deep pools, low-velocity runs, undercut banks, and vegetation. They are not typically found where centrarchids have become established. Sacramento pikeminnow prefer summer water temperatures above 59°F (15°C) with a maximum of 79°F (26°C) (Moyle 2002).

Sacramento Pikeminnow. Photo: Juan Cervantes ©

Sexually mature fish move upstream in April and May when water temperatures are 59 to 68°F (15 to 20°C). Sacramento pikeminnow spawn over riffles or the base of pools in smaller tributaries. Pikeminnow are slow growing and may live longer than 12 years. Before the introduction of larger predatory fishes, pikeminnows may have been the apex predator in the Central Valley. Pikeminnow prey includes insects, crayfish, larval and mature fish, amphibians, lamprey ammocoetes, and occasionally small rodents (Moyle 2002).

Sacramento Sucker

Sacramento sucker. Photo: Peter Moyle, UC Davis

Sacramento suckers have a wide distribution in California including streams and reservoirs of the Sacramento and San Joaquin watersheds. Sacramento suckers are most commonly found in cold, clear streams and moderate-elevation lakes and reservoirs. Shifts in microhabitat use occur with smaller fish using shallow, low-velocity peripheral zones moving to areas of deeper water as they grow (Cech et al. 1990). Sacramento suckers can tolerate a wide range of temperature fluctuations, from streams that rarely exceed 59°F (15°C) to those that reach up to 86°F (30°C). They have high salinity tolerances, having been found in reaches with salinities greater than 13 ppt. Sacramento suckers have the ability to colonize new habitats readily (Moyle 2002).

Sacramento suckers typically feed nocturnally on algae, detritus, and small benthic invertebrates. They spawn over riffles from February through June when temperatures are approximately 54 to 64°F (12 to 18°C). After embryos hatch in 2 to 4 weeks, larvae remain close to the substrate until they are swept into warm, shallow water or among flooded vegetation (Moyle 2002).

Prickly Sculpin

Prickly sculpin. Photo: USFWS, Delta Juvenile Fish Monitoring Program

Central Valley populations of prickly sculpin (*Cottus asper*) are found in the San Joaquin Valley south to the Kings River. Prickly sculpin are generally found in medium-sized, low-elevation streams with clear water and bottoms of mixed substrate and dispersed woody debris. In the San Joaquin Valley, they are absent from warm, polluted areas, implying their distribution is regulated by water quality. Prickly sculpin have been found in abundance in cool flowing water near Friant Dam, in Millerton Lake, and in the small, shallow Lost Lake where bottom temperatures exceed 79°F (26°C) in the summer (Moyle 2002).

Prickly sculpin spawn from February through June when water temperatures reach 46 to 55°F (8 to 13°C). After hatching, larvae move down into large pools, lakes, and estuaries where they spend 3 to 5 weeks as planktonic fry. Their prey include large benthic invertebrates, aquatic insects, mollusks, and small fish and frogs (Moyle 2002).

Riffle Sculpin

Riffle sculpin (*Cottus gulosus*) have a scattered distribution pattern throughout California including the Sacramento-San Joaquin watersheds. Riffle sculpin prefer habitats that are fairly shallow with moderately swift water velocities and oxygen levels near saturation (Moyle and Baltz 1985). They move where water temperatures do not surpass 77 to 79°F (25 to 26°C) and temperatures greater than 86°F (30°C) are generally lethal (Moyle 2002).

Riffle sculpins are benthic, opportunistic feeders. Spawning occurs between February and April, with eggs deposited on the underside of rocks in swift riffles or inside cavities of submerged logs. Eggs hatch in 11 to 24 days, and when fry reach approximately 0.25 inches (6 mm) total length, they become benthic (Moyle 2002).

Tule Perch

Tule perch. Photo: USFWS, Delta Juvenile Fish Monitoring Program

Endemic Sacramento-San Joaquin River subspecies of tule perch were historically widespread throughout the lowland rivers and creeks in the Central Valley. Currently, in the San Joaquin River watershed, they occur in the Stanislaus River, occasionally in the San Joaquin River near the Delta, and the lower Tuolumne River. Tule perch in riverine habitat are usually found in emergent plant beds, deep pools, and near banks with complex cover. They require cool, well-oxygenated water, and tend not to be found in water exceeding 77°F (25°C) for extended periods. They are capable of tolerating high salinities (i.e., 30 ppt) (Moyle 2002).

Tule perch generally feed on the bottom or among aquatic plants. They are primarily adapted to feed on small invertebrates and zooplankton. Females mate multiple times between July and September, and sperm is stored until January when internal fertilization occurs. Young develop within the female, and are born in June or July when food is most abundant. Juveniles begin to school soon after birth.

White Sturgeon

White sturgeon (*Acipenser transmontanus)* have a marine distribution spanning from the Gulf of Alaska south to Mexico, but a spawning distribution ranging only from the Sacramento River northward (McCabe and Tracy 1994). Currently, self-sustaining spawning populations are only known to occur in the Sacramento, Fraser, and Columbia rivers. In California, primary abundance is in the San Francisco Estuary with spawning occurring mainly in the Sacramento and Feather rivers; however DFG fisheries catch information obtained from fishery report cards (DFG Report Card Data 2007, 2008) documented 25 mature white sturgeon encountered by fisherman in 2007, and 6 mature white sturgeon encountered in 2008 upstream from Highway 140 (Reach 5). In addition, an unknown number of white sturgeon were captured in the Restoration Area in 2009 (DFG Draft Report Card Data 2009). Adult sturgeon were caught in the sport fishery industry in the San Joaquin River between Mossdale and the confluence with the Merced

River in late winter and early spring, suggesting this was a spawning run (Kohlhorst 1976). Kohlhorst et al. (1991) estimated that approximately 10 percent of the Sacramento River system spawning population migrated up the San Joaquin River. Spawning may occur in the San Joaquin River when flows and water quality permit; however, no evidence of spawning is present (Kohlhorst et al.1976, Kohlhorst et al. 1991). Landlocked populations are located above major dams in the Columbia River basin, and residual nonreproducing fish above Shasta Dam and Friant Dam have been occasionally found. Sturgeon migrate upstream when they are ready to spawn in response to increases of flow. White sturgeon are benthic feeders and juveniles consume mainly crustaceans, especially amphipods and opossum shrimp. Adult diets include mainly fish and estuarine invertebrates, primarily clams, crabs, and shrimps.

Nonnative Fish Species

There are a number of nonnative fish species present in the Restoration Area include largemouth bass (*Microptenus salmoides)*, green sunfish (*Lepomis cyanellus*), black crappie (*Pomoxis nigromaculatus*), and striped bass (*Morone saxatittus*) (McBain and Trush 2002; DFG 2007a) (see Table 2.2). Electrofishing surveys of the Restoration Area in 2004 and 2005 indicated that largemouth and spotted bass (*Micropterus puretulatus*), two predatory species, were prevalent as far upstream as Reach 1 and were very common in Reaches 3 and 5 (DFG 2007a). Largemouth bass are adapted to low-flow and high-water temperature habitats and typically inhabit instream and off-channel mine pits in the San Joaquin River Basin.

2.3 Climate Change

Climate change has become a recent topic of concern throughout the nation, including in the Central Valley. There is broad scientific agreement on the existence, causes, and threats of climate change. The Intergovernmental Panel on Climate Change (IPCC) reports that “warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level ” (IPCC 1995). As a result, climate change will likely affect California’s water resources (DWR 2008) with expected consequences such as reduced snowpack; changes to timing, location, and intensity of precipitation; and increased water temperatures (DWR 2006). The southern Sierra Nevada is expected to retain its snow pack longer than the northern part of the range; thus, the San Joaquin River and its tributaries may maintain cold-water resources longer than the Sacramento River’s tributaries (Lindley et al. 2007). Nevertheless, any changes in streamflow timing are a critical management issue.

Climate change is expected to affect the San Joaquin River Basin through a variety of pathways including warmer air and ocean temperatures, sea-level rise, summer drought, decreases in Sierra snowpack, and shifts in runoff from melting snow to rain. Changes in precipitation patterns within California (e.g., timing, amount, intensity, variability) will likely contribute to variations in stream and river flows (DWR, 2006). Along with directly effecting salmonid habitat conditions through the afore mentioned routes, climate change is also expected to influence salmonid life history stages including reproductive success, migration, growth, and survival (Bryant 2009, Scheuerell et al. 2009, Crozier et al. 2008, O'Neal 2002).

For Central Valley salmon populations, climate change may pose major threats to freshwater habitat throughout the full extent of their range. Lindley et al. (2007) examined the possible effects of climate warming on the availability of over-summering habitat for Central Valley spring-run Chinook salmon. They found that even under the most conservative warming scenario where mean summer air temperatures rises 3.5°F (2°C) by 2100, historical summer habitat on the Merced and upper San Joaquin rivers may no longer exist due to increasing stream temperatures. Increases in air temperature are associated with increases in water temperature, thus reducing the range of suitable thermal habitat (Morrill et al. 2005; Pilgrim et al. 1998). Climate change is also a major long-term threat for fall-run Chinook salmon in the San Joaquin River and its tributaries. Warming temperatures will shorten the amount of time that low-elevation habitat is within an acceptable temperature range for emigrating salmon. According to Williams (2006), low-elevation warming will be a particular problem for fingerlings emigrating in May and June.

Increasing water temperatures resulting from climate change would likely result in loss of suitable thermal habitat for Chinook salmon in the San Joaquin River within the project area. Cold water releases from the hypolimnion of a reservoir can help maintain suitable temperatures for spawning and rearing habitat downriver of major dams (e.g., Shasta Dam). Yates et al. (2008) modeled cool water availability from Shasta Dam under different climate change scenarios. They found that without cool water releases, water temperatures downriver of the dam would exceed spawning thresholds during May through September. Under a 3.5°F (2°C) warming scenario, releases from Shasta Dam maintained suitable spawning temperatures, but under a 7°F (4°C) warming scenario, cool water released from the reservoir was insufficient to keep downstream water temperatures within thermal thresholds for Chinook salmon. Evaluating such actions in the project area would require a model of the cold-water pool in Millerton Reservoir, the San Joaquin River temperature model, and climate change data on air temperatures and reservoir inflows.

The potential impacts of climate change to the habitat and fish populations within the Restoration Area are further discussed in Exhibit A.

Chapter 3 Fish Management Goals and Objectives

Overarching population and habitat goals are necessary to provide a comprehensive vision to restore fish populations and appropriate habitat in the Restoration Area. Goals are defined as broad statements of intent that provide focus or vision for planning. Goals are not meant to be specific or measurable. The SJRRP goals were used to form specific objectives, which are intended to be realistic and measurable so the program will have a quantitative means of evaluating program success (described in Chapter 6). While goals provide focus and vision for planning purposes, some goals are related to factors beyond the scope and authority of the SJRRP. The development of fish management goals as part of the Adaptive Management Approach is illustrated in the upper right of Figure 3-1. Actions developed with the intention of addressing specific limiting factors, often limited to specific reaches of the Restoration Area, are addressed in Chapter 5.

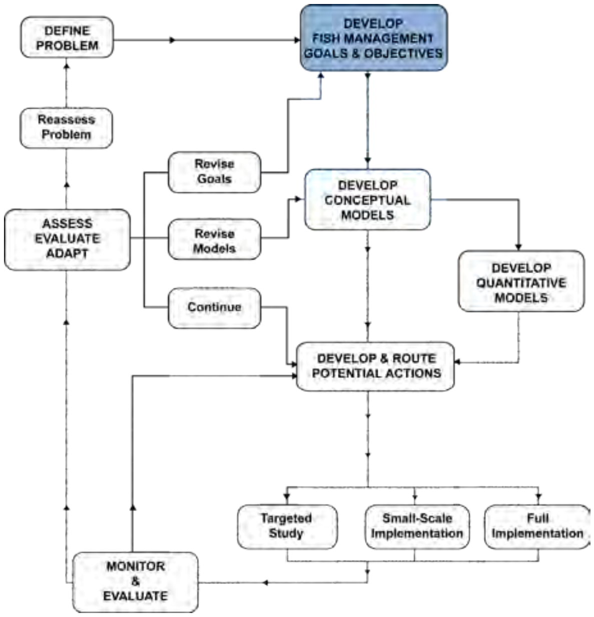

Figure 3-1.
Fisheries Management Plan Adaptive Management Approach – Develop Goals and Objectives

The Settlement requires fish in the San Joaquin River to be restored in ‘good condition.’ The California Fish and Game Code (Section 5937) does not provide guidance on what constitutes ‘good condition’; therefore, for the purposes of the FMP, the definition provided by Moyle (2005) will be used:

> *The definition of “good condition” has three tiers: individual, population, and community (Moyle et al. 1998). By this definition, the fish in the stream below the dam should be in good physical health (i.e., not show obvious signs of stress from poor water quality and quantity) and also be part of a self-sustaining population. In addition, individuals and populations do not show ill effects of inbreeding, outbreeding, or other negative genetic factors that affect their survival, reproduction, or population viability. For salmonids, populations meet criteria for viability in terms of diversity, spatial structure, abundance, and productivity, and are supported by habitat*

> *that is adequately sized, of adequate quality, properly connected, and properly functioning, so as to enable the viability of all life history stages and essential biological processes. The third level of good condition, community health, reflects the fact that the San Joaquin River historically supported runs of salmon, other anadromous fish, and complex assemblages of native fishes, as well as fisheries for both native and nonnative fishes. A healthy community (assemblage) of fishes therefore was defined as one that (1) is dominated by coevolved species, (2) has a predictable structure as indicated by limited niche overlap among species and multiple trophic levels, (3) is resilient in recovering from extreme events, (4) is persistent in species membership through time, and (5) is replicated geographically. This definition reflects recent ecological thinking and recognizes that a fish community is a complex, dynamic entity whose persistence through time requires a complex, dynamic habitat. For streams, in particular, a healthy fish community requires flows and habitats that have attributes of those that existed historically.*

While the above definition identifies nonnative fishes as an indicator of community health and condition, the focus of the SJRRP is to restore salmon and other native fishes as described in the Restoration Goal. The above definition focuses on individual, population, and community levels and serves as a good platform for the development of fish management goals and specific objectives; with exception to the reference to nonnative fish.

The Restoration Goal of the Settlement requires the reintroduction of spring- and fall-run Chinook salmon; however, if unforeseen factors make this goal infeasible, priority is to be given to spring-run Chinook salmon. The Settlement flow schedule is designed with the goal of providing streamflow for spring- and fall-run Chinook salmon and most, if not all, of the restoration actions for spring-run Chinook salmon will also benefit fall-run and late fall-run Chinook salmon. Spring-run Chinook salmon are likely better suited than fall-run Chinook salmon for reintroduction for a number of reasons. For example, adult fall-run Chinook salmon migrate upriver to spawning habitat during the fall when pulse flows are used, as opposed to spring-run adults that migrate upriver during spring freshets typically of higher volume. Passage and water quality conditions during the fall are likely less hospitable for adult migration than in the spring. In addition, because fall-run and late fall-run spawn after spring-run Chinook salmon and thus develop after spring-run Chinook salmon, they are potentially more exposed to elevated temperatures during juvenile rearing if they migrate as fry to the lower reaches of the Restoration Area. The reader is referred to the limiting factors analysis in the spring-run and fall-run Chinook salmon conceptual models (Exhibit A) for more information about the factors impacting the two races of salmon.

The introduction of late fall-run, rather than fall-run Chinook salmon may offer several advantages to meeting the Restoration Goal. The spatial and temporal differences between late fall-run and fall-run adults and juveniles could: (1) help reduce in-river competition between juveniles of each race, (2) reduce the redd superimposition between races, and (3) reduce chances of hybridization between races. Additionally, the tendency for late fall-run Chinook salmon to use a yearling life stage may offer better outmigrant survival than fall-run Chinook salmon that migrate predominantly as subyearlings. These factors could make late fall-run Chinook salmon more favorable for reintroduction than fall-run Chinook salmon. Because late fall-run Chinook salmon are recognized by many as a distinct race from fall-run Chinook salmon and as having unique life history strategies, the merits of their introduction in lieu of fall-run Chinook salmon will be evaluated by the FMWG in the future.

3.1 Fish Management Goals

Fish management goals are separated into two categories – population goals and habitat goals.

3.1.1 Population Goals

Goals are necessary to guide the vision of the SJRRP. The RA recommended population goals for spring-run and fall-run Chinook salmon (Meade 2007, 2008). For purposes of this plan, the RA's recommended goals were adopted as the first three population goals in the FMP. The FMWG developed the fourth goal for Chinook salmon based on principles of population dynamics, and a fifth goal to address other native fishes. Note it is not the intention of the SJRRP to control hatchery production for the entire Central Valley population or to implement specific actions to protect the fishery within or outside the Restoration Area.

The five population goals are:

1. Establish natural populations of spring-run and/or fall-run Chinook salmon that are specifically adapted to conditions in the upper San Joaquin River. Allow natural selection to operate on the population to produce a strain that has its timing of upstream migration, spawning, outmigration, and physiological and behavioral characteristics adapted to conditions in the San Joaquin River. In the case of spring-run Chinook salmon, the initial population would likely be established from Sacramento River Basin stock. For fall-run Chinook salmon, the nature of the Settlement flow regime indicates it may be desirable to establish late-spawning (November to December) fall-run Chinook salmon from tributaries of the San Joaquin River (e.g., Merced or Tuolumne rivers).

2. Establish populations of spring-run and/or fall-run Chinook salmon that are genetically diverse so they are not subject to the genetic problems of small populations, such as founder's effects, inbreeding, and the high risk of extinction from catastrophic events. The minimum population threshold established in the Settlement was set with this goal in mind and suggests genetic and population monitoring will be required.

3. Establish populations of spring-run and fall-run Chinook salmon that are demographically diverse in any given year, so returning adults represent more than two age classes. Given the vagaries of ocean conditions, the likelihood of extreme droughts, and other factors that can stochastically affect Chinook salmon numbers in any given year, resiliency of the populations requires that multiple cohorts be present. Chinook salmon populations in the Central Valley are dominated by 3-year-old fish, plus 2-year-old jacks, partly as the result of the effect of fisheries harvest. Both population resiliency and genetic diversity require that 4-, 5-, and even 6-year-old Chinook salmon be part of the population each year.

4. Each established San Joaquin River population (spring-run, fall-run) should show no substantial signs of hybridizing with the other. In addition, each San Joaquin River population (spring-run, fall-run) should show no substantial signs of genetic mixing with **nontarget** hatchery stocks.

5. Establish a balanced, integrated, adaptive community of fishes having a species composition and functional organization similar to what would be expected in the Sacramento-San Joaquin Province (Moyle 2002).

The San Joaquin River Basin does not currently support a self-sustaining population of spring-run Chinook salmon, and the restoration of a naturally reproducing population will likely require artificial propagation to seed the population, as significant recolonization from Central Valley populations is highly unlikely. Stock selection objectives and reintroduction strategies for spring- and fall-run Chinook salmon are included in the RA's recommendations (Meade 2007, 2008). The FMP describes goals and objectives for a naturally reproducing population of spring- and fall-run Chinook salmon that may initially include artificial propagation; however, the specifics of an artificial rearing facility such as the site of the facility, facility type, propagation method, and broodstock management issues have yet to be determined. The FMWG has started the planning process with the development of a Chinook Salmon Genetic Management Plan that will include a Hatchery Management Plan.

3.1.2 Habitat Goals

Habitat goals apply to the entire Restoration Area, and are discussed in this chapter, whereas goals relevant to specific reaches within the Restoration Area are addressed in Chapter 5. The habitat goals established for the Restoration Area focus on improved streamflow conditions and the establishment of suitable habitat. The following habitat goals focus on Chinook salmon and other native fishes:

- Restore a flow regime that (1) maximizes the duration and downstream extent of suitable rearing and outmigration temperatures for Chinook salmon and other native fishes, and (2) provides year-round river habitat connectivity throughout the Restoration Area.

- Provide adequate flows and necessary structural modifications to ensure adult and juvenile passage during the migration periods of both spring- and fall-run Chinook salmon.

- Provide a balanced, integrated, native vegetation community in the riparian corridor that supports channel stability and buttressing, reduces bank erosion, filters sediment and contaminants, buffers stream temperatures, supports nutrient cycling, and provides food resources and unique microclimates for the fishery.

- Provide suitable habitat for Chinook salmon holding, rearing, and outmigration during a variety of water year types, enabling an expression of a variety of life-history strategies. Suitable habitat will encompass appropriate holding habitat, spawning areas, and seasonal rearing habitat.

- Provide water-quality conditions suitable for Chinook salmon and other native fishes that allow successful completion of life cycles.

- Reduce predation losses in all reaches by reducing the extent and suitability of habitat for nonnative predatory fish.

- Restore habitat complexity, functional floodplains, and diverse riparian forests that provide habitat for spawning and rearing by native resident species, including salmon, during winter and spring.

3.2 Population Objectives

The aforementioned goals were used to establish realistic and measurable population objectives that will be used to evaluate overall program success. Specific objectives are necessary to adaptively manage the reintroduction process. The population objectives are listed below and follow with justification of those objectives. The recommended population objectives should be treated as preliminary recommendations, recognizing that the objectives will very likely be revised as more is learned about the conditions and capacities of the system.

The SJRRP population objectives are listed below and justified later in the FMP:

1. A 5-year running average target of a minimum of 2,500 naturally produced adult spring-run Chinook salmon and 2,500 naturally produced adult fall-run Chinook salmon (Table 3-1).

2. Each year, a minimum of 500 naturally produced adult spring-run and adult fall-run Chinook salmon each should be in adequate health to spawn successfully. Thus, the minimum annual effective population target would be 500 adult Chinook salmon of each run. Note, the expectation is that there will be a 50-percent sex ratio. Additional objectives related to genetics will be described in the Hatchery and Genetics Management Plan currently under development.

3. Ten years following reintroduction, less than 15 percent of the Chinook salmon population should be of hatchery origin. Additional objectives related to genetics will be further described in the Hatchery and Genetics Management Plan currently under development.

4. A Growth Population Target of 30,000 naturally produced adult spring-run Chinook salmon and 10,000 naturally produced fall-run Chinook salmon (Table 3-1).

5. Prespawn adult Chinook salmon mortality related to any disease should not exceed 15 percent.

6. Mean egg production per spring-run Chinook salmon female should be 4,200, and egg survival should be greater than or equal to 50 percent.

7. A minimum annual production target of 44,000 spring-run Chinook salmon juveniles and 63,000 fall-run Chinook salmon juveniles and maximum production target of 1,575,000 spring-run Chinook salmon juveniles and 750,000 fall-run juveniles migrating from the Restoration Area. Juvenile production includes fry, parr, subyearling smolts, and age 1+ yearling smolts. Estimated survival rate from fry emergence until they migrate from the Restoration Area should be greater than or equal to 5 percent. Ten percent of juvenile production for spring-run Chinook salmon should consist of age 1+ yearling smolts.

8. The incidence of highly virulent diseases should not exceed 10 percent in juvenile Chinook salmon.

9. A minimum growth rate of 0.4 grams per day (g/d) during spring and 0.07 g/d during summer should occur in juvenile Chinook salmon in the Restoration Area.

10. Document the presence of the following fish assemblage structures in the Restoration Area: rainbow trout assemblage (Reach 1), pikeminnow-hardhead-sucker assemblage (Reaches 2 through 5), and deep-bodied fish assemblage (Reaches 2 through 5).

Table 3-1.
Potential Adult and Juvenile Restoration Targets (Preliminary Targets in Bold) for Chinook Salmon Populations in the San Joaquin River Restoration Area

Performance Period	Annual Average Target	Period of Average	Annual Minimum/ Maximum	SR[1]	FR[2]	Source
Adult						
n/a	833	5 years	500/none	X	X	Lindley et al. (2007)
by Dec. 31, 2019	**n/a**	**n/a**	**500/none**	**X**	**X**	**Meade (2007, 2008)**
Jan. 1, 2020 – Dec. 31, 2024	**2,500**	**5 years**	**500/5,000**	**X**	**X**	**Meade (2007, 2008)**
Jan. 1, 2025 – Dec. 31, 2040	**Spring-run: 30,000**	**5 years**	**500/none[3]**	**X**		**Meade (2007)**
Jan. 1, 2025 – Dec. 31, 2040	**Fall-run: 10,000**	**5 years**	**500/none[3]**		**X**	**Meade (2008)**
Juvenile						
n/a	n/a	n/a	Spring-run: 44,000[4]/1,575,000 Fall-run: 63,000[4]/750,000	X	X	Various sources

Notes:

[1] Spring-run Chinook salmon

[2] Fall-run Chinook salmon

[3] Acknowledges potential annual fluctuations of up to 50 percent for each run and corresponding annual maxima and minima

[4] Derived from the annual average adult target of 833 (Lindley et al. 2007) and based on estimates of fecundity and life stage-specific survival

3.2.1 Justification for Adult Salmonid Population Objectives 1 Through 5

Many fishes are expected to benefit from actions taken to meet the Restoration Goal, such as the implementation of Restoration Flows (Exhibit E). However, the emphasis of the Restoration Goal is primarily on spring-run Chinook salmon, and secondarily on fall-run Chinook salmon.

A recent tenet of salmonid conservation biology known as the “Viable Salmonid Population” (VSP) concept (McElhany et al. 2000) was used in conjunction with Moyle’s definition of ‘good condition’ to guide the development of salmon population objectives. ‘Good condition’ and the VSP concept are similar. A viable population is an independent population that has a negligible risk of extinction resulting from threats from demographic variation, local environmental variation, and genetic diversity changes that may occur over a 100-year time frame. The VSP is used here to define objectives for Chinook salmon because it includes qualitative guidelines. In contrast, ‘good condition’ is a general term used to describe goals for all native fishes. A comparison between the VSP and Moyle’s definition of ‘good condition’ is outlined in Table 3-2.

Table 3-2.
Comparison Between VSP Parameters and “Good Condition”

VSP Parameters	“Good Condition”
Genetic Diversity	“genetically fit and diverse” “do not show ill effects of inbreeding, outbreeding” “no reliance on artificial propagation” “resilience to catastrophic events” “self-sustaining”
Population Abundance	“persistent membership over time” “self-sustaining”
Population Growth	“productivity” “viability of all life history stages and biological processes”
Spatial Structure	“replicated geographically” “resilience to catastrophic events”

Source: McElhaney et al., 2000; Moyle 2005

Preliminary population objectives were established for spring- and fall-run Chinook salmon in the Restoration Area. The objectives established will be used to guide and prioritize specific restoration actions, described in Chapter 5, and provide a benchmark for measuring restoration success, described in Chapter 6. Information on the genetic composition of likely source populations and the population genetics of the restored Chinook salmon populations is currently unknown. Further, information regarding Chinook salmon spawning and rearing habitat quality and quantity is currently lacking. Therefore, the recommended population objectives should be treated as preliminary recommendations, recognizing that the objectives will likely be revised as more is learned about the conditions and capacities of the system.

The adult population objectives recommended by the RA (Meade 2007, 2008) have been developed considering the following: (1) historical population estimates, (2) population estimates of runs immediately after Friant Dam was completed, (3) post-dam population estimates of fall-run Chinook salmon in the Merced, Tuolumne, and Stanislaus rivers below the lowest major dams, (4) estimates of the number of spawners and juveniles that can be supported by existing and/or improved habitat (habitat carrying capacity), and (5) basic genetic and demographic models for minimum viable population sizes (e.g., Lindley et al. 2007) (Table 3-1).

The RA's recommended targets were adopted by the FMWG as the Chinook salmon population objectives (bold text in Table 3-1) because these considerations currently represent the most comprehensive knowledge available for Chinook salmon targets. It is expected that the preliminary targets will be revised as more information is gathered regarding appropriate genetics, carrying capacity, and other important factors.

For adult Chinook salmon, the typical population indicator is escapement, which is the number of adults that return to the spawning habitat each year. Escapement reflects the total population of adults that return to spawn, but it is not equivalent to the number of adults that reproduce successfully (i.e., the effective population size). The RA (Meade 2007, 2008) defined four milestones: (1) a Reintroduction Period between the present and December 31, 2019; (2) an Interim Period between January 1, 2020, and December 31, 2024; (3) a Growth Population Period between January 1, 2025, and December 31, 2040; and (4) a Long-term Period beyond January 1, 2041. These time periods are also used in the FMP to help identify population targets. The following preliminary adult population targets include consideration of the total population size and effective population size.

As described by Lindley et al. (2007), spring- and fall-run Chinook salmon would meet the minimum viable population size and minimum effective population size as well as achieve a low (less than 5 percent) risk of extinction over a period of 100 years under the following conditions:

- A 3-year target of at least 2,500 naturally produced adult spring-run Chinook salmon and 2,500 naturally produced adult fall-run Chinook salmon. The target of 2,500 adult Chinook salmon in the escapement over a 3-year period is based on population viability assessment and estimated risk of extinction.
- Each year, a minimum of 500 naturally produced adult spring-run and adult fall-run Chinook salmon each should be in adequate health and spawn successfully. Thus, the minimum annual effective population target would be 500 Chinook salmon of each run. Healthy adults are those that show few signs of disease or other causes of prespawn mortality.

It is likely that a portion of the population will have to be produced in a hatchery or other artificial methods during the initial 10-year Reintroduction Period. After the initial 10-year Reintroduction Period, the target for the proportion of hatchery and other artificially produced fish will be less than 15 percent of the population, except potentially during periods of prolonged drought. If strays from out-of-basin hatcheries cannot be substantially excluded from the Restoration Area, then the minimum escapement target would be increased to achieve the goal of limiting the proportion of hatchery fish to 15 percent.

According to Meade (2007, 2008), a 5-year running average annual escapement target of at least 2,500 (with allowable population fluctuation between 500 and 5,000) adult spring-run Chinook salmon and 2,500 adult fall-run, should be achieved during the period from January 1, 2020, through December 31, 2024 (defined by the RA as the Interim Population Period). During the RA-defined Growth Population Period (2025 to 2040), a 5-year running average annual escapement should target at least 30,000 adult spring-run Chinook salmon and 10,000 adult fall-run. During the RA-defined Long-Term Period (2041 and beyond), a 5-year running average escapement target should be at least 30,000 adult spring-run Chinook salmon and 10,000 adult fall-run Chinook salmon. The 5-year running average for the Long-Term Period assumes a 50-percent range of fluctuation in the populations: equating to 15,000 to 45,000 for spring-run and 5,000 to 15,000 for fall-run Chinook salmon. For each period, the rate of increase in the number of spawners (cohort replacement rate) should be greater than 1.0.

Salmon populations have coevolved with pathogens present in their native watersheds. Under normal stream conditions, fish harbor numerous microorganisms at low levels, but the population may never suffer a disease outbreak. Fish exposed to environmental stress, such as increased temperature or turbidity, may have decreased resistance to pathogens and mortality from diseases may increase. Further, importing eggs or fish from a hatchery for river introduction increases the risk of associated disease, though eggs introduced from a tested broodstock should decrease the risks of moving vertically transmitted pathogens (i.e., offspring of infected parents are infected at birth). There are no clear guidelines regarding acceptable levels of disease in populations of adult Chinook salmon. USFWS recommends prespawn mortality related to any disease should not exceed 15 percent (Foott pers. com.).

3.2.2 Justification for Juvenile Salmonid Population Objectives 6 Through 9

Juvenile production can also be used as a population indicator. Used as a basis for the recommended average annual effective population size of 833 spawners associated with a low population extinction risk (Lindley et al. 2007), a minimum annual target of 44,000 spring-run Chinook salmon subyearling smolts, and 63,000 fall-run Chinook salmon subyearling smolts migrating from the Restoration Area can be derived. When the population growth targets (Table 3-2) are used, a target of 1,575,000 spring-run Chinook salmon subyearling smolts and 750,000 fall-run subyearling smolts can be derived. These targets are based on the following assumptions:

- The mean annual minimum escapement target of 833 spawners for each run (per Lindley et al. 2007) includes 417 females (a 50-percent sex ratio), and the growth population target for spring-run Chinook salmon of 30,000 (15,000 females) and growth population target for fall-run Chinook salmon of 10,000 (5,000 females). Spring-run Chinook salmon females produce an average of 4,200 eggs each based on fecundity estimates for spring-run Chinook salmon in the Sacramento River system (DFG 1998a and 2008). Fall-run Chinook salmon produce an average of 6,000 eggs per female (DFG 1990).

- Eggs survive at a mean rate of 50 percent based on the results of survival studies with fall-run Chinook salmon eggs in restored spawning habitats in the lower Stanislaus River in 2004 and 2005 (Carl Mesick Consultants and KDH Environmental Services 2009).
- The mean survival rate is 5 percent for Chinook salmon fry from the time they emerge until they migrate from the Restoration Area as subyearling smolt-sized fish (FL greater than 2.8 inches (70 mm). This is based on rotary screw trap estimates of total juveniles estimated on the Stanislaus River at Oakdale, relative to the number of subyearling smolt-sized fish passing Caswell State Park on the Stanislaus River between mid-December and early June during 2000 through 2003 (Mesick 2008).
- Up to 10 percent of the spring-run Chinook juvenile production could be composed of age 1+ yearling smolts (Garman and McReynolds 2006).

Juvenile production targets for both populations (spring- and fall-run) may emigrate as fry, parr, subyearling smolts, or age 1+ yearling smolts. All of these life stages will contribute to escapement. However, there is insufficient data to establish separate targets for each life-history strategy separately.

Fish diseases do occur naturally. Salmon have coevolved with these pathogens and can often carry them at less-than-lethal levels (Walker and Foott 1993). If water quality or quantity conditions cause crowding and stress, or when parasite spore loads are high, lethal outbreaks can occur (Spence et al. 1996, Guillen 2003, Foott 1995, Nichols and Foott 2005). There are no clear guidelines regarding acceptable levels of disease in populations of juvenile Chinook salmon. USFWS recommends the incidence of highly virulent diseases should not exceed 10 percent (Foott pers. com.).

Growth is a critical fitness parameter in juvenile fishes closely tied to survival. Many studies that evaluated growth of juvenile Chinook salmon occurred in estuary systems. Of the relatively few studies conducted in freshwater systems, the growth estimates reported are quite variable (and used several different methods to obtain the estimates). The extreme (lowest and highest) mean growth rates reported were 0.02 g/d (April through May in the Chehalis River, Washington; Miller and Simenstad 1994) and 0.9 g/d ("spring" in the Sixes River, Oregon; Reimers 1973). The FMWG recommends an initial objective of 0.4 g/d during the spring and 0.07 g/d during early summer for the San Joaquin River Restoration Area. The first number represents the mean of the extremes reported during April and May and the latter number represents Reimers' (1973) estimate for months with warmer water. These values should be viewed only as initial estimates and will likely be revised as more information is gathered. In addition, larger, healthier juveniles will likely have a better chance of surviving to and in the ocean.

3.2.3 Justification for Other Native Fish Population Objective 10

There is limited information about the population requirements, habitat carrying capacities and limiting factors for non-salmonid fishes of the Restoration Area. This lack of information prevents the development of population targets for other fishes at this time. However, the expectation of appropriate assemblage structure within the Restoration Area is expressed in Objective 10. When more information is available regarding population characteristics of members in these assemblages, the objectives for other fishes will likely be revised to reflect quantitative assessments.

Native fish species anticipated to occupy the Restoration Area after the implementation, through natural recolonization may include:

- Rainbow trout/steelhead
- Pacific lamprey
- Kern brook lamprey
- Hitch
- Sacramento blackfish
- Sacramento splittail
- Hardhead
- Sacramento pikeminnow
- Sacramento sucker
- Threespine stickleback
- Prickly sculpin
- Riffle sculpin
- California roach
- Tule perch

The expectation is that conditions established for Chinook salmon functioning as a focal species will benefit the species listed above that share habitat in the Restoration Area (Lambeck 1997). When considering passage, screening, and instream-habitat modifications, actions may also incorporate criteria for other fishes. Other fishes not documented historically or assumed extirpated from the San Joaquin River include North American green sturgeon (*Acipenser medirostris*), Sacramento perch, western brook lamprey, river lamprey (*Lampetra ayersi*), and speckled dace (*Rhinichthys osculus*). These fishes may be present in the San Joaquin River upstream from the confluence with the Merced River following the implementation of the SJRRP, but would likely be uncommon. It is expected the Restoration actions implemented for Chinook salmon may enable the natural recolonization of these species in the Restoration Area; however, SJRRP actions will not prioritize these species above spring-run Chinook salmon. Management actions benefitting other fishes, including Central Valley steelhead, may be implemented unless they compromise Chinook salmon reintroduction success.

Central Valley Steelhead

Whereas the VSP criteria discussed above apply to all salmonids, the SJRRP has not determined specific numeric objectives for Central Valley steelhead for two reasons: (1) difficulties associated with a viability assessment, and (2) Central Valley steelhead were not specifically identified as a target species in the Settlement. However, in the event that Central Valley steelhead reestablish in the Restoration Area as a result of the SJRRP, NMFS may develop additional management goals through the NMFS recovery planning process.

Population numbers of Central Valley steelhead present on the San Joaquin tributaries downstream from the Restoration Area (Stanislaus, Tuolumne, and Merced rivers) are unknown, owing to limited data, but the numbers likely range in the tens to low hundreds (DFG unpublished information), and may be present in the Restoration Area once flows are connected to Friant Dam.

There are existing populations of resident *O. mykiss* below Friant Dam, although this population is substantially supplemented from hatchery releases. In principle, the concepts upon which Chinook salmon population targets are based also apply to steelhead (McElhany et al. 2000, Lindley et al. 2007). However, considerable uncertainty exists regarding population viability metrics and development of population targets for Central Valley steelhead. The widespread influence of hatchery propagation, uncertainties regarding the influence of resident *O. mykiss*, and a general lack of data on Central Valley steelhead populations confound any viability assessment and introduce substantial uncertainty into efforts to develop population restoration targets. Data deficiencies prevented Lindley et al. (2007) from assessing the status of wild Central Valley steelhead populations (not hatchery influenced), and the authors cautioned that viability analysis of extant populations is problematic because of uncertainties regarding the effects of resident *O. mykiss* on population viability. Therefore, population targets for Central Valley steelhead have not been developed.

3.3 Habitat Objectives

The aforementioned habitat goals (Section 3.1.2) were used to establish realistic and measurable habitat objectives that will be used in conjunction with population objectives to evaluate overall program success. For the Restoration Area as a whole, the fish habitat goals will be realized primarily through improved streamflow and passage, and the establishment of suitable habitat. Note, although these objectives are developed to assist with program success and evaluation, some of them are not within the scope of the SJRRP. For example, selenium can be problematic to control as many remedial actions are beyond the scope of the SJRRP.

Habitat and water quality objectives are listed below and follow with justification of those objectives. In addition, additional information on water quality objectives are found in Exhibit B. The recommended objectives should be treated as preliminary recommendations, recognizing they will very likely be revised as more is learned about the habitat needs and the response of reintroduced fish populations to flows and other physical factors.

The SJRRP habitat objectives are:

1. A minimum of 30,000 square meters (m^2) of high-quality spring-run Chinook salmon holding pool habitat.
2. A minimum of 78,000 m^2 of quality functioning spawning gravel in the first 5 miles of Reach 1 should be present for spring-run Chinook salmon.
3. A minimum of 7,784 acres (3.15×10^7 m^2) of floodplain rearing habitat for spring-run Chinook salmon subyearling rearing/migrating juveniles and 2,595 acres (1.05×10^7 m^2) of floodplain rearing habitat for fall-run subyearling rearing/migrating juveniles.
4. Provide passage conditions that allow 90 percent of migrating adult and 70 percent of migrating juvenile Chinook salmon to successfully pass to suitable upstream and downstream habitat respectively, during all base flow schedule component periods and water year types of the Settlement, except the Critical-Low water year type.
5. Provide appropriate flow timing, frequency, duration, and magnitude enabling the viability of 90 percent of all life-history components of spring-run Chinook salmon.
6. Water temperatures for spring-run Chinook salmon adult migrants should be less than 68°F (20°C) in Reaches 3, 4, and 5 during March and April, and less than 64°F (18°C) in Reaches 1 and 2 during May and June (Exhibit A).
7. Water temperatures for spring-run Chinook salmon adult holding should be less than 59°F (15°C) in holding areas between April and September (Exhibit A).
8. Water temperatures for spring-run Chinook salmon spawners should be less than 57°F (14°C) in spawning areas during August, September, and October (Exhibit A).
9. Water temperatures for spring-run Chinook salmon incubation and emergence should be less than 55°F (13°C) in spawning areas between August and December (Exhibit A).
10. Water temperatures for spring-run Chinook salmon juveniles should be less than 64°F (18°C) in the Restoration Area when juveniles are present (Exhibit A).
11. Selenium levels should not exceed 0.020 milligrams per liter (mg/L) or a 4-day average of 0.005 mg/L in the Restoration Area (Exhibit B).
12. DO concentrations should not be less than 6.0 mg/L when Chinook salmon are present (Exhibit B).

13. Total ammonia nitrogen should not exceed 30-day average of 2.43 milligrams nitrogen per liter (mg N/L) when juvenile Chinook salmon are present or exceed a 1-hour average of 5.62 mg N/L when Chinook salmon are present (Exhibit B).

14. The ecological integrity of the Restoration Area should be restored as a result of improved streamflow, water quality conditions, and the biological condition of aquatic communities. Over 50 percent of the total target river length should be estimated to be in good condition (benthic index of biotic integrity (B-IBI) = 61-80) or very good condition (B-IBI=81-100). In addition, none of the study sites should be in “very poor condition” (B-IBI=0-20).

3.3.1 Justification for Area and Passage Habitat Objectives 1 Through 4

Deep pools are needed for spring-run Chinook salmon because they migrate to the spawning reaches in the spring as sexually immature adults and then hold through the summer. According to DFG (1998b), ideal holding pool depth for Central Valley spring-run Chinook salmon are between 1 and 3.3 meters (3 and 10 feet). Spring-run Chinook salmon were estimated to occupy high-quality holding pools in Butte Creek at a mean density of 1.0 fish/m^2 (range: 0.5 fish/m^2 to 1.5 fish/m^2) (Stillwater Sciences 2003). Because the Butte Creek spring-run Chinook salmon population is considered the healthiest, most stable Central Valley spring-run population, and pre-spawning mortality rates are generally within the acceptable range, mean holding pool densities found in Butte Creek were used to develop the holding habitat objective. Based on the mean growth population target of 30,000 spring-run Chinook salmon spawners described above, and a mean density of 1.0 fish/m^2, a minimum 30,000-m^2 high-quality holding pool habitat should be provided.

Sufficient quality and quantity of spawning gravel in Reach 1 are needed for spring-run Chinook salmon spawning. Estimates of existing and needed Chinook salmon spawning habitat in Reach 1 and the potential adult population carrying capacity vary considerably (Meade 2007), primarily due to differing redd size estimates. For example, estimated redd sizes are reported to range from 16.8 m^2 (EA Engineering 1992), to 20.0 m^2 (Meade 2007). Because these estimates likely consider the territorial range of spawners and represent the area defended by the female and not the redd or egg pocket area, they are likely overestimates (Frank Ligon and Bruce Orr, pers. com.). To calculate redd size, the average size reported in the Central Valley Salmon and Steelhead Restoration and Enhancement Plan (Reynolds et al. 1990) was used (5.2 m^2). With a mean growth population target of 30,000 spring-run Chinook salmon and a 50-percent sex ratio, 78,000 m^2 of spawning gravel would be needed.

Population Objective 7 established a minimum annual target of 44,000 spring-run and 63,000 fall-run Chinook salmon subyearling smolts migrating from the Restoration Area. Standards have not been established to quantify the amount of floodplain habitat needed to support rearing of juvenile salmonids. However, Sommer et al. (2005) described spatial and temporal trends in Chinook salmon habitat use on a Sacramento River floodplain (Yolo Bypass). The authors calculated an estimate of abundance per hectare for Chinook salmon using floodplain habitat. Using this estimate and assuming their sampling gear (seining) was 1 percent effective (Shannon Brewer, USFWS, personal communication), an approximate density estimate of 0.47 fish/m^2 was calculated. This estimate was similar to the benchmark used in Ecosystem Diagnosis and Treatment (EDT) modeling (0.50 fish/m^2 for age-0 transient rearing) as well as that found on a floodplain on the lower American River (0.72 fish/m^2) by Jones and Stokes (1999). The density estimate of 0.50 fish/m^2 was used to calculate the amount of floodplain habitat recommended based on the minimum targets established in the population objectives. Based on a mean growth population target of 30,000 spring-run Chinook salmon each with a mean egg production of 4,200 eggs, a 50 percent survival rate of eggs and a 50 percent survival rate to fry stage[1], $3.1\text{x}10^7$ m2 of floodplain rearing habitat would be needed. Two-dimensional modeling of multiple San Joaquin River inundation scenarios was used to refine the floodplain objective. This initial estimate of needed floodplain habitat should provide a starting point for restoration activities, though this preliminary estimate will likely be revised as we learn more about the system capacity and constraints.

Sufficient passage for adult and juvenile salmon is needed to meet the Restoration Goal. Potential passage impediments are described in McBain and Trush (2002) and Exhibit A, and the Settlement specifies the remediation of numerous known passage impediments in the Restoration Area. While implementation of the Settlement is expected to remove most passage impediments, changes in flow and passage rates of salmon are unpredictable and 100-percent passage is not guaranteed. A preliminary passage objective of 90-percent success for adults and 70-percent success for juveniles is established.

3.3.2 Justification for Flow Habitat Objective 5

The Settlement specifies a flow schedule that varies with the annual unimpaired runoff of the San Joaquin River at Friant Dam for the October 1 to September 30 water year. The flow schedules are described in Exhibit B of the Settlement and are designed to provide suitable conditions for adult migration for spring- and fall-run Chinook salmon, spring-run Chinook salmon adult holding, as well as spawning and incubation, and juvenile rearing and outmigration for both runs. Specific goals of the flow schedule are detailed in Exhibit E.

3.3.3 Justification for Water Quality and Temperature Habitat Objectives 6 Through 13

To meet the SJRRP Restoration Goal, water quality should meet minimum standards for protection of aquatic resources. Because of the lack of information on the effects of many water quality constituents on Chinook salmon and other fishes, the water quality objectives for beneficial uses defined by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) are used to establish water-quality goals. The main beneficial uses for the enhancement of fisheries resources within the Restoration Area are: (1) cold, freshwater habitat, (2) migration of aquatic organisms, and (3) spawning, reproduction, and early development.

The temperature objectives are based on a DFG proposal to assess temperature impairment (DFG 2007b), U.S. Environmental Protection Agency (EPA) guidelines (EPA 2003), and a report on temperature impacts on fall-run Chinook salmon and steelhead (Rich and Associates 2007).

Water-quality objectives are "the limits or levels of water quality constituents or characteristics established for the reasonable protection of beneficial uses of the water or the prevention of a nuisance in a specific area" (California Water Code Section 13050(h)).Water-quality standards consist of the designated beneficial uses and water quality objectives set forth by the State Water Resources Control Board (SWRCB) and the Central Valley Water Board and are contained in the Water Quality Control Plan for the Sacramento River Basin and the San Joaquin River Basin (Basin Plan). For the San Joaquin River system, including the Restoration Area, SWRCB has set a goal to be free from toxic substances in surface water (Central Valley Water Board 1998). Selenium, DO, and ammonia objectives are based on the Central Valley Water Board and SWRCB standards described above. Additional water quality criteria are defined in Exhibit B.

3.3.4 Justification for Ecological Integrity Habitat Objectives 14

Bioassessment data are needed to evaluate the ecological integrity of the Restoration Area. Assessing the biological condition of aquatic communities helps determine how well a water body supports aquatic life (Barbour et al. 1996). Aquatic communities, such as benthic macroinvertebrates (BMI), comprise the effects of different pollutant stressors. Collection of BMI and physical habitat data in different areas of the San Joaquin River will help assess water quality conditions and identify habitat features responsible for the restoration of ecological integrity (Harrington 1999, Rehn and Ode 2005). A study by Henson et al. (2007) showed that a pulse flow event in the Mokelumne River can affect downstream fish and macroinvertebrate habitat quality. Similarly, Restoration Flows in the San Joaquin River could impact aquatic communities as a result of changes in habitat suitability.

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Chapter 4 Conceptual and Quantitative Models

Conceptual and quantitative models are critical components to the Adaptive Management Approach (Figure 4-1), as they are tools to illustrate system understanding and to make predictions about how the system responds to management actions. In addition, models can be used to highlight biological and management uncertainties. The following presents the current conceptual models defined for the SJRRP, as well as a brief description of the EDT framework that will be used as a quantitative tool. EDT is the first quantitative model to be used to model the potential outcomes of the SJRRP actions on fisheries resources in the Restoration Area.

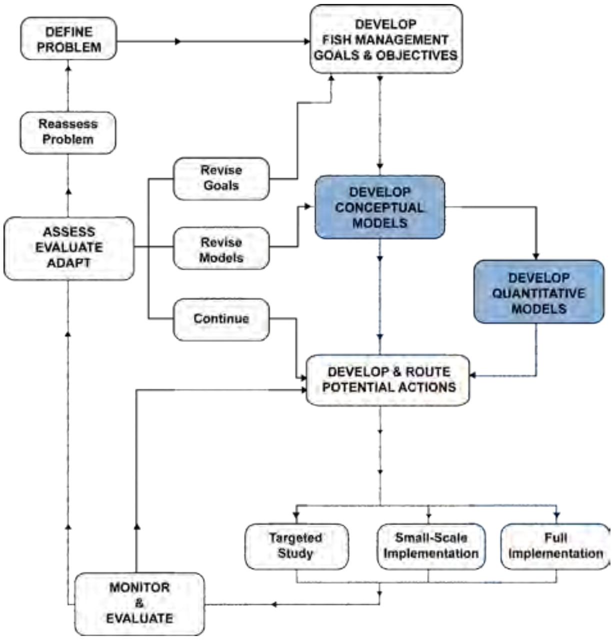

Figure 4-1.
Fisheries Management Plan Adaptive Management Approach – Model Development

4.1 Conceptual Models

Before the development of the FMP, conceptual models were developed for spring- and fall-run Chinook salmon to lay the foundation for the FMP (Exhibit A). Conceptual models provide the explicit link between goals and restoration actions. Conceptual models are simple depictions of how parts of the ecosystem are believed to work and how they might respond to restoration actions. These models are representations of scientists' and resource managers' understanding of system functions. Conceptual models are used to develop and discriminate restoration actions that have a high likelihood of achieving an objective while providing information to increase understanding of ecosystem function and, in some instances, to resolve conflicts among alternative hypotheses about the ecosystem.

By breaking down the problem into a series of limiting factors, the conceptual models are used to develop specific objectives for restoration. The conceptual models are living documents, continually under revision as new information becomes available. As indicated in Figure 4-1, conceptual models can be strengthened further by the development of quantitative models.

The conceptual models defined for the SJRRP describe life-history requirements and environmental factors most likely to affect the abundance of San Joaquin River spring- and fall-run Chinook salmon in the Study Area and Pacific Ocean (Exhibit A). Exhibit A also describes (1) the historical status of Chinook salmon in the San Joaquin River before the construction of Friant Dam, (2) the life history and habitat requirements of Chinook salmon in the Central Valley, (3) potential stressors of Chinook salmon in the San Joaquin River Basin, (4) a limiting factors assessment of fall-run Chinook salmon populations in the Stanislaus and Tuolumne rivers, (5) conceptual models identifying likely mechanisms controlling environmental factors that affect the abundance and recovery of spring-and fall-run Chinook salmon populations in the San Joaquin River Basin, and (6) data needs (i.e., knowledge gaps) for spring-and fall-run Chinook salmon in the San Joaquin River Basin.

The limiting factors assessment assumes all restoration actions prescribed in the Settlement will be implemented. The conceptual models will be used to assist in evaluating program alternatives, guiding flow management, and identifying key habitat restoration needs. As part of an adaptive management process, monitoring data will be used to refine the conceptual models and revise management and restoration priorities. The conceptual models will also be used to help develop quantitative population models and will help establish and refine targets, inform development of testable hypotheses, and provide a foundation for adaptively managing restoration of the San Joaquin River for fishes. As new information becomes available and restoration actions begin, the conceptual models will be revised accordingly.

4.2 Quantitative Models

The conceptual and quantitative models provide a critical framework for understanding the observed responses of Chinook salmon in the Restoration Area and provide a means of assessing the relative effects of in-river restoration and management actions. In addition, quantitative models are needed to develop testable hypotheses, gather information to reduce uncertainty, and further refine conceptual models.

The absence of Chinook salmon populations in the San Joaquin River provides considerable uncertainty in planning their reintroduction. Therefore, quantitative models provide structured analyses enabling adaptive management of the SJRRP. Specifically, selected fisheries quantitative model(s) will assist in the following tasks:

- Refining population goals
- Planning habitat restoration and flow management actions
- Developing expected fish survival rates attributable to different restoration activities
- Identifying and prioritizing limiting factors that will require restoration or other actions
- Adaptive management planning through the identification of key uncertainties and data needs, and development of testable hypotheses

EDT was the first modeling approach selected for use in the SJRRP because it provides a framework that views Chinook salmon as the diagnostic species for the ecosystem. The EDT framework was designed so that analyses made at different scales (i.e., from tributary watersheds to successively larger watersheds) can be related and linked. Biological performance is a central feature of the framework and is defined in terms of three elements: life history diversity, productivity, and capacity. These elements of performance are characteristics of the ecosystem that describe persistence, abundance, and distribution potential of a population. The analytical model uses environmental information and draws conclusions about the ecosystem. The model incorporates an environmental attributes database and a set of mathematical algorithms that compute productivity and capacity parameters for the diagnostic species.

The general approach for comparing existing and desired conditions is called the Patient-Template Analysis (PTA). This approach compares existing conditions of the diagnostic populations and their habitat (Patient) with a hypothetical potential state (Template), where conditions are as good as they can be within the watershed. The Template is sometimes approximated with a reconstruction of historic conditions. The Template is intended to capture the unique characteristics and limitations of the watershed because of its combination of climate, geography, geomorphology, and history.

The diagnosis is performed by comparing the Patient and Template to identify the factors or functions preventing the realization of goals. The diagnosis can be qualitative or quantitative, depending on the type and quality of the information used to describe the ecosystem. Regardless, the diagnosis forms a statement of understanding about the present conditions of the watershed as related to the diagnostic species. Following the diagnosis, potential actions to achieve objectives are identified. Candidate actions are tailored to solve problems identified in the diagnosis. To complete the EDT modeling framework, the modeling team first identifies and characterizes the existing habitat, and populates the model with this information. Next, a proof of concept model consisting of existing habitat information and modeling structure is used to construct a “draft” model (Exhibit F). Lastly, the modeling team incorporates local data into the framework to construct a final San Joaquin River EDT model. The EDT Proof of Concept documentation is found in Exhibit F.

The water temperature model (SJR5Q) was used for the SJRRP to help examine existing conditions and predict future conditions of the river with respect to water temperature. This HEC-5Q-based model is the result of combining and extending a number of smaller model development efforts throughout the San Joaquin River Basin. The final SJR5Q model includes a reservoir operation and temperature model of Millerton Reservoir, and a river temperature model of the San Joaquin River from Millerton Reservoir downstream to the Old River bifurcation north of Mossdale, and the three major tributaries, the Merced, Tuolumne, and Stanislaus rivers. Subsets of the model that included only the Restoration Area were used by the FMWG.

The reservoir model portion of SJR5Q is a one-dimensional, vertically segmented model of Millerton Reservoir. The river portion of the model is a one-dimensional, longitudinally segmented model of the San Joaquin River from Millerton Reservoir to the Old River bifurcation. The model functions on a daily flow time-step with a 6-hour temperature interval to capture diurnal temperature fluctuations. As currently implemented, the model simulates the time interval of 1980 to 2006. This model has been used in the SJRRP to generate temperature simulation estimates assuming existing channel geometry and implementation of Settlement flows, with results summarized in Draft TMs *Temperature Model Sensitivity Analysis Sets 1 and 2* (SJRRP WMWG 2008a) and *Temperature Model Sensitivity Analysis Set 3* (SJRRP WMWG 2008b).

Other modeling approaches may be pursued in the future as the SJRRP enters the implementation phase. For example, individual-based models, Bayesian statistical models (McAllister and Kirkwood 1998), species-portioning models (Higgins and Strauss 2008), three-dimensional temperature models, or instream flow incremental methodology may be useful.

Chapter 5 Develop and Route Actions

Likely limiting factors are identified in the conceptual models, and potential solutions (i.e., actions) to ameliorate the limiting factors need to be developed and assessed in a transparent structured analysis. In many cases, there may be more than one potential action that could reduce the effects of a limiting factor. As new information becomes available, the perceived relative importance of limiting factors may change, resulting in the development of new actions or the removal of actions. In the Adaptive Management Approach, the potential actions include Settlement actions and additional actions considered as a means to meet particular fisheries goals.

Note, the subsequent discussion of uncertainty in this chapter focuses on uncertainty of a specific action achieving the desired outcome and not on the uncertainty associated with the importance of the particular potential limiting factor the action is designed to address. The uncertainty of the limiting factors analysis and associated conceptual models as well as their future refinement was described in Chapter 4.

5.1 Action Development

The likely limiting factors identified in the conceptual models have actions developed and routed as described in Figure 5-1. Potential actions for limiting factors were developed based on Settlement requirements, pre-Settlement background information, actions commonly applied in the Central Valley, and additional actions identified in scientific literature. Actions were developed and sorted into adaptive management categories via a process termed **action routing** in this document.

Potential actions are developed to reduce the effects of limiting factors and routed through a decision tree (Figure 5-2). Action routing results in recommendations to conduct a targeted study, small-scale implementation, or full implementation, depending on evaluation factors (e.g., worth, risk, reversibility). For example, inadequate streamflow is a limiting factor addressed by the Settlement flow schedule action. The Settlement flow schedule was routed through the decision tree and ranked as high worth and magnitude, high uncertainty, and low risk resulting in full implementation being recommended for that action.

Actions will be modified, developed, or added as new information becomes available from conceptual and quantitative models, and from evaluation of the program. For example, EDT is a spatially explicit model that has been tailored for the SJRRP and will be used to help assess the potential contribution of various actions. Results from this model will be used to help prioritize and route potential actions.

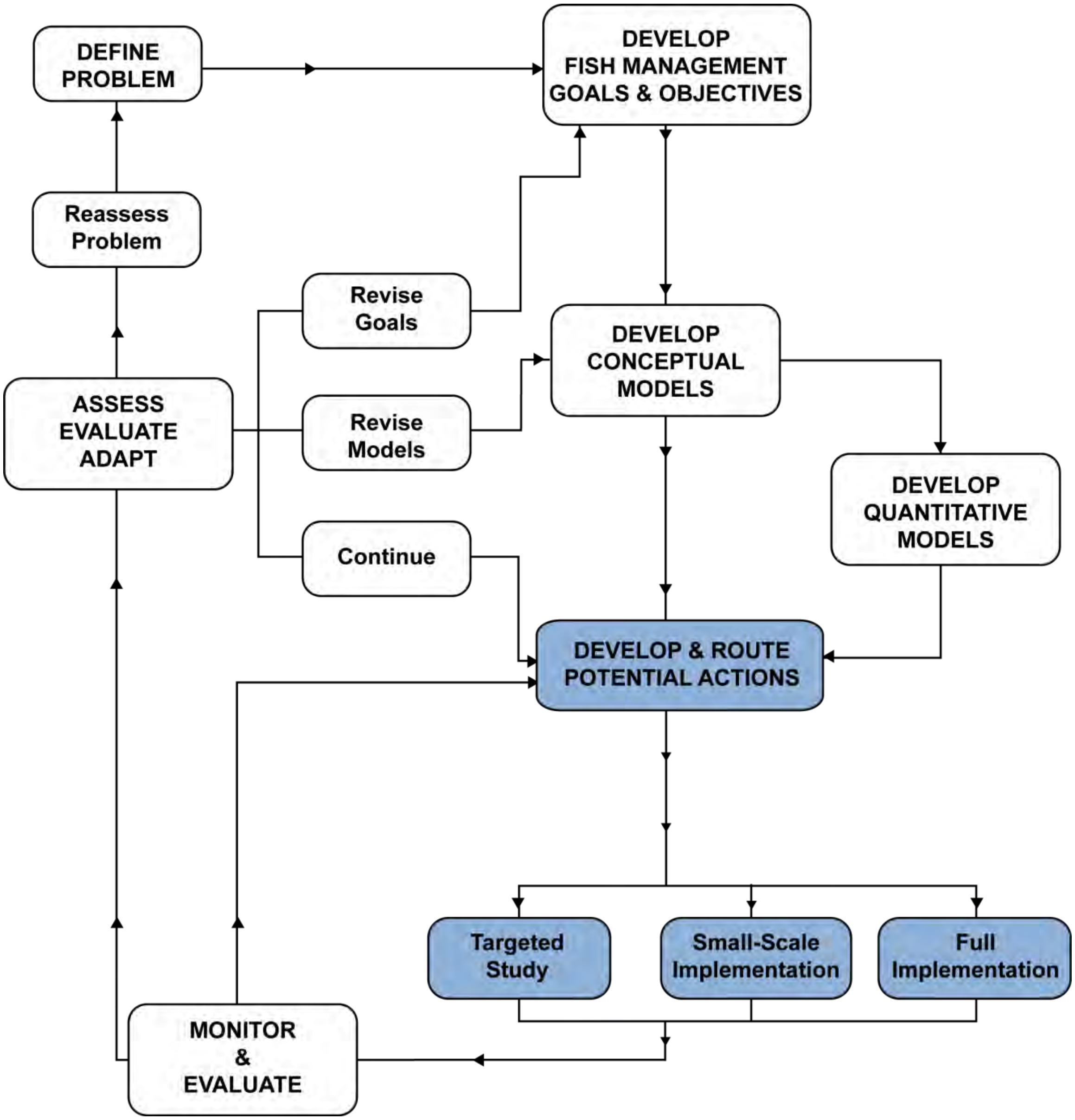

Figure 5-1.
Fisheries Management Plan Adaptive Management Approach – Develop and Route Potential Actions

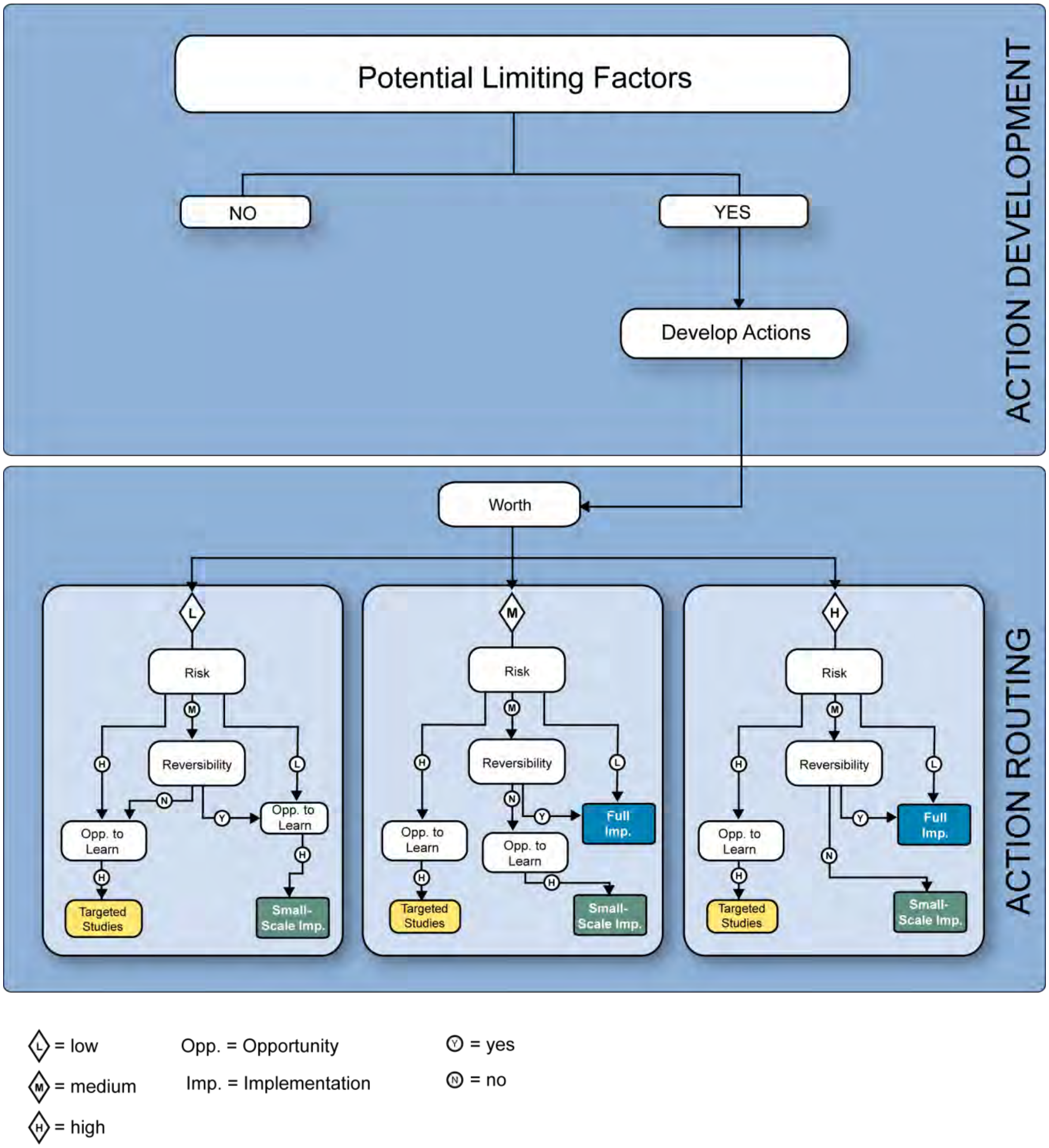

Figure 5-2.
Limiting Factor Prioritization and the Routing of Potential Actions

The terms worth, risk, reversibility, and opportunity for learning combine considerations of magnitude and certainty to assess the consequences of an action and recommend whether the action should be considered as: targeted studies, a small-scale implementation action, or a large-scale implementation project using the decision tree. **Scale** addresses temporal and spatial considerations, quantity and/or degree of change contained within the action. **Magnitude** assesses the contribution of the outcome, as opposed to the scale of the action, and can consider population and habitat effects, or cost relative to the outcome. **Certainty and/or uncertainty** describes the likelihood that a given action will achieve a specific outcome and considers the predictability of reaching the outcome.

Worth is the measure of the probability of a positive outcome, and combines the **magnitude** and **certainty** of positive outcomes to convey the cumulative "value" of an action. Potential actions with low worth have negligible positive impacts, while moderate worth indicates measurably positive impacts that may not significantly enhance meeting the Restoration Goal. High worth indicates that not taking the potential action would likely preclude meeting the Restoration Goal.

Risk is a measure of the probability of a negative biological or physical outcome of creating an impediment to appropriate stream function (e.g., instream sediment processes). Risk combines the **magnitude** and **certainty** of negative outcomes to convey the cumulative "potential" for a restoration action to result in an adverse or negative outcome. **Low risk** indicates the potential for a slight, unmeasurable negative impact. **Moderate risk** indicates a measurable negative impact that likely will not hinder achieving the Restoration Goal. **High risk** suggests with high certainty that the potential action will have a measurable negative impact that will likely hinder meeting the Restoration Goal.

Reversibility is defined as the probability that the system undergoing the restoration action *can* or *will* be returned to its original state. Criteria used to assess reversibility are the probability of being able to return the system to the original state, and the cost of reversing the action relative to the biological impacts of not reversing the action (even if the action does not improve the limiting factor). For example, a change in flow regime is reversible because there is a100-percent likelihood that the flow regime can be changed back to its prior state. Contrarily, there would be a small likelihood that installing a large bypass system would be reversible to its original state, regardless of the cost. As another example, if an action were fully implemented to create side channel habitat for Chinook salmon spawning, but no fish spawned in the new habitat, the action would not be reversible because the new side channel habitat would not result in negative biological impacts, and would be costly to fill in the created habitat.

Finally, the **opportunity for learning** represents the likelihood that a restoration action or a group of restoration actions will increase the level of understanding with regard to the species, process, condition, region, or system in question, assuming appropriate monitoring and evaluation is conducted.

Action routing results in recommendations to apply either a targeted study, small-scale implementation, or full implementation, depending on evaluation factors. **Targeted studies** would be implemented when uncertainty is high and may be developed into special research studies or monitoring components, as necessary, depending on the opportunity to learn and level of understanding. These studies may include efforts such as monitoring, modeling (conceptually or quantitatively), cost assessments, literature reviews, or small targeted research studies (that may have small implementation components) with an emphasized learning component. **Small-scale implementation** projects (or “pilot projects”) generally have a high opportunity to learn, and are associated with a low-to-medium amount of risk. These projects may be reversible or nonreversible depending on the level of risk involved. These types of projects are typically smaller projects with specific learning opportunities and focused monitoring efforts. **Full implementation** projects are medium- or high-worth actions and must have a low or medium amount of risk of adverse consequences. As actions are evaluated, they may terminate if completed and the goal is met, continue if progress is sufficient, or be rewritten and/or revised. These actions are usually associated with limited monitoring efforts because of the low level of uncertainty associated with these actions.

As an example, Chinook salmon spawning gravel augmentation is considered a high-priority action in Reach 1, having a high worth because of the importance for meeting the Restoration Goal (Worth = High), and a low risk of negative outcomes (Risk = Low). As a result, the augmentation of spawning gravel is recommended for full implementation (Figure 5-2).

5.2 Action Routing

Adaptive management is a systematic approach that acknowledges our limited understanding (i.e., uncertainty) about how systems operate. Adaptive management provides a framework for testing hypotheses about system responses while learning (with the expectation of reducing uncertainty) about the processes governing the system (Lee 1993, Shea et al. 1998). Adaptive management has been broadly categorized as either passive or active. With **passive adaptive management**, managers determine the best possible model or hypothesis based on prior comparisons with alternative hypotheses and sufficient support for one of those hypotheses via scientific evidence. Ultimately, this results in a single “best” hypothesis about the management approach expected to be the most useful. Managers may use monitoring data to improve or refine the hypothesis and then use that information when making decisions regarding actions dealing with similar situations in the future (Walters and Hillborn 1978).

In contrast, **active adaptive management** is used to test competing hypotheses about how a system will work with targeted studies used to test the validity of each hypothesis (Walters and Hillborn 1978, Walters and Holling 1990). The distinction between the two adaptive management approaches serves as a framework for understanding the similarities and differences between the actions presented in this chapter.

The aforementioned distinction between passive and active adaptive management was not made to strictly classify actions into either group, but to make distinctions between how actions are routed. Many actions identified in the Settlement are in the passive adaptive management framework because the single hypothesis associated with each action has a low level of uncertainty. Actions with low uncertainty will often not require targeted studies to determine if they should be implemented or will require limited monitoring. For example, it has already been demonstrated in many other systems that screening large water diversions is an effective way to reduce juvenile Chinook salmon losses and the screening of Arroyo Canal is appropriately placed in the passive adaptive management framework. Consequently, the goal of a fish screen monitoring evaluation would be to determine whether or not the screen functioned hydraulically as designed, rather than to determine how many juvenile fish it saved from entrainment. On the other hand, the worth of screening smaller diversions may be low and the action is associated with higher uncertainty (Moyle and Israel 2005). The screening of smaller diversions therefore is placed in the active adaptive management framework.

Alternatively, some actions dictated by the Settlement are treated as passive because it is the best model available at this time, but may have a high degree of uncertainty. Actions with high uncertainty may only have one hypothesis, but monitoring will likely lead to modification or additional alternatives to this action. For example, increasing discharge in the San Joaquin River is a necessary component of improving river connectivity, but there is a tremendous amount of uncertainly related to the appropriate discharge conditions. This action would have one hypothesis, but monitoring the proposed conditions will likely lead to alternative actions to better meet the Settlement goals.

Actions treated as active adaptive management are those actions with a relatively high degree of uncertainty. These actions will have competing hypotheses that will be evaluated via targeted studies to determine the next possible course of action. For example, a variety of actions could be taken to improve the quality or quantity of Chinook salmon spawning habitat and there is a high degree of uncertainty related to each action. In this case, targeted studies would be implemented to evaluate all the competing hypotheses before a decision is made to implement a larger scale action.

The specific process of action routing began with limiting factor analyses in the conceptual models (Exhibit A). Potential salmon-related actions were developed and routed through a decision tree by the FMWG. Note, some potential actions are routed multiple times; however, they are routed under different limiting factors and may have different goals and objectives. Goals were developed to ameliorate limiting factors affecting particular life stages and reaches. Data needs and monitoring of actions were included to highlight what data were needed to evaluate the actions and how it would be monitored to obtain that data. Data needs are expected to yield additional information to better inform a management action and may be necessary before recommendations can be made to implement an action. Monitoring allows for assessing hypotheses (H_A), especially actions associated with moderate to high uncertainty. Potential triggers and adaptive responses address how results from monitoring actions will be used to determine alterations of actions or the development of new actions.

The salmon-related action routing results for the SJRRP is summarized in Table 5-1. The actions identified to ameliorate limiting factors tend to focus on individual corresponding limiting factors; however, large-scale problems encompassing multiple limiting factors (climate change, life history tactic, fish community structure) also need to be addressed. Because these factors encompass multiple limiting factors already addressed in Table 5-1, they are only discussed here and not included in the table. These topics are discussed in further detail here. **Climate change** is thought to primarily affect streamflow and water temperatures but can also negatively impact other factors as a result of changes to streamflow and temperatures, such as fish passage, pumping rates, genetic viability through reduced species ranges, holding pool habitat, redd superimposition, sedimentation, predation, and food availability. Actions to ameliorate these negative impacts have been developed and routed as part of the action routing section. Factors impacting the potential **Life-History Tactic** exhibited by salmon include the frequency and magnitude of streamflow, passage conditions, and habitat quality and availability. For a description of the life-history tactic concept, the reader is referred to the Conceptual Models document (Exhibit A). One of the goals identified in the FMP (Chapter 3), is to establish a balanced, integrated, adaptive community of fishes having a species composition and functional organization similar to what would be expected in the Sacramento-San Joaquin Province. The expectation is that conditions established for Chinook salmon functioning as a focal species will benefit the native **Fish Community Structure** that share habitat in the Restoration Area (Lambeck 1997).

Table 5-1.
Action Routing Results and Estimated Timelines

Limiting Factor	Objective(s)	Potential Salmon-Related Action	Recommended Implementation	Settlement Paragraph	Settlement Timeline	FMWG Tentative Timeline	Status
Inadequate Streamflow	A: Provide flows sufficient to ensure habitat connectivity and allow for unimpeded upstream passage and outmigration	1: Modify San Joaquin River and Eastside and Mariposa bypasses to create a low-flow channel suitable to support fish passage	Full Implementation	11	12/31/2013	12/31/2013	Site Specific
		2: Modify channels in Reaches 2B and 4B to increase flow capacity (low-flow or migration-flow capacity)	Full Implementation	11, 12	12/31/2013	12/31/2013	Site Specific
		3: Implement Settlement flow schedule	Full Implementation	13	10/1/2009	2009	On Schedule
		4: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary	Full Implementation	13	1/1/2014	1/1/2014	On Schedule
		5: Implement trap-and-haul operation to move Chinook salmon into suitable habitat areas when flows are inadequate	Targeted Study	Not Described	12/31/2016	2010	Not Determined
Inadequate Streamflow	B: Provide flows sufficient to ensure suitable Chinook salmon spawning depth and velocity	1: Implement Settlement flow schedule	Full Implementation	13	10/1/2009	2009	On Schedule
		2: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary	Full Implementation	13	1/1/2014	1/1/2014	On Schedule
		3: Modify channels to provide Chinook salmon spawning habitat	Small-Scale Implementation	12	12/31/2016	TBD	Developing Sediment Management Plan
Inadequate Streamflow	C: Provide suitable flow for egg incubation and fry emergence	1: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary	Full Implementation	13	1/1/2014	1/1/2014	On Schedule

Table 5-1.
Action Routing Results and Estimated Timelines (contd.)

Limiting Factor	Objective(s)	Potential Salmon-Related Action	Recommended Implementation	Settlement Paragraph	Settlement Timeline	FMWG Tentative Timeline	Status
Entrainment	D: Minimize juvenile entrainment losses	1: Screen Arroyo Canal to prevent fish losses	Full Implementation	11	12/31/2013	12/31/2013	Site Specific
		2: Construct Mendota Pool Bypass	Full Implementation	11	12/31/2013	2010	Site Specific
		3: Modify Chowchilla Bifurcation Structure to reduce juvenile entrainment	Targeted Study	11	12/31/2013	TBD	Not Determined
		4: Fill and isolate the highest priority mining pits	Targeted Study	11	12/31/2016	TBD	Not Determined
		5: Consolidate diversion locations	Targeted Study	Not Described	12/31/2013	2010	Developing SOW
		6: Screen all large and small diversions	Targeted Study	Not Described	12/31/2013	TBD	Developing SOW
Excessive Straying	E: Minimize losses to nonviable pathways and prevent migration delays	1: Implement temporary or permanent barriers at Mud and Salt sloughs or any other location deemed necessary	Full Implementation	11	12/31/2013	12/31/2013	Not Determined
		2: Screen Arroyo Canal to prevent fish losses	Full Implementation	11	12/31/2013	12/31/2013	Developing SOW
		3: Fill and isolate the highest priority mining pits	Targeted Study	11	12/31/2016	TBD	Developing Work Plan
Impaired Fish Passage	F: Eliminate fish passage barriers and minimize migration delays	1: Modify Sand Slough control structure	Full Implementation	11	12/31/2013	12/31/2013	Developing SOW
		2: Modify Reach 4B headgate	Full Implementation	11	12/31/2013	12/31/2013	Developing SOW
		3: Retrofit Sack Dam to ensure fish passage	Full Implementation	11	12/31/2013	12/31/2013	Developing SOW
		4: Construct Mendota Pool Bypass	Full Implementation	11	12/31/2013	2010	Developing SOW
		5: Ensure fish passage is sufficient at all other structures and potential barriers	Full Implementation	11, 12	12/31/2016	TBD	Not Determined
		6: Implement trap-and-haul operation to move Chinook salmon into suitable habitat areas when flows are inadequate	Targeted Study	Not Described	12/31/2016	2010	Not Determined

Table 5-1.
Action Routing Results and Estimated Timelines (contd.)

Limiting Factor	Objective(s)	Potential Salmon-Related Action	Recommended Implementation	Settlement Paragraph	Settlement Timeline	FMWG Tentative Timeline	Status
Unsuitable Water Temperature	G: Provide suitable water temperatures for upstream passage, spawning, egg incubation, rearing, and outmigrating Chinook salmon smolts to the extent achievable considering hydrologic, climatic, and physical channel characteristics	1: Implement Settlement flow schedule	Full Implementation	13	10/1/2009	2009	On Schedule
		2: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary	Full Implementation	13	1/1/2014	1/1/2014	On Schedule
		3: Fill and isolate the highest priority mining pits	Targeted Study	11	12/31/2016	TBD	Developing Work Plan
Unsuitable Water Temperature	H: Provide suitable water temperature releases from Friant Dam	1: Modify Friant and Madera canals to preserve cold water pool in Millerton Reservoir (instead of: Modify water control structures to provide suitable water temperature releases from Friant Dam).	Targeted Study	Not Described	12/31/2016	TBD	Not Determined
Reduced Genetic Viability	I: Meet or exceed the genetic fitness goals for Chinook salmon	1: Select and manage genetically fit stock sources for Chinook salmon	Targeted Study	Not Described	Not specified	2009	In Progress
		2: Incorporate conservation practices in artificial propagation of Chinook salmon	Full Implementation	Not Described	12/31/2016	2009	In Progress
		3: Modify operation of Hills Ferry Barrier or construct other temporary barriers to segregate Chinook salmon runs	Targeted Study	Not Described	12/31/2016	12/31/2013	Not Determined

Table 5-1.
Action Routing Results and Estimated Timelines (contd.)

Limiting Factor	Objective(s)	Potential Salmon-Related Action	Recommended Implementation	Settlement Paragraph	Settlement Timeline	FMWG Tentative Timeline	Status
Degraded Water Quality	J: Suitable water quality	1: Implement Settlement flow schedule	Full Implementation	13	10/1/2009	2009	On Schedule
		2: Implement public outreach and education program incorporating education on best management practices	Full Implementation	Not Described	12/31/2016	2010	Not Determined
Excessive Harvest	K: Minimize in-river harvest, unlawful take, and disturbance	1: Implement public outreach program to reduce unlawful take of salmon and disturbance associated with spawning habitat	Full Implementation	Not Described	12/31/2016	2010	Not Determined
		2: Restrict seasonal access in sensitive reaches (i.e., Chinook salmon holding and spawning reaches)	Full Implementation	Not Described	12/31/2016	TBD	Not Determined
		3: Evaluate the need to augment the existing law enforcement program	Full Implementation	Not Described	12/31/2016	TBD	Not Determined
Excessive Redd Superimposition	L: Minimize redd superimposition	1: Determine if additional spawning habitat is necessary (augment gravel at existing riffles and other suitable locations) to sustain Chinook salmon population numbers	Full Implementation	12	12/31/2016	TBD	Developing Sediment Management Plan
		2: Modify operation of Hills Ferry Barrier or construct other temporary barriers to segregate Chinook salmon runs	Targeted Study	12	12/31/2016	12/31/2013	Not Determined
Excessive Hybridization	M: Minimize hybridization between spring-run and fall-run Chinook salmon	1: Modify operation of Hills Ferry Barrier or construct other temporary barriers to segregate Chinook salmon runs	Targeted Study	12	12/31/2016	12/31/2013	Not Determined
		2: Increase the amount of Chinook salmon spawning habitat available to minimize overlap of races and reduce hybridization	Targeted Study	12	12/31/2016	TBD	Developing Sediment Management Plan

Table 5-1.
Action Routing Results and Estimated Timelines (contd.)

Limiting Factor	Objective(s)	Potential Salmon-Related Action	Recommended Implementation	Settlement Paragraph	Settlement Timeline	FMWG Tentative Timeline	Status
Limited Holding Pool Habitat	N: Ensure sufficient quantity and quality holding habitat to meet Restoration Goal	1: Implement Settlement flow schedule	Full Implementation	13	10/1/2009	2009	On Schedule
		2: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary	Full Implementation	13	1/1/2014	1/1/2014	On Schedule
		3: Evaluate the quality and quantity of holding pool habitat	Full Implementation	12	12/31/2016	TBD	Not Determined
Limited Gravel Availability	O: Provide sufficient quantity and quality of spawning habitat for Chinook salmon	1: Implement Settlement flow schedule	Full Implementation	13	10/1/2009	2009	On Schedule
		2: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary	Full Implementation	13	1/1/2014	1/1/2014	On Schedule
		3: Augment gravel at existing riffles and other suitable locations	Full Implementation	12	12/31/2016	TBD	Developing Sediment Management Plan
		4: Modify channels to provide Chinook salmon spawning habitat	Small-Scale Implementation	12	12/31/2016	TBD	Developing Sediment Management Plan

Table 5-1.
Action Routing Results and Estimated Timelines (contd.)

Limiting Factor	Objective(s)	Potential Salmon-Related Action	Recommended Implementation	Settlement Paragraph	Settlement Timeline	FMWG Tentative Timeline	Status
Excessive Sedimentation	P: Minimize fine deposited and suspended sediment	1: Implement measures to clean Chinook salmon spawning gravel	Small-Scale Implementation	13	12/31/2016	TBD	Developing Sediment Management Plan
		2: Implement public outreach program	Full Implementation	Not Described	12/31/2016	2010	Not determined
		3: Construct settling basins	Small-Scale Implementation	12	12/31/2016	TBD	Developing Sediment Management Plan
		4: Create log vein, J hook vein, or rock vein structures to facilitate sediment transport.	Targeted Study	12	12/31/2016	TBD	Not Determined
		5: Implementation of sediment management actions	Targeted Study	12	12/31/2016	TBD	On Schedule
Insufficient Floodplain and Riparian Habitat	Q: Ensure suitable quantity and quality of floodplain and riparian habitat to provide habitat and food resources for Chinook salmon and other fishes	1: Implement Settlement flow schedule	Full Implementation	13	10/1/2009	2009	On Schedule
		2: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary	Full Implementation	13	1/1/2014	1/1/2014	On Schedule
		3: Restore floodplain habitat	Small-Scale Implementation	12	12/31/2016	TBD	Not Determined
		4: Create off-channel Chinook salmon rearing areas	Small-Scale Implementation	12	12/31/2016	TBD	Not Determined
		5: Simultaneously fill gravel pits and create floodplain salmon rearing habitat	Targeted Study	11,12	12/31/2016	TBD	Not Determined
		6: Create structural modifications to provide floodplain rearing habitat	Targeted Study	Not Described	12/31/2016	TBD	Not Determined

Table 5-1.
Action Routing Results and Estimated Timelines (contd.)

Limiting Factor	Objective(s)	Potential Salmon-Related Action	Recommended Implementation	Settlement Paragraph	Settlement Timeline	FMWG Tentative Timeline	Status
Limited Food Availability	R: Ensure favorable conditions for food availability, growth, and development	1: Increase invertebrate production	Small-Scale Implementation	Not Described	12/31/2016	TBD	Not Determined
		2: Restore floodplain habitat	Small-Scale Implementation	Not Described	12/31/2016	TBD	Not Determined
Excessive Predation	S: Reduce predation by nonnative fishes and other aquatic organisms	1: Fill and isolate the highest priority mining pits	Targeted Study	11	12/31/2016	TBD	Developing Work Plan
		2: Construct a low-flow channel	Full Implementation	12	12/31/2016	TBD	Not Determined
		3: Restore floodplain habitat	Small-Scale Implementation	Not Described	12/31/2016	TBD	Not Determined
		4: Reduce the number of nonnative predatory fishes in the Restoration Area	Targeted Study	Not Described	12/31/2016	TBD	Not Determined
		5: Create an increase in turbidity during juvenile downstream migration to reduce detection and therefore predation by piscivore fishes	Targeted Study	Not Described	12/31/2016	TBD	Not Determined
		6. Use pulse flows to displace nonnative predatory fishes in the Restoration Area	Targeted Study	Not Described	12/31/2016	TBD	Not Determined

Key:
FMWG = Fisheries Management Work Group
SOW = scope of work
TBD = to be determined

5.2.1 Inadequate Streamflow

Inadequate streamflow is a limiting factor in the Restoration Area and actions for improving flow conditions and/or effects to fish resulting from flows are addressed below.

Goal A

Provide flows sufficient to ensure habitat connectivity and allow for unimpeded upstream passage and outmigration

Adult Chinook salmon require adequate flows for upstream migration. A fall and spring pulse flow ("attraction flow") would increase stream depth and velocity, help eliminate low-flow barriers, reduce water temperatures, improve water quality, and may provide a cue for migrating adult Chinook salmon (Flemming and Gross, 1994; Jager and Rose 2003). Successful smoltification and outmigration of juveniles are critical for survival to adulthood. Factors determining successful outmigration include suitable water quality, adequate and timely flow for downstream movement, and a passable watercourse.

The importance of augmented flow is low for Reach 1 because it currently has adequate flow for all life stages (Exhibit A). Augmented flows in Reach 2 are considered of high importance because of uncertainty as to whether Settlement flows will provide sufficient water throughout the reach during dry years or in late summer/early fall during normal conditions. Augmented flows in Reach 3 are considered of moderate importance because inputs from Mendota Pool via the DMC provide flow to Sack Dam, but parts of Reach 3 may be dewatered if inputs from the DMC are inadequate. Augmented flows in Reach 4 are considered of high importance since the Arroyo Canal diverts almost all flow from the channel at the beginning of Reach 4 and leaves the channel dry in most parts of Reach 4. Additionally, it has not been determined if flows will go down Reach 4B or the Eastside Bypass. The importance of augmented flows in Reach 5 is considered high because it has a braided channel and multiple sources of flow that could delay juvenile and/or adult migration.

Action A1: Modify San Joaquin River and/or Eastside and Mariposa bypasses to create a low-flow channel suitable to support fish passage.

> The low-flow channel will be designed to maintain flow and habitat connectivity. Reaches 2B and 4B are of primary concern because of the lack of flow in these reaches during dry seasonal conditions. Additionally, flow conditions in the Eastside and Mariposa bypasses and Reaches 3 and 5 are considered impaired and adequate connectivity must be provided.

- **H_A:** Creating a low-flow bypass will facilitate fish passage.
- **Decision Tree Routing:** The worth of Action A1 is high because access to suitable Chinook salmon over-summering, spawning, and juvenile rearing habitat and smolt outmigration are essential for survival. Action A1 has high magnitude due to the biological implications of migration to fish

production, and because it is expected to achieve the objective, it has low uncertainty. The risk associated with Action A1 is low because properly constructed bypasses are highly effective. Action A1 is not reversible, but additional construction could modify the initial structure. Based on the results of routing through the decision tree, full implementation is recommended for Action A1.

- **Data Needs and Monitoring:** Data needed to evaluate the low-flow channel are hydraulic information on depth and velocity and temperature in the low-flow channel during a variety of flow conditions. Channel hydraulics and temperature would be monitored during the low-flow period to determine additional actions needed, and evaluate the hypothesis based on known temperature tolerances and hydraulic channel features suitable for Chinook salmon passage.
- **Potential Triggers and Adaptive Responses:** If monitoring does not result in validation of the hypothesis after meeting hydraulic and temperature standards for fish passage, then recommendations will be made regarding channel reconfiguration or augmentation of restoration hydrographs within the scope of the Settlement. New actions will then be evaluated through the action routing process.

Action A2: Modify channels in Reaches 2B and 4B to increase flow capacity (low-flow or migration-flow capacity).

Reaches 2B and 4B are a high priority due to the extensive amount of work necessary to accommodate Restoration Flows and the need to meet Settlement deadlines. These reaches will require modifications including levee expansion and floodplain development to accommodate Restoration Flows and ensure connectivity for fish passage.

- **H_A:** Increasing flow capacity in Reaches 2B and 4B will facilitate fish passage.
- **Decision Tree Routing:** The worth of improving the flow capacity in Reaches 2B and 4B is high because providing suitable flows for adult migration and smolt outmigration are essential to Chinook salmon survival. Action A2 is of high magnitude because it is an essential component for successful fish migration. The uncertainty associated with Action A2 is moderate because the specific interaction between channel capacity and flow is unknown. The risk associated with Action A2 is moderate as failure to appropriately implement this action could have negative impacts (e.g., inappropriate geomorphic channel function, increased erosion). Action A2 is reversible as additional construction could correct or modify any actions taken. Based on the results of routing this action through the decision tree, full implementation is recommended for Action A2.

- **Data Needs and Monitoring:** Data needed to evaluate channel alterations in Reaches 2B and 4B in conjunction with the hypothesis include hydraulic information (i.e., depth, velocity, sheer stress) and temperature in low-flow areas during base-flow conditions. Monitoring channel modifications for appropriate depths, temperatures and hydro-geomorphic function will determine whether the hypothesis can be accepted by comparing hydraulic and temperature data from the altered channel with known hydraulic channel features suitable for Chinook salmon passage.

- **Potential Triggers and Adaptive Responses:** If monitoring does not result in accepting the hypothesis after meeting set hydraulic and temperature standards for fish passage, then recommendations will be made regarding channel reconfiguration or augmentation of restoration hydrographs within the scope of the Settlement. New actions will then be evaluated through the action routing process.

Action A3: Implement Settlement flow schedule.

The Settlement identifies six flow schedules that vary in volume and timing according to hydrologic water-year types (Exhibit B in the Settlement) to help meet the Restoration Goal. Components of the flow schedule are:

- Base Flow
- Spring-Run Incubation Flow
- Fall-Run Attraction Flow
- Fall-Run Spawning and Incubation Flow
- Winter Base Flow
- Spring Rise and Pulse Flows
- Summer Base Flow
- Spring-Run Spawning Flow

Each water-year type and corresponding flow schedule were developed with specific thresholds. Specific monitoring measures will need to be developed to evaluate the success of the Settlement flow schedule.

- **H_A:** Implementing the Settlement flow schedule will result in habitat connectivity and successful fish passage.

- **Decision Tree Routing:** The worth of Action A3 is high because it is dictated by the Settlement and is a requirement for the various Chinook salmon life stages. The magnitude of Action A3 is high because implementing Settlement flows could provide adequate migration cues, river connectivity for fish passage and various habitat needs. The uncertainty of Action A3 is high because it is unknown whether prescribed flows will meet the desired outcome. There is risk of stranding fish as well as unknown impacts to water quality and downstream fisheries. However, successful restoration is not likely without implementation of the Settlement flow schedule. Therefore, the risk associated with implementing Action A3 is considered low. Full implementation is recommended for Action A3.

- **Data Needs and Monitoring:** To evaluate the hypothesis, data are necessary for hydraulics and groundwater seepage in the Restoration Area under Settlement flows. The Settlement requires monitoring flow at a minimum of six locations throughout the Restoration Area. Monitoring will determine the adequacy and compliance of the flow schedule.

- **Potential Triggers and Adaptive Responses:** Monitoring associated with Action A3, in conjunction with monitoring at locations with passage concerns (see Actions A1 and A2) will be used to evaluate the hypothesis related to habitat connectivity and passage. The Settlement assumes riparian pumping will remain at historical levels and certain seepage losses will occur throughout the various reaches. If river losses are greater than predicted, then additional actions may be developed.

Action A4: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary.

Implementation of real-time water management options may be necessary to ensure releases are sufficient to maintain channel connectivity, migration cues, suitable temperatures and habitat, and fish passage throughout all reaches. Available water supplies may need to be optimized to provide the flexibility necessary to maximize spring pulse flows and other time periods where additional flow may be beneficial. The Settlement further gives the Secretary of the Interior (Secretary) the option to use up to 10 percent of the applicable flow schedule (referred to as “buffer flows”) for release when necessary. The Settlement also indicates additional water can be purchased from willing sellers in the event the flow schedule is not sufficient to meet the discharge and physical targets needed to provide suitable migration conditions. Additional flows beyond buffer flows will only be used when necessary because of the high cost of implementation.

- **H_A:** No hypothesis is generated because Action A4 will not be implemented unless the hypothesis in Action A3 is rejected or if future hypotheses are developed as a result of Action A3.

- **Decision Tree Routing:** The worth of improving flow conditions is high because having adequate flow is vital for Chinook salmon upstream migration, outmigration, spawning, unimpeded passage, and suitable habitat. The magnitude of Action A4 is high because of the biological importance of flow conditions. Uncertainty of Action A4 is moderate because it is unknown if buffer flows will provide adequate discharge conditions or how much water will be available for purchase, if needed.

Real-time flow management and additional water could substantially improve flow conditions and reduce limiting factors. The risk associated with Action A4 is low because increasing flow is thought to have the single greatest effect on successful fisheries restoration and flows would be closely managed for beneficial fishery use. Based upon the results of routing Action A4 through the decision tree, full implementation is recommended.

- **Data Needs and Monitoring:** See Action A3.
- **Potential Triggers and Adaptive Responses:** See Action A3.

Action A5: Implement trap-and-haul operation to move Chinook salmon into suitable habitat areas when flows and/or habitat conditions are unsuitable.

Trap-and-haul operations are used to move fish from unsuitable to suitable habitat, most often when a barrier to fish passage exists. Action A5 was suggested as a way to facilitate fish passage in the event that flow connections do not exist or barriers are present.

- **H_A:** Implementing a cost-effective trap-and-haul operation in the event of an unforeseen barrier to fish migration will result in increased survival over what would occur if no management action was taken.
- **Decision Tree Routing:** The worth of implementing Action A5 is low and carries high uncertainty, because trap-and-haul operations are rarely successful at maintaining fish populations and the goal is to restore Chinook salmon without migration limitations. The magnitude of Action A5 is medium because it could have a moderate impact in the event of an emergency situation. The uncertainty is moderate because of the biological disadvantages of trap-and-haul operations. The risk associated with Action A5 is medium because trap-and-haul operations result in fish holding and handling stress, delayed passage, and often reduced juvenile passage because of inabilities to capture juveniles in large numbers. Action A5 is not reversible. A targeted study is recommended for Action A5.
- **Data Needs and Monitoring:** To evaluate the hypothesis the relative survival of Chinook salmon in the event of no management intervention would need to be estimated. If survival is estimated to be relatively low, data on survival post-trap-and-haul would need to be gathered. Data on the cost for implementing a trap-and-haul procedure are also needed. This information would determine the feasibility of future trap-and-haul operations. Evaluating the hypothesis can be achieved by implementing a monitoring effort to estimate immediate and post-haul survival.

- **Potential Triggers and Adaptive Responses:** Monitoring and a cost analysis of Action A5 will be used to evaluate the hypothesis related to the biological and economic feasibility of implementing trap-and-haul operations. If this management activity is found to be cost prohibitive or result in high fish mortality, Action A5 would be discontinued. However, if Action A5 is feasible, implementation of trap-and-haul during restoration activities would be continued, until the river connectivity is fully restored.

Goal B

Release flows sufficient to provide suitable Chinook salmon spawning depth and velocity

Factors associated with suitable spawning habitat for Chinook salmon are all influenced by flow conditions (e.g., depth, velocity). The suitability of existing conditions, effectiveness of Restoration Flows in maintaining suitable Chinook salmon spawning habitat, and the likelihood that existing or newly constructed spawning habitat will be used by adults are unknown. Regional groundwater conditions may also be a factor controlling intragravel flow.

Flows in Reach 1 are considered of high importance because all Chinook salmon spawning is expected to take place in this reach. However, discharge may not be limiting in Reach 1, which currently has temperatures and existing habitat that may be acceptable to support initial population goals. Flows in Reaches 2 through 5 are considered irrelevant because Chinook salmon spawning habitat even with improved flow conditions likely will not exist in these reaches.

Action B1: Implement Settlement flow schedule (see Action A3).

Action B2: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary (see Action A4).

Action B3: Modify existing channel(s) to provide Chinook salmon spawning habitat.

Modification of in-channel habitat to improve the quality or quantity of spawning habitat and the Chinook salmon response to the modified habitat is an action with high uncertainty, particularly because the adequacy of channel design is related to hydrologic events (e.g., high-flow conditions). Nonetheless, there may be a need to implement actions to improve the quality or quantity of spawning habitat to meet the Restoration Goals. There are two competing hypotheses concerning how to best implement this action: (1) the creation of side-channels for spawning habitat, and (2) modification of channel shape and or slope to improve the quality and quantity of spawning habitat in existing channels.

- **H_{A1}:** Creation of side channel(s) with gravel injection in Reach 1 will result in creation of Chinook salmon spawning habitat, which would be documented by the presence of redds the following year.

- **Decision Tree Routing:** The worth of creating side channel habitat is medium because Chinook salmon usually spawn in pool tails and riffle habitats, but these habitats are limited. Action B3 is of moderate magnitude and high uncertainty. The risk associated with Action B3 is medium because creation of side channels may alter flow or connection with groundwater, but it is unlikely to directly adversely affect Chinook salmon spawning habitat that already exists. Action B3 is likely cost prohibitive in terms of reversibility. There is a lot of uncertainty associated with Action B3 because it is unknown if the new spawning habitat would be used by Chinook salmon. Based upon the results of routing through the decision tree, a small-scale implementation is recommended for Action B3.

- **Data Needs and Monitoring:** Data will be needed to assess the hypothesis associated with use of side-channel habitats for Chinook salmon spawning, specifically, the number of redds present the following year and how many alevins successfully emerged from the redds. To obtain this information, the presence of redds in the created habitat, the number of redds within that habitat, and emergence rate would be monitored.

- **Potential Triggers and Adaptive Responses:** It is uncertain as to whether the created potential Chinook salmon spawning habitat in side channels will be used by adults. If redds are observed the following year, the habitat would be modified, as needed, to increase emergence rate. If redds are not observed in the created channel the following year, morphological conditions will be assessed and the channel may be modified as needed, or creation of side channel habitats will be discontinued.

- **H_{A2}:** Modifying channel shape and or slope in Reach 1 to double the amount of habitat with depths of 25 centimeters (cm) to100 cm and velocities of 30 to 80 cm per second (cm/s) (Healey 1991) during average spawning-flow conditions will double the amount of redds present the following year.

- **Decision Tree Routing:** The worth of modifying channel shape to provide better Chinook salmon spawning depth and velocity is medium because although improved quality and quantity of spawning habitat are assumed beneficial to Chinook salmon, it is uncertain what impacts this construction may have on the integrity of existing habitat and downstream habitat. Action B3 is of moderate magnitude and high uncertainty. The risk associated with Action B3 is medium because it will be implemented on a small scale and therefore unlikely to have large adverse impacts. Action B3 is considered cost prohibitive in terms of reversibility. Based upon the results of routing Action B3 through the decision tree, a small-scale implementation is recommended.

- **Data Needs and Monitoring:** Data will be needed to assess the hypothesis for modifying channel shape to create Chinook salmon spawning habitat. Geomorphological conditions would be monitored at the appropriate times of year. The number of redds present and the number of alevins successfully emerged from redds the following year are needed. To obtain this information, the number of redds within the modified channel and the emergence rates would be monitored.

- **Potential Triggers and Adaptive Responses:** It is uncertain if altering channel morphology to increase the amount of potential Chinook salmon spawning habitat will result in use of that habitat. If the number of redds increases the following year, modifications to additional habitat with the goal of doubling the spawning habitat may be made. If increasing the number of redds does not result in a sufficient number of successfully emerging fry, the modifications will be reevaluated. If the number of redds does not increase or decrease by more than 10 percent, Action B3 would be continued for an additional year before making additional decisions regarding channel modifications. In the event there is a decrease in redds, channel modifications would be discontinued but monitoring would continue for several more years.

Goal C
Provide suitable flow for egg incubation and fry emergence

Factors associated with suitable egg incubation and fry emergence are linked to Chinook salmon spawning habitat characteristics and influenced by flow characteristics (DO, intergravel flow, temperature, fine sediment deposition; Wu 2000). The suitability of existing conditions, effectiveness of Restoration Flows in maintaining the features required for survival to emergence in existing or newly constructed spawning habitat are unknown. Flow in Reach 1 is considered of high importance because all Chinook salmon spawning is expected to take place in this reach. However, flow may not be limiting in Reach 1, which currently has temperatures and existing habitat that may be acceptable to support initial population goals. Flow in Reaches 2 through 5 are considered inapplicable as these reaches are not expected to support spawning habitat even with improved flow conditions.

Action C1: Implement Restoration Flows including hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary (see Action A4).

5.2.2 Entrainment

Entrainment is a limiting factor in the Restoration Area. Objectives and associated actions for reducing entrainment are routed below.

Goal D
Minimize juvenile entrainment losses

The impacts of juvenile entrainment depend on diversion type and flow, and are highly variable and have the potential to significantly reduce the ability to meet the Restoration Goal. Although the Settlement requires specific diversions to be screened, an assessment of the effectiveness of the screen is needed so the screens can be modified to increase their effectiveness and apply the information to additional areas, as needed. Entrainment of migrating juveniles may occur if the design, operation, and maintenance at some facilities are not modified. Entrainment may result in reduced escapement, increased stress, reduced fitness and injury to fish, and increased predation, thereby reducing survival of outmigrating smolts. To what extent juveniles, smolts, and yearlings are entrained and fail to reach suitable habitat would be determined.

Juvenile entrainment in Reaches 1 through 5 is considered of high importance. There is a high degree of uncertainty about diversion and entrainment losses in the Restoration Area and the Settlement has identified several features that must be modified to protect Chinook salmon. Restoration measures are expected to take place in all five reaches to minimize entrainment losses.

Action D1: Screen Arroyo Canal to prevent fish losses.

> Arroyo Canal is a potential and likely source of fish losses by entrainment. Screening of the canal is an action that has been mandated by the Settlement.

- **H_A:** Screening Arroyo Canal will result in negligible juvenile losses from entrainment at the Arroyo Canal diversion.
- **Decision Tree Routing:** The screening of Arroyo Canal is important to prevent Chinook salmon juvenile and other fish losses because the large size and capacity of the diversion could result in high fish losses. Because fish screening projects of a similar size have been successful in the past, the certainty of Action D1 producing a beneficial result is high and the magnitude is high. For these reasons, worth of this action is high. There is medium risk associated with this action because screen effectiveness relies on proper installation. Action D1 is reversible because it is possible to remove the screen if it does not provide the desired outcome. Full implementation is recommended for Action D1.
- **Data Needs and Monitoring:** Action D1 is scheduled to be completed before Chinook salmon are reintroduced. Accordingly, only post-project entrainment data collection will likely be possible. Screens have been extensively studied so the only data needed to evaluate Action D1 relates

to hydraulics near the screen (i.e., approach and sweeping velocity). If monitoring determines hydraulics meet screen criteria for juvenile Chinook salmon, it is assumed the screen is operating effectively and resulting in negligible juvenile losses.

- **Potential Triggers and Adaptive Responses:** If monitoring does not result in acceptance of the hypothesis after meeting hydraulic standards, then recommendations will be made for structural modifications to ensure this feature is protective and successful in meeting Restoration Goal.

Action D2: Construct Mendota Pool Bypass.

Paragraph 11(a)(1) of the Settlement calls for Action D2. The development of a fish bypass at Mendota Pool is necessary because of the complex network of diversions near Mendota Pool and the susceptibility of juveniles to entrainment.

- **H_A:** A bypass around Mendota Pool will result in negligible fish losses via entrainment in Mendota Pool.
- **Decision Tree Routing:** Construction of the Mendota Pool Bypass to prevent juvenile Chinook salmon and other fish losses is considered of high worth. Action D2 is of high magnitude because Mendota Pool as currently situated could result in high fish losses. Projects of a similar size have been successful in the past, but depend on interactions between flow and connectivity; therefore, there is a medium degree of uncertainty. There is a low risk associated with Action D2 because fish bypass structures are expected to be highly effective when properly constructed. Action D2 is not reversible though structural modifications may be completed to improve function. Full implementation is recommended for Action D2.
- **Data Needs and Monitoring:** Action D2 is scheduled to be completed before Chinook salmon are reintroduced and bypass and design features will be addressed during site-specific implementation. Accordingly, only post-project passage data collection will be possible. Data on channel hydraulics and water temperature in the bypass under different discharge scenarios is needed. The effectiveness of the bypass channel will be determined by monitoring depth, velocity, and temperature in the bypass and relating that information to known tolerances of Chinook salmon (passage requirements and temperature tolerances). This will allow indirect evaluation of the hypothesis that a bypass will result in negligible fish losses from entrainment.
- **Potential Triggers and Adaptive Responses:** If the bypass does not meet passage requirements and tolerances of Chinook salmon and the hypothesis is rejected, recommendations will be made for structural modifications to ensure this action is successful in meeting the Restoration Goal.

Action D3: Modify the Chowchilla Bypass Bifurcation Structure to reduce juvenile Chinook salmon entrainment.

- **H_A:** Screening Chowchilla Bypass Bifurcation Structure will significantly reduce juvenile entrainment into the Chowchilla Bypass.
- **Decision Tree Routing:** Screening Chowchilla Bypass Bifurcation Structure has low magnitude because of the spatial extent and cost associated with screening relative to the amount of time entrainment is expected to be problematic (at flows greater than 4,500 cubic feet per second (cfs)). The uncertainty of Action D3 is moderate. Therefore, the worth of Action D3 is low. There is moderate risk associated with screening such a large structure and because of the cost, Action D3 is not reversible. To learn more about the potential magnitude and risk of Action D3, a targeted study is recommended.
- **Data Needs and Monitoring:** Specific data are needed to estimate any reduction in entrainment loss as a consequence of adjusting this structure and the cost. Determining what temporal scale juvenile Chinook salmon entrainment is expected to be problematic at this structure will allow a better assessment of the cost-benefit of making structural modifications. Stranding monitoring will be conducted in the Chowchilla Bypass following flood events. Modeling may be used to estimate entrainment in the Chowchilla Bypass Bifurcation Structure at high flows.
- **Potential Triggers and Adaptive Responses:** If modeling indicates the Chowchilla Bypass Bifurcation Structure will result in moderate-to-high losses of juvenile Chinook salmon, new actions would be routed. If modeling indicates only minimal losses during high flows, no modifications would be proposed.

Action D4: Fill and/or isolate the highest priority mining pits.

Paragraph 11(b)(3) of the Settlement calls for this action, but identification of mining pits that present the greatest challenge to meeting the Restoration Goal has not been completed. Mining pits that have been captured by instream flows may hinder successful restoration.

- **H_A:** Filling or isolating high-priority mining pits will significantly reduce entrainment losses.
- **Decision Tree Routing:** Filling or isolating mining pits to minimize straying and stranding has an unknown magnitude (i.e., an uncertain biological contribution associated with high cost) and high uncertainty of reducing fish losses. The worth of Action D4 is medium because of the associated high cost with this action and the unknown biological return for the investment. There is a high risk associated with Action D4 because failure to properly construct modifications and incorporate them into

instream habitat could lead to erosion, improper geomorphic function, and increased turbidity and sedimentation. Action D4 is considered nonreversible because of the high cost of implementation, and it is uncertain as to its beneficial nature or which mining pits present the greatest challenges. A targeted study is recommended for Action D4 because learning more about the magnitude and risk associated with this action would be beneficial to determining the worth of future actions. Note this action is also addressed (Action S1) as a possible remedial factor in reducing impacts of predation of juvenile salmon and this targeted study will likely address multiple hypotheses.

- **Data Needs and Monitoring:** Specific data are needed to estimate any reduction in entrainment loss as well as the geomorphic and water quality-related consequences of Action D4. Monitoring of juvenile abundance above and below the location of the targeted study, as well as predator prey dynamics within the gravel pit areas will be used to estimate juvenile loss in particular mining pits. Changes in geomorphology and water quality need to be evaluated at discrete spatial and temporal intervals to better assess the costs and benefits of Action D4.
- **Potential Triggers and Adaptive Responses:** If it is determined that mining pit isolation and filling would not reduce juvenile entrainment, Action D4 would not be implemented. Additionally, the hypothesis is accepted, geomorphic and water-quality information gathered may require routing additional actions.

Action D5: Consolidate diversion locations.

Consolidating the diversions to a single location may result in reduced juvenile entrainment at a reduced cost.

- **H_A:** The relative cost of reducing entrainment via diversions will be reduced if the number of diversions is consolidated rather than being dealt with on an individual basis, with the same reduction in entrainment losses.
- **Decision Tree Routing:** Consolidating entrainment features has an unknown magnitude, that is, it is unclear at this time what the biological benefit is relative to the cost. There is moderate certainty of reducing juvenile entrainment. The worth of Action D5 is low because of the unknown cost in relation to dealing individually with each entrainment feature. There is a medium risk associated with Action D5 because failure to properly construct modifications could lead to erosion, improper geomorphic function, and increased sedimentation. Action D5 is considered nonreversible due to the likely cost of implementation. A targeted study is recommended for Action D5 because learning more about the magnitude and risk associated with this action would be beneficial to determining the worth of full implementation.

- **Data Needs and Monitoring:** Data will need to be gathered to estimate the cost-benefits of this action. No monitoring will occur with Action D5. The hypothesis will be evaluated based on the results of targeted efforts to design and do a cost analysis on the implementation of consolidation and then compare that with what it would cost to reduce entrainment for each individual diversion. It is assumed that entrainment losses will be sufficiently reduced by consolidating or dealing with individual entrainment features.

- **Potential Triggers and Adaptive Responses:** If it is determined that Action D5 is not feasible, this action would not be implemented. Additionally, if the hypothesis is accepted, new actions would be routed.

Action D6: Screen all large and small diversions.

The Settlement requires the screening of large diversions in the Restoration Area such as Arroyo Canal, to prevent juvenile salmon entrainment; however, the screening of all other diversions including smaller ones may be needed to meet fish passage objectives.

- **H_A:** Screening of all diversions to reduce entrainment of juvenile Chinook salmon will significantly reduce entrainment losses.

- **Decision Tree Routing:** The screening of all diversions to minimize juvenile salmon entrainment has an unknown magnitude (i.e., an uncertain biological contribution associated with high cost) and a high uncertainty of reducing fish losses. The worth of Action D6 is low because of the associated high cost with this action and the unknown biological return for the investment. There is a high risk associated with Action D6 because failure to properly construct modifications and incorporate them into instream habitat could lead to erosion, improper geomorphic function, and increased turbidity and sedimentation. Action D6 is considered reversible and it is uncertain as to its beneficial nature or which unscreened diversions present the greatest challenges. A targeted study is recommended for Action D6 because learning more about the magnitude and risk associated with this action would be beneficial to determining the worth of future actions.

- **Data Needs and Monitoring:** Specific data are needed to estimate any reduction in entrainment loss and subsequent population level improvements in survival of Chinook salmon as a consequence of Action D6. Monitoring of juvenile salmon entrainment potential will be used to estimate juvenile loss in particular unscreened diversions.

- **Potential Triggers and Adaptive Responses:** If it is determined that screening of all diversions would not reduce juvenile entrainment, Action D6 would not be implemented in its entirety. Additionally, if the hypothesis is accepted, additional screening actions may be addressed.

5.2.3 Excessive Straying

Excessive straying is a limiting factor in the Restoration Area. Objectives and associated actions for reducing straying are routed below.

Goal E
Minimize losses to nonviable pathways and prevent adult migration delays

The straying of adult Chinook salmon into nonnatal streams is a natural occurrence; however, in highly modified systems, it can become problematic when there are false pathways. If a fish enters a false pathway, it is typically lost to the population. Therefore, actions to reduce straying are routed below.

Action E1: Implement temporary or permanent barriers at Mud and Salt sloughs or any other location deemed necessary.

Action E1 is mandated by Paragraph 11(a)(10) Settlement. Temporary barriers at Mud and Salt sloughs or any other location deemed necessary would be installed to prevent straying and migration delays of adult fish. Flows in Reach 5 tributaries can be seasonally substantial and straying in these tributaries could significantly hinder success in meeting the Restoration Goal. Competing hypotheses exist over how to best implement Action E1: (1) installing temporary barriers at Mud and Salt sloughs, and (2) installing permanent barriers at Mud and Salt sloughs. The same hypotheses will be used to evaluate other entrainment locations, as necessary.

- **H_{A1}:** Temporary barriers (e.g., acoustic bubble screens or rock barriers such as used at the Head of Old River) are cost-effective methods that will significantly reduce straying of Chinook salmon in Mud and Salt sloughs.

- **Decision Tree Routing:** The magnitude of Action E1 is high and the uncertainty is low. The worth of Action E1 is high as the ability for migrating adult Chinook salmon to reach adequate spawning habitat is vital to the success of the Restoration Goal. The risk associated with Action E1 is low as barriers are expected to be temporary in nature and would be subject to modification, as necessary. Assessment of suitable locations and identification of proper design and operation of barriers are recommended during the Interim Flows. Full implementation is recommended for Action E1.

- **Data Needs and Monitoring:** To evaluate the hypothesis, data are necessary for the cost of the temporary barrier methods as well as an assessment of the effectiveness of the method (most temporary barriers have already been evaluated). This information would be available once locations for barriers and methods are chosen; therefore, no monitoring would be necessary. However, post-installation monitoring of a temporary barrier will be needed to evaluate the timing of when these barriers should be operational. New actions would be routed when the timing of barrier operation is addressed.

- **Potential Triggers and Adaptive Responses:** If it is determined that the temporary barrier chosen does not adequately protect fish (i.e., hypothesis is rejected), recommendations would be made for modifications to ensure these features are protective and successful in meeting the Restoration Goal.

- **H_{A2}:** Permanent barriers (e.g., bottom-hinged gates) are cost-effective methods that will significantly reduce straying of Chinook salmon in Mud and Salt sloughs while maintaining hydraulic conditions suitable for the associated channel.

- **Decision Tree Routing:** The magnitude of Action E1 is medium and the uncertainty is moderate. The worth of Action E1 is medium because the ability for migrating adult Chinook salmon to reach adequate spawning habitat is vital to the success of the Restoration Goal, but permanent barriers may be costly and have unforeseen effects on the hydraulics of the channel. The risk associated with Action E1 is high because it is unclear what the impacts of a permanent barrier would have on hydraulics and the cost for barriers at each location is unknown at this time. Assessment of suitable locations and identification of proper design and operation of barriers are recommended during the Interim Flows. A targeted study is recommended for Action E1.

- **Data Needs and Monitoring:** To evaluate the hypothesis, data are necessary for the cost of the permanent barrier methods as well as an assessment of the effectiveness of the method (biologically, many of these barriers have already been evaluated). This information would be available once locations for barriers and methods are chosen; therefore, no monitoring would be necessary. Information will need to be obtained describing how the barrier affects the associated channel (i.e., hydraulic conditions).

- **Potential Triggers and Adaptive Responses:** If it is determined that a permanent barrier is not a cost-effective way to reduce straying, either a new design or modifications to the barrier would be evaluated or new actions routed. If the hypothesis is accepted, new actions would be routed before a small-scale or full implementation.

Action E2: Screen Arroyo Canal to prevent fish losses (see Action D1).

Action E3: Fill and isolate the highest priority mining pits (see Action D3).

5.2.4 Impaired Fish Passage

Impaired fish passage may limit Chinook salmon survival in the Restoration Area. Objectives and associated actions for improving fish passage conditions are routed below.

Goal F
Eliminate fish passage barriers and minimize migration delays

Passage may be impeded for migrating adults and juveniles if design, operation and maintenance at some facilities and locations do not afford passage under a range of flows. Impacts of fish barriers may include impaired passage and injury to fish, resulting in reduced numbers of spawning adult Chinook salmon reaching suitable spawning areas and low survival for outmigrating smolts. If and to what extent adults, juveniles, smolts and yearlings fail to access suitable habitat because of barriers would need to be determined.

Fish passage in Reaches 1 through 5 are considered of high importance as there is a high degree of uncertainty about potential barriers and the Settlement has identified several features that must be modified to be protective for Chinook salmon. It is expected that measures will be taken in all five reaches to minimize fish barriers.

Action F1: Modify Sand Slough Control Structure.

Action F1 is required by Paragraphs 11(a)(5) and 11(b)(4) in the Settlement.

- **H_A:** Modifying the Sand Slough Control Structure to provide adequate water depth, velocity, and flow will result in suitable passage conditions for all life stages of Chinook salmon.
- **Decision Tree Routing:** The worth of Action F1 is high because access to suitable Chinook salmon over-summering, spawning, and juvenile rearing habitat and smolt outmigration are essential for survival. Action F1 has high magnitude and because it is expected to achieve the objective, it has a low uncertainty. The risk associated with Action F1 is low as it is unlikely to have adverse impacts. Based on the results of routing Action F1 through the decision tree, full implementation is recommended.
- **Data Needs and Monitoring:** Data needed to evaluate the modification of the Sand Slough Control Structure are hydraulic information (i.e., depth, velocity and discharge) during base-flow conditions. Monitoring channel hydraulics will help determine future actions and maintenance needs, and help evaluate the hypothesis based on known tolerances and hydraulic features suitable for Chinook salmon passage.

- **Potential Triggers and Adaptive Responses:** If monitoring does not result in accepting the hypothesis, then recommendations will be made regarding structural modifications or augmentation of the Restoration Flow schedule (Exhibit E) within the scope of the Settlement. New actions will then be evaluated through the action routing process.

Action F2: Modify Reach 4B headgate.

Action F2 is required by Paragraph 11(a)(4) of the Settlement.

- **H_A:** Modifying the Reach 4B headgate to provide adequate water depth, velocity, and discharge will result in suitable passage conditions for Chinook salmon.

- **Decision Tree Routing:** The worth of Action F2 is high because Chinook salmon access to suitable holding, spawning, and juvenile rearing habitat and smolt outmigration are essential for survival. Action F2 has a high magnitude and because it is likely to achieve the objective, it has a low uncertainty. The risk associated with Action F2 is low as it is unlikely to have measurable adverse impacts. Full implementation is recommended for Action F2.

- **Data Needs and Monitoring:** Hydraulic data such as depth, velocity, and discharge during base-flow conditions are needed to evaluate modification of the Reach 4B headgate. Channel hydraulics would be monitored to determine future actions and evaluate the hypothesis based on known tolerances and hydraulic features suitable for Chinook salmon passage.

- **Potential Triggers and Adaptive Responses:** If monitoring results in rejecting the hypothesis of meeting hydraulic standards for fish passage, then recommendations will be made regarding structural modifications or augmentation of the Restoration Flow schedule within the scope of the Settlement. New actions will then be evaluated through the action routing process.

Action F3: Retrofit Sack Dam to ensure fish passage.

Sack Dam diverts water into the Arroyo Canal and as currently structured, can block upstream passage of adult Chinook salmon and inhibit juveniles from moving safely downstream without modification. An improved fish ladder will be necessary to successfully meet the Restoration Goal, and specifically defined in paragraph 11(a)(7) of the Stipulation of Settlement.

- **H_A:** Modifying the Sack Dam fish ladder to provide adequate water depth, velocity, and flow will result in suitable passage conditions for Chinook salmon.

- **Decision Tree Routing:** The worth of Action F3 is high because Chinook salmon access to suitable holding, spawning, and juvenile rearing habitat and smolt outmigration are essential for survival. Action F3 has a high magnitude and because Action F3 is expected to achieve the objective, it has a low uncertainty. The risk associated with Action F3 is medium as failure to appropriately implement this action could result in migration delays and associated fish losses. Action F3 is reversible as additional construction could correct or modify any structural modification. Based on the results of routing Action F3 through the decision tree, full implementation is recommended.

- **Data Needs and Monitoring:** Hydraulic data such as depth, velocity, and flow during a variety of flow conditions are needed to evaluate the modification of the Sack Dam fish ladder. Ladder hydraulics would be monitored to determine future actions and evaluate the hypothesis based on known tolerances and hydraulic features suitable for Chinook salmon passage.

- **Potential Triggers and Adaptive Responses:** If monitoring results in rejecting the hypothesis of meeting hydraulic standards for fish passage, then recommendations will be made regarding structural modifications or augmentation of the restoration flow schedule within the scope of the Settlement. New actions will then be evaluated through the action routing process.

Action F4: Construct Mendota Pool Bypass (see Action D2).

Action F5: Ensure fish passage is sufficient at all other structures and potential barriers.

Fish passage may be a limiting factor at locations and features not specifically identified in the Settlement. The identification and evaluation of potential fish passage issues at other locations will be necessary.

- **H_A:** Modifying passage barriers to provide adequate water depth, velocity, and discharge will result in suitable passage conditions for Chinook salmon.

- **Decision Tree Routing:** The worth of Action F5 is high because Chinook salmon access to suitable over-summering, spawning, and juvenile rearing habitat and smolt outmigration are essential for survival. Action F5 has a high magnitude and because Action F5 is expected to achieve the objective, it has a low uncertainty. The risk associated with Action F5 is low as it is unlikely to have adverse impacts. Full implementation is recommended for Action F5.

- **Data Needs and Monitoring:** Hydraulic data such as depth, velocity, and discharge under a variety of flow conditions are needed to evaluate the modification of passage barriers. Monitoring needs will be tailored to each flow situation. Hydraulic conditions would be monitored to determine future actions and evaluate the hypothesis based on known tolerances and hydraulic features suitable for Chinook salmon passage.

- **Potential Triggers and Adaptive Responses:** If monitoring results in rejecting the hypothesis of meeting hydraulic standards for fish passage, then recommendations will be made regarding structural modifications or augmentation of the restoration flow schedule within the scope of the Settlement. New actions will then be evaluated through the action routing process.

Action F6: Implement a trap-and-haul operation to move Chinook salmon into suitable habitat areas when flows are inadequate (see Action A5).

5.2.5 Unsuitable Water Temperatures

Elevated water temperatures would likely limit Chinook salmon and some other fishes survival in the Restoration Area. Objectives and associated actions for creating suitable water temperature conditions are routed below.

Goal G

Provide suitable water temperatures for upstream passage, spawning, egg incubation, rearing, smoltification, and outmigration to the extent necessary and achievable considering hydrologic, climatic, and physical channel characteristics

Water temperature may be a key limiting factor for successful upstream migration, reproductive viability of adult fish and successful rearing and survival of juveniles, successful smoltification and outmigrating smolts in the Restoration Area. Thermal conditions in migration and spawning habitats along with potential factors that influence temperature are not well understood.

Egg maturation and survival to hatch are critical periods in the Chinook salmon life-history cycle. Water temperature may be a limiting factor for successful spawning and incubation and survival of juveniles and smolts, especially in the driest years. Furthermore, water temperatures in sections of the Restoration Area may present thermal barriers to successful fish migrations resulting in stranding and increased mortality. The maintenance of suitable water temperatures to successfully meet the Restoration Goal will require consideration of the appropriate timing and duration of temperatures as well as determining the appropriate spatial extent of those temperatures. All life stages of Chinook salmon would be affected by this limiting factor.

Water temperatures in Reach 1 is considered of moderate importance because the uppermost section of Reach 1 currently has consistently low water temperatures, and flow schedules prescribed under the Settlement may provide acceptable temperatures to support initial population goals, except during extremely dry years.

Water temperatures in Reaches 2 through 5, and the bypass system, are considered of high importance because water temperatures increase significantly moving further downstream from Friant Dam.

The actions listed below are expected to help achieve appropriate water temperature goals.

Action G1: Implement Settlement flow schedule (see Action A3).

Action G2: Implement hydrograph flexibility, buffer flows, and use of additional purchased water, as necessary (see Action A4).

Action G3: Fill and isolate the highest priority mining pits (see Action D4).

Goal H

Provide suitable water temperature releases

Temperature issues may be addressed in the Restoration Area (as in Goal G) or appropriate temperatures may also be the focus of water entering the river via Friant Dam releases. Competing hypotheses addressing how to provide adequate temperature releases from Friant Dam are: (1) modifying Friant and Madera canals to help preserve cold water pool in Millerton Reservoir, (2) installing a temperature control device (TCD) on Friant Dam, and (3) implementing measures to lower the temperatures in Millerton Lake. Specific hypotheses are routed below the action.

Action H1: Modify Friant and Madera canals to preserve cold water pool in Millerton Reservoir.

- **H_{A1}:** Modifying Friant-Kern and Madera canals to release water into the San Joaquin River will result in preservation of a cold water pool in Millerton Reservoir helping provide suitable water temperatures for all life stages of spring-run Chinook salmon to the bottom of Reach 1A.
- **Decision Tree Routing:** The worth of Action H1 is low because there is high uncertainty regarding the degree that altering the location of water release will impact the availability of cold water and subsequently help water temperatures in Reach 1. The risk associated with Action H1 is high because of the potential for a detrimental impact to reservoir water quality (e.g., cold water pool). Based upon the results of routing Action H1 through the decision tree, a targeted study is recommended for Action H1.
- **Data Needs and Monitoring:** Data will be needed to assess the hypothesis associated with modification of Friant and Madera canals to lower water temperature releases. Specifically, water temperatures, and other water quality constituents may be modeled in Reach 1 and in Millerton Lake. The relative effects of Action H1 on Reach 1B water temperatures would be important to identify.

- **Potential Triggers and Adaptive Responses:** Should modeling indicate modification of Friant-Kern and Madera canals is contributing to adverse water temperature or quality in Millerton Reservoir or that it is ineffective at modifying temperatures in Reach 1, then recommendations will be made for alteration in design, change in operation, or options for achieving adequate water temperatures. New actions will then be evaluated through the action routing process.

- **H_{A2}:** Installing a TCD on Friant Dam will result in suitable water temperatures for all life stages of spring-run Chinook salmon to the head of Reach 1B.

- **Decision Tree Routing:** The worth of Action H1 is low because there is high uncertainty regarding the degree that altering the location of water release will impact the availability of cold water because of the limited size of Millerton Lake. The risk associated with Action H1 is high because of the potential for a detrimental impact to water quality (e.g., increased sediment delivery, low DO). Based upon the results of routing Action H1 through the decision tree, a targeted study is recommended.

- **Data Needs and Monitoring:** Data will be needed to assess the hypothesis associated with installation of a TCD on Friant Dam to lower water temperature releases. Specifically, water temperatures, and other water-quality constituents may be modeled in Reach 1.

- **Potential Triggers and Adaptive Responses:** Should monitoring indicate that the installation of a TCD on Friant dam is contributing to adverse water temperature or quality, then recommendations will be made for alteration in design, change in operation, or options for achieving adequate water temperatures. New actions will then be evaluated through the action routing process.

- **H_{A3}:** Implementing measures to reduce Millerton Lake water temperatures (e.g., shading, solar reflector panels, floating white balls) will result in suitable water temperatures for all life stages of spring-run Chinook salmon to the head of Reach 1B.

- **Decision Tree Routing:** The worth of Action H1 is low because there is high uncertainty regarding the degree of impact of measures implemented to lower Millerton Lake water temperatures. The magnitude of Action H1 is also expected to be low because the changes in water temperature downstream are largely controlled by ambient conditions below Reach 1. The risk associated with Action H1 is medium because of the possible negative impacts that might occur in Millerton Lake (e.g., changes in bottom-up controls on food web structure because of limited light penetration). Based upon the results of routing Action H1 through the decision tree, a targeted study is recommended for Action H1.

- **Data Needs and Monitoring:** Data will be needed to assess the hypothesis associated with modification of Friant and Madera canals to lower water temperature releases. Specifically, temperatures, suspended sediment, and DO data below the dam through Reach 1 would need to be modeled. Additionally, a targeted study would need to be conducted on Millerton Lake to assess possible biological changes that might occur if light penetration were reduced.

- **Potential Triggers and Adaptive Responses:** Should monitoring indicate covering Millerton Lake to lower water temperatures is contributing to adverse downstream water temperature or quality, then recommendations will be made for alteration in design, change in operation, or options for achieving adequate water temperatures. Additionally, considerations will be made regarding changes in Millerton Lake because of reduced light penetration. New actions will then be evaluated through the action routing process.

5.2.6 Reduced Genetic Viability

Reduced genetic viability may limit the success of Chinook salmon restoration. Objectives and associated actions for reducing this limiting factor are described below.

Goal I

Meet or exceed the genetic fitness goals for Chinook salmon

Scientific literature indicates a minimum of 500 adults in any year will be necessary to maintain a minimum genetically viable population of Chinook salmon. A Genetic Management Plan will be developed to provide further analysis and may provide alternative targets for population goals.

Genetic fitness in Reaches 1 through 5 are considered of high importance because management actions to reduce Chinook salmon hybridization and provide that adequate spawning habitat will occur in Reach 1 and to provide for suitable habitat conditions and optimizing survival in the Restoration Area will be necessary to maintain minimum populations.

Action I1: Select and manage genetically fit stock sources for Chinook salmon.

> The identification of source stocks for reintroduction and the management of reintroduced stocks will be outlined in the SJRRP Genetics Management Plan. Resulting actions will be adaptively managed and routed, as appropriate, as developed. Currently, the University of California, Davis, is conducting studies needed to assist in the development of choosing appropriate source stocks.

- **H_A:** No hypothesis has been generated for Action I1 because specific information will be available in the Genetics Management Plan. Ultimately, several hypotheses will be developed related to appropriate source stocks.

- **Decision Tree Routing:** There is high worth associated with Action I1 because of the implications associated with choosing appropriate source stocks. The magnitude of Action I1 is high. There is a high risk associated with Action I1 because Action I1 may adversely affect existing and restored stocks, to an unknown degree. The high uncertainty associated with Action I1 provides an opportunity to learn from Action I1, and apply that information to reintroduction strategies. Based upon the results of routing Action I1 through the decision tree, a targeted study is recommended. Action I1 will be implemented based on the results of the Genetics Management Plan. Proposed measures may be recommended for the Interim Flow period and potentially carried out through the life of the project.

- **Data Needs and Monitoring:** Much information will be necessary before implementing the target study. For example, which out-of-basin spring-run Chinook salmon stocks would be used, and what is the adaptive potential of particular strain characteristics? How many founders will be used to ensure genetic diversity? Does the source population have an extended spawning season, and if so, will founders be acquired from the period of time desired? The development of the Genetics Management Plan will likely address some of these questions. Therefore, no specific data needs or monitoring will be included here at this time. The University of California, Davis, will provide recommendations for developing actions once research studies are completed.

- **Potential Triggers and Adaptive Responses:** Selecting and managing genetically fit stocks will be addressed following the development of hypotheses in conjunction with the completion of the Genetics Management Plan. Actions will be routed at that time.

Action I2: Incorporate conservation practices in artificial propagation of Chinook salmon.

Hatchery-reared Chinook salmon are often produced to meet numerical stocking/planting demands. The SJRRP Restoration Goal is to establish natural reproducing, self-sustaining populations of Chinook salmon. This will begin with Action I1 and transition to Action I2.

- **H_A:** No hypothesis has been generated for Action I2. Ultimately, several hypotheses will be developed relating to conservation practices during propagation.

- **Decision Tree Routing:** Action I2, likely a set of actions, has a high magnitude because the contribution is expected to be high and moderate uncertainty because there are still many unknowns with respect to conservation-specific propagation. The worth of Action I2 is high. The risk of Action I2 is medium because of the uncertainty associated with conservation genetics. Full implementation of conservation practices is recommended for Action I2.

- **Data Needs and Monitoring:** Program-wide monitoring will be used to address questions related to conservation genetics.

- **Potential Triggers and Adaptive Responses:** New actions will continue to be added as they relate to findings regarding conservation genetic practices.

Action I3: Modify operation of Hills Ferry Barrier or construct other temporary barriers to segregate Chinook salmon runs.

Hybridization is expected to reduce the fitness parameters (i.e., growth, survival, and reproduction) of fishes. This is especially true for subspecies and races because genetic divergence may disrupt physiological and developmental regulation. In addition, hybridization may disrupt homing mechanisms and lead to reduced survival and increased straying in fishes. This action may also be used to reduce risk of redd superimposition between runs of Chinook salmon (see Goal L).

- **H_A:** No hypothesis will be generated at this time. More information will be needed before hypotheses are generated.

- **Decision Tree Routing:** The magnitude of Action I3 is unknown because hybridization may or may not be an issue in the Restoration Area. The uncertainty of Action I3 is high and therefore, the worth of Action I3 is low. The risk of Action I3 is moderate because modification could impede passage for other fishes and races at inappropriate times. Action I3 may not be reversible depending on the alteration and associated cost. A targeted study is recommended for Action I3. If Action I3 is implemented, monitoring after reintroduction of Chinook salmon should be conducted to assess run timing and assess how best to optimize barrier operation to achieve desired goals (Goal I and M).

- **Data Needs and Monitoring:** A risk assessment for hybridization will need to be completed during the target study to better evaluate the worth of this action. During the targeted study, different modifications to a barrier will need to be proposed and assessed. No monitoring will take place during this time. If Action I3 is proposed with more information, it will be routed.

- **Potential Triggers and Adaptive Responses:** If the risk assessment demonstrates that hybridization is expected to be a major factor in the Restoration Area, new actions would be routed.

5.2.7 Degraded Water Quality

Degraded water quality has been identified as a potential limiting factor for Chinook salmon and other native fishes. The following goals and associated actions to reduce the impacts of degraded water quality are described below.

Goal J

Provide and/or maintain suitable water quality

Constituents such as pesticides and other urban and agricultural wastes may affect water quality parameters such as DO and turbidity, creating habitat unsuitable for Chinook salmon. Sources of adverse water-quality conditions and whether or not discharge conditions will improve water quality are unknown. Evaluating and taking management actions for these conditions may be necessary to successfully meet the Restoration Goal. All life stages of Chinook salmon could be affected.

Three species toxicity testing (Central Valley Water Board/EPA standards) has not been done, so it is unknown what water quality could be considered a limiting factor in Reaches 1 and 2. Water quality in Reaches 3 through 5 is considered of moderate importance because it experiences a significant amount of agricultural return flows, but effects on Chinook salmon are largely unknown.

Action J1: Implement Settlement flow schedule (see Action A3).

Action J2: Support existing public outreach and education programs incorporating education on best management practices.

> Many anthropogenic activities threaten the health of the river in the Restoration Area. The entire region faces challenges from a growing human population and a changing climate that may exacerbate the many existing pressures on the San Joaquin River. It is beneficial to educate the community regarding the best management practices available to protect the resources of the river. This action is intended to support and work with existing public outreach and education programs related to water quality, such as those implemented by agencies such as the Central Valley Water Board and the Metropolitan Flood Control District.
>
> - **H_A:** Informing and working with existing public outreach programs will increase the use of best management practices in the San Joaquin watershed.
> - **Decision Tree Routing:** The magnitude and uncertainty of Action J2 are medium because although Action J2 would likely be well received, the link between outreach and implementation of best management practices by landowners is not well understood. The worth of Action J2 is medium. The risk associated with planned outreach is low. Full implementation is recommended for Action J2.

- **Data Needs and Monitoring:** To evaluate the benefits of a public outreach and education program, data are needed to estimate how responsive the public to implementing best management practices. Monitoring to collect this information could be accomplished using surveys directed toward landowners in the watershed.
- **Potential Triggers and Adaptive Responses:** If the assessment demonstrates little response to outreach and education, the objectives of this program will be reevaluated and new actions routed.

5.2.8 Excessive Harvest

Excessive harvest in the Restoration Area has been identified as a potential limiting factor for Chinook salmon. The following goals and associated actions to reduce the impacts of excessive harvest are described below.

Goal K

Minimize in-river harvest, unlawful take, and disturbance

Harvest of adult Chinook salmon and disturbance of redds and habitat may limit success in meeting the Restoration Goal. Current take limits specified by State fishing regulations allow legal catch throughout the year of one Chinook salmon (no size restriction) in the San Joaquin River from Friant Dam downstream to the Highway 140 bridge (DFG 2007b). One Chinook salmon may be harvested from January through October downstream of the Highway 140 bridge. During November and December, a no-take limit for Chinook salmon requiring any incidental capture to be released unharmed without removing fish from the water, is enforced downstream from the Highway 140 bridge. Harvest could directly or indirectly affect all life stages.

Harvest in Reach 1 is considered to have high importance owing to the long residence period for adult spring-run Chinook salmon. Additionally, Reach 1 is expected to provide the majority of suitable spawning habitat for Chinook salmon.

Harvest in Reaches 2 through 5 is considered to have a low importance because these are only migratory corridors for Chinook salmon, so they won’t be in these reaches for long periods of time and public access is somewhat limited in these reaches. However, passage limiting structures currently in these reaches could provide harvest/poaching opportunities due to migration delays. However, the degree to which ongoing public actions (e.g., construction) may impact or improve instream conditions and fishery resources is currently unknown.

Action K1: Implement public outreach program to reduce unlawful take of Chinook salmon and disturbance associated with spawning habitat.

> Helping stakeholders understand the biological significance of illegal harvest of Chinook salmon and the implications of disrupting spawning activities are critical to the success of the Restoration Goal.

- **H_A:** Implementing a public outreach program will help reduce unlawful take of Chinook salmon in the Restoration Area.

- **Decision Tree Routing:** The magnitude of Action K1 is high and the uncertainty is low because stakeholders are anticipated to react positively to the outreach. The worth of Action K1 is high and associated risk is low. Full implementation is recommended for Action K1.

- **Data Needs and Monitoring:** No specific data needs exist for Action K1. Monitoring will be limited to periodic interactions with enforcement personnel to evaluate illegal harvest and disruptive activities in Chinook salmon spawning areas.

- **Potential Triggers and Adaptive Responses:** If law enforcement personnel report unusual levels of illegal harvest or adverse activities, the objectives of Action K1 would be reevaluated and new actions routed. If adverse instream activities are minimal, outreach will be continued at regularly scheduled events, as necessary.

Action K2: Restrict seasonal access in sensitive river sections (i.e., spring-run Chinook salmon holding and spawning habitat) and change current fishing regulation.

As a protective measure, river sections are often closed to Chinook salmon fishing to reduce mortality during the spawning season. It is reasonable to implement Action K2 on the San Joaquin River to protect the reintroduced Chinook salmon fishery.

- **H_A:** No hypothesis is generated for Action K2 because limiting access during Chinook salmon spawning is a practice that has been previously used and evaluated in the Central Valley.

- **Decision Tree Routing:** The magnitude of Action K2 is high and the uncertainty is low because evidence based on prior closures in other areas indicates Action K2 would be beneficial. The worth of Action K2 is high and associated risk is low. Full implementation is recommended for Action K2.

- **Data Needs and Monitoring:** No specific data needs exist for Action K2. DFG staff will be responsible for Action K2. Monitoring will be limited to periodic interactions with enforcement personnel to evaluate illegal harvest and disruptive activities in Chinook salmon spawning areas.

- **Potential Triggers and Adaptive Responses:** Action K2 will be evaluated on a regular basis to see if Action K2 needs to be revised or new actions routed.

Action K3: Increasing law enforcement in the Restoration Area will reduce unlawful harvest of Chinook salmon.

> Fisheries resources are protected by DFG Game Wardens. State budget limitations restrict the number of wardens available to protect and conserve the resources. Because of the key role law enforcement plays in any conservation program, it may be necessary to evaluate the need for more enforcement in the Restoration Area.

- **H_A:** No hypothesis will be generated for Action K3 because it is simply an evaluation of a needed action.
- **Decision Tree Routing:** The magnitude of Action K3 is high and the uncertainty is low because it would be relatively easy to conduct the evaluation and it would clearly be beneficial to know whether enhanced law enforcement is needed to adequately protect reintroduced Chinook salmon. The risk of investigating the need to augment law enforcement in this area is low. The worth of Action K3 is high. Full implementation is recommended for Action K3.
- **Data Needs and Monitoring:** Data needed to evaluate this action are: (1) the amount of time a law enforcement agent can spend assessing the area during Chinook salmon spawning season, (2) the number of poaching calls received by agents that pertain to the Restoration Area, and (3) the amount of money that would need to be devoted to augmenting law enforcement personnel, if necessary. Monitoring would include interactions with enforcement personnel to evaluate illegal harvest and disruptive activities within the Restoration Area and an assessment of the funds needed to augment existing personnel.
- **Potential Triggers and Adaptive Responses:** If a need to augment law enforcement in the Restoration Area is identified, a new action will be routed. If no additional law enforcement is necessary, interacting with law enforcement officials as outlined in Action K1 will continue.

5.2.9 Excessive Redd Superimposition

Existing or newly constructed Chinook salmon spawning habitat may or may not be sufficient to avoid excessive redd superimposition. Superimposition may occur if fall-run Chinook salmon deposit eggs on top of spring-run eggs leading to embryo mortality of spring-run eggs, effectively limiting survival. The ability to control run timing through modified operations of barriers to separate races of Chinook salmon is unknown. Further, the reliability of flow management to prevent overlap of spawning races and hybridization is unknown.

Goal L

Minimize Chinook salmon redd superimposition

Excessive redd superimposition in Reach 1 is considered of high importance because Reach 1 contains all suitable spawning habitat and deployment of seasonal barriers in Reach 1 may prove effective in separating spring- and fall-run Chinook salmon. Excessive redd superimposition in Reaches 2 through 5 are considered to have low importance as spawning is not expected to occur in these reaches and barrier deployment to separate Chinook salmon runs is not expected to be beneficial.

Action L1: Determine if additional spawning habitat (i.e., augment gravel at existing riffles and other suitable locations) is necessary to sustain Chinook salmon populations.

> Investigation of existing Chinook salmon spawning habitat quality and quantity needs to be completed to determine if spawning habitat needs to be augmented. If spawning habitat quality and quantity is determined to be insufficient to meet long-term population goals, augmentation of suitable gravel in appropriate hydraulic conditions will be necessary.

- **H_A:** The creation of additional spawning habitat would help minimize redd superimposition of spring-run Chinook salmon.
- **Decision Tree Routing:** The worth of Action L1 is high because providing Chinook salmon spawning habitat of sufficient quantity and quality will be necessary to meet the Restoration Goal. Action L1 has a high magnitude and, because it is expected to achieve the objective, it has a low uncertainty. The risk associated with Action L1 is low as it is unlikely to have adverse impacts. Further, gravel placement can be modified if site selection is determined to be inappropriate because fluvial conditions are unable to adequately redistribute material. Based on the results of routing Action L1 through the decision tree, full implementation is recommended.
- **Data Needs and Monitoring:** Data are needed to evaluate the population abundance that can be supported by existing Chinook salmon spawning habitat conditions and the timing of runs after reintroduction as well as female preferences for spawning gravels and redd locations. Data from other rivers may be used to estimate the relationship between availability of spawning habitat and escapement.
- **Potential Triggers and Adaptive Responses:** Should monitoring indicate that Chinook salmon spawning habitat is not of sufficient quality or quantity, recommendations will be made to improve or create spawning habitat, and new actions will be routed.

Action L2: Modify operation of Hills Ferry Barrier or construct other temporary barriers to segregate Chinook salmon runs (see Action I3).

5.2.10 Excessive Hybridization

Separation of runs may result from homing or assortive mating (i.e., mating between like individuals). When runs return to their natal stream, considerable assortive mating and/or temporal and spatial segregation are thought to isolate the races. There are known benefits of natural levels of hybridization between runs, however, excessive hybridization can result in outbreeding depression and degraded performance can occur (e.g., swimming performance, sexual maturity, size). Such hybridization may need to be minimized.

Goal M

Minimize hybridization between spring-run and fall-run Chinook salmon

A control structure may be used to minimize interactions between spring- and fall-run Chinook salmon. Additionally, there are two alternative hypotheses that may increase the amount of spawning habitat and thereby reduce hybridization: augment gravel at existing riffles and other suitable locations, and increase flows to provide additional spawning habitat to segregate spawning runs.

Action M1: Modify operation of Hills Ferry Barrier or construct other temporary barriers to segregate Chinook salmon runs (see Action I3).

Action M2: Increase the amount of Chinook salmon spawning habitat available to minimize overlap of runs and reduce hybridization.

- **H_{A1}:** Augmenting gravel at existing riffles and other suitable locations will reduce hybridization between spring- and fall-run Chinook salmon (see Action L1).
- **H_{A2}:** Providing additional spawning habitat by increasing discharge will minimize overlap of spawning locations for spring- and fall-run Chinook salmon.

The relation between the amount of Chinook salmon spawning habitat available and discharge is unknown. However, it is likely additional spawning habitat may be available by increasing discharge, until some threshold (currently unknown) is reached.

- **Decision Tree Routing:** The magnitude of Action M2 is unknown and uncertainty is high. The worth of Action M2 is low because the relation between habitat and discharge on this river is unknown and obtaining additional water is costly. The risk associated with Action M2 is high as it may have adverse impacts to existing Chinook salmon spawning habitat. Based on the results of routing Action M2 through the decision tree, a targeted study is recommended.

- **Data Needs and Monitoring:** Data are needed to evaluate the effect of Action M2 on the quantity and quality of existing and potential Chinook salmon spawning habitat. Modeling will be used to provide estimates of habitat availability and suitability under different discharge scenarios.

- **Potential Triggers and Adaptive Responses:** Should monitoring indicate that spawning habitat for spring-run Chinook salmon is adversely impacted by implementing this action, new actions would be recommended and then routed.

5.2.11 Limited Holding Pool Habitat

Limited holding pool habitat has been identified as a potential limiting factor for Chinook salmon and other native fishes. The following goals and associated actions to improve holding pool habitat are described below.

Goal N

Ensure sufficient quantity and quality of holding pool habitat to meet Restoration Goal

Existing holding pool habitat immediately downstream from Friant Dam is considered sufficient (Exhibit A); however, holding pool quantity and quality will need to be further evaluated.

Holding pool habitat in Reach 1 is considered of high importance as Reach 1 is expected to provide all suitable holding habitat.

Holding pool habitat in Reaches 2 through 5 are considered to have low importance as holding spring-run Chinook salmon are not expected to occupy these reaches.

Action N1: Implement Settlement flow schedule (see Action A3).

Action N2: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary (see Action A4).

Action N3: Evaluate the quality and quantity of holding pool habitat.

> An investigation of existing holding pool habitat needs to be completed to determine if additional holding pool habitat needs to be created. If holding pool habitat quality and quantity are determined to be insufficient to meet long-term population goals, it may be necessary to take remedial action to improve habitat conditions.

- **H_A:** No hypothesis will be generated for Action N3 because confirmation of existing holding pool conditions is necessary before remedial actions can be developed.

- **Decision Tree Routing:** The worth of Action N3 is high because providing holding pool habitat of sufficient quantity and quality will be necessary to meet the Restoration Goal. Action N3 has a high magnitude and, because it is anticipated to achieve the objective, it has a low uncertainty. The risk associated with Action N3 is low as it is unlikely to have adverse impacts. Based on the results of routing Action N3 through the decision tree, full implementation is recommended.

- **Data Needs and Monitoring:** Data are needed to evaluate population numbers that can be supported by existing holding pool habitat conditions. Data from other rivers could be used to estimate the relationship between availability of holding pool habitat and escapement. No monitoring is needed at this time.
- **Potential Triggers and Adaptive Responses:** Once estimates of the relation between holding pool habitat quantity and escapement are obtained, recommendations will be made to improve holding pools and create additional habitat. New actions will then be evaluated through the action routing process.

5.2.12 Limited Gravel Availability

Gravel availability is considered a limiting factor in the Restoration Area and actions for improving gravel availability are routed below.

Goal O

Provide sufficient quantity and quality of spawning habitat for Chinook salmon

Suitability of Chinook salmon spawning habitat depends upon a combination of physical factors including temperature, flow, DO, and geomorphology. Geomorphology plays a critical role in providing material of suitable size for excavation and egg burial while providing for adequate oxygen and metabolic waste removal. Recruitment of suitable gravel has altered by construction of Friant Dam and the suitability of existing gravel and the maintenance and adequate distribution of suitable gravel sizes is unknown. If gravel recruitment and geomorphic function is unsuitable, it will be necessary to augment existing spawning gravel.

Spawning habitat in Reach 1 is considered of high importance as Reach 1 is expected to provide all suitable spawning habitat. Spawning habitat in Reaches 2 through 5 are considered to have a low importance as no spawning is expected to occur in these reaches.

Action O1: Implement Settlement flow schedule (see Action A3).

Action O2: Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary (see Action A4).

Action O3: Augment gravel at existing riffles and other suitable locations (see Action L1).

Action O4: Modify channels to provide Chinook salmon spawning habitat (see Action B3).

5.2.13 Excessive Sedimentation

Excessive sedimentation has been identified as a potential limiting factor for Chinook salmon and other native fishes. The following goals and associated actions to reduce the impacts of excessive sedimentation are described below.

Goal P

Minimize fine deposited and suspended sediment

Fine sediments are a natural and necessary element of streams. However, excess levels of fine sediments can prove detrimental to stream biota. High suspended sediment loads can alter fish composition (e.g., reduce site feeding fishes), reduce recognition of visual cues for spawning, or settle out and create high amounts of deposited sediment. High levels of deposited sediment may reduce fish populations by filling in the interstitial spaces between gravel. Filling the spaces between coarse sediments may kill organisms that form the basis of the food web (i.e., food availability). Additionally, fine sediment normally hinders successful redd development and inhibits egg development/incubation within spawning gravel. It is unclear if flushing flows, as prescribed in the Settlement flow schedule, will sufficiently remove fines from these critical habitats.

Fines and suspended sediment in Reach 1 are considered of high importance as this reach is expected to provide all suitable Chinook salmon spawning habitat. Fines and suspended sediment in Reaches 2 through 5 are considered of low importance as no spawning is expected to occur in these reaches.

Action P1: Implement measures to clean Chinook salmon spawning gravel.

> Gravel cleaning refers to the removal of fine sediment from gravel (mechanized or flow scouring) with the goal of increasing interstitial flow and improving the quality of spawning habitat. Gravel cleaning may increase egg survival rates, but unless the source of the fines has been identified and dealt with effectively, these benefits are likely temporary. Action P1 has two competing hypotheses: (1) implementing flushing flows to clean spawning gravel and improve reproductive success, and (2) using mechanized gravel cleaning to improve spawning habitat and success.

- **H_{A1}:** Implementing flushing flows to clean gravel will increase reproductive success of Chinook salmon.
- **Decision Tree Routing:** (see Action A4).
- **Data Needs and Monitoring:** Data needed to evaluate Action P1 are: (1) the amount of time the gravel remains in a relatively clean state following flushing flows, and (2) the number of redds before and after the implementation of flushing flows. Monitoring will need to take place pre-

and post-flushing so estimates of redds can be made. Additionally, intermittent visits will need to be made to the site to estimate the amount of deposited sediment in the area.

- **H_{A2}:** Implementing mechanized gravel cleaning in Chinook salmon spawning habitat will increase reproductive success.
- **Decision Tree Routing:** The magnitude of Action P1 is high as the beneficial effects of gravel cleaning on reducing limiting factors associated with excessive sedimentation are high; however, they may be short-lived and adverse conditions may therefore reoccur without frequent gravel cleaning. The uncertainty of Action P1 is high because it is unclear what lasting effect this measure would have on Chinook salmon spawning habitat or the downstream effects of this action (e.g., sedimentation). The worth of Action P1 is low. The risk of this action is medium. Action P1 would not be reversible. A small-scale implementation is recommended for Action P1.
- **Data Needs and Monitoring:** Data needed to evaluate Action P1 are: (1) the amount of time the gravel remains in a relatively clean state following mechanized cleaning, and (2) the fry emergence rate of redds pre- and post-mechanized cleaning. Monitoring will need to take place pre- and post-cleaning so estimates of redds can be made. Additionally, intermittent visits will need to be made to the site to estimate the amount of deposited sediment in the area.
- **Potential Triggers and Adaptive Responses:** If the hypothesis is accepted and the number of redds increase post-gravel-cleaning then the frequency will have to be increased to retain the benefit of increased redds will need to be determined, following which, new actions would be routed.

Action P2: Implement public outreach program (see Action J2).

Action P3: Construct settling basins.

Properly designed settling basins retain water long enough for coarse suspended solids to settle. Water leaving settling basins will be lower in suspended solids than water entering them. Therefore, settling basins provide one alternative for reducing sediment loads.

- **H_A:** Constructing a settling basin will reduce suspended sediment loads in the Restoration Area.
- **Decision Tree Routing:** The magnitude of Action P3 is low as the beneficial effects of settling basins are expected to be short-lived and adverse conditions will therefore reoccur without frequent action. The uncertainty of Action P1 is high because it is unclear what lasting effect this measure would have on fish habitat and food availability or what kind

of maintenance would be required. The worth of Action P1 is low. The risk of Action P1 is medium. Action P1 would be reversible. Small-scale implementation is recommended for Action P1.

- **Data Needs and Monitoring:** Data needed to evaluate Action P1 would be the change in suspended sediment loads after settling basin construction. Data needs indicate monitoring will need to take place pre- and post-construction to estimate suspended sediment values. Additionally, a cost estimate for maintenance would need to be established as well as a timeline (i.e., how often would this need to be completed). Monitoring would have to take place over a spatial scale large enough to determine how far downstream from the settling basins the benefits of the basin occur so a better estimate could be made regarding how many settling basins would be necessary. Additional monitoring to assess impacts to water temperature and/or the creation of predator habitat related to settling basins is also advisable.

- **Potential Triggers and Adaptive Responses:** If the hypothesis is accepted, settling basins are effective at reducing sediment loads, a cost estimate and implementation plan will be created so new actions can be routed. If the settling basins do not effectively reduce suspended sediment, different alternatives to address excessive suspended sediment would be evaluated (see Action J2).

Action P4: Create log vein, J hook vein, or rock vein structures to facilitate sediment transport.

Vein structures are designed to perform a variety of functions. Applications depend on design, placement location, spacing, etc. One application is to trap sediment in the upstream end of the vein and create scour on the downstream side. Placement of individual veins may also reduce bank erosion.

- **H_A:** Creating vein structures will reduce downstream sediment deposition thereby improving water quality and habitat in downstream reaches.

- **Decision Tree Routing:** The worth of this action is low because this action has low magnitude due to likely maintenance to keep the structure functional (due to the amount of sand and fines in the system), and because of high uncertainty due to variability in the results produced by vein structures. The risk associated with this activity is moderate due to construction activities needed to construct veins. This action is not reversible, but additional construction could modify the initial structure. Based on the results of routing this action through the decision tree, a targeted study is recommended.

- **Data Needs and Monitoring:** Data needed to evaluate these structures are an analysis of the different veins that might be constructed and a cost estimate, including any necessary maintenance. We will investigate veins that have been constructed in other systems and the results produced to further evaluate the hypothesis associated with this action.

- **Potential Triggers and Adaptive Responses:** If information is found to support use of veins in this system, then recommendations will be made regarding specific vein types and possible locations within the San Joaquin System. New actions will then be routed.

Action P5: Fine sediment management actions.

- **H_A:** Implementation of fine sediment management actions will result in increased gravel quality and spawning success of Chinook salmon.

- **Decision Tree Routing:** The worth of this action is low because it is not know whether this action is needed to increase spawning success of Chinook salmon and improve gravel quality. The potential to improve spawning habitat can have a large magnitude and previous projects of a similar nature have proven to be reliable, however, more information is needed about the condition of existing spawning gravel and there is a high opportunity to learn. The risk associated with this activity is high and Action P5 is recommended as a targeted study.

- **Data Needs and Monitoring:** Data will be needed to assess the current condition of spawning gravel and possible problems with sedimentation and their impacts to spawning gravel quality. To obtain this information, a sediment management plan is recommended.

- **Potential Triggers and Adaptive Responses:** It is uncertain as to whether the implementation of sediment management actions will result in improvements of spawning gravel quality to be used by Chinook salmon.

5.2.14 Insufficient Floodplain and Riparian Habitat

Floodplain and riparian habitat availability are considered limiting factors and actions for improving floodplain and riparian conditions are routed below.

Goal Q

Ensure suitable quantity and quality of floodplain and riparian habitat to provide habitat and food resources for Chinook salmon and other fishes

The quantity and quality of floodplain and riparian habitat in the Restoration Area are currently unknown. Floodplain and riparian habitat provide many important ecological benefits (e.g., Chinook salmon juvenile rearing habitat, predator and flow refuge, food resources, sediment control). The physical and chemical characteristics of streams that are optimal for macroinvertebrate communities can be related to optimal conditions for life stages and species of salmon (Plotnikoff and Polayes 1999). Species composition and abundance are an indication of overall stream health. Invertebrate production plays a key role between primary producers and higher trophic levels (Rader 1997). The growth and survival of salmonids vary between rivers, and studies indicate differences in invertebrate biomass contribute to some of this variation (Cada et al. 1987, Filbert and Hawkins 1995).

Invertebrate production and conditions for growth and development in the Restoration Area are unknown. It will be necessary to evaluate and monitor food availability, growth, and development to provide a measure of what effect in-river conditions may have on the fishery and measure SJRRP restoration success.

Providing and maintaining the ecological benefits of floodplain and riparian habitat will be important in all reaches.

Action Q1: Implement Settlement flow schedule (see Action A3).

Action Q2: Implement hydrograph flexibility, buffer flows, and use of additional purchased water, as necessary (see Action A4).

Action Q3: Restore floodplain habitat.

- **H_A:** Restoration of floodplain habitat will result in creation of Chinook salmon rearing habitat (documented by the presence of juveniles) in subsequent years.

- **Decision Tree Routing:** The worth of restoring floodplain habitat is high because Action Q3 is of high magnitude potential for salmon and other native fishes and high uncertainty since it is unknown where restoration of the floodplains would provide the greatest benefits for Chinook salmon. For example, benefits of upstream vs. downstream could change temporally and depends on the life-history strategy of spring-run Chinook salmon. The risk associated with Action Q3 is medium because restoration of floodplains may alter flow or connection with groundwater, but it is unlikely to adversely affect existing habitat. Action Q3 is considered cost prohibitive in terms of reversibility. A small-scale implementation is recommended for Action Q3.

- **Data Needs and Monitoring:** Data will be needed to assess use of floodplain habitats for Chinook salmon rearing. Specifically, data on the number of juveniles present the following year needs to be collected. To obtain this information, the presence of fry and smolts in the restored habitat and the number of juveniles reaching the smolt life stage within the reach where habitat was restored would be monitored.

- **Potential Triggers and Adaptive Responses:** It is uncertain whether restored floodplain habitat will be used by juveniles in all water year types and inter-annual variability needs to be factored in to the post-implementation monitoring and assessment. If juveniles are not found in the restored floodplain in subsequent years, the morphological conditions would be evaluated and recommendations made to increase juvenile use of the floodplain or discontinue the restoration of floodplain habitats.

Action Q4: Create off-channel Chinook salmon rearing areas.

- **H_A:** Creation of off-channel rearing areas will result in creation of Chinook salmon rearing habitat (documented by the presence of juveniles) in subsequent years.
- **Decision Tree Routing:** The worth of creating off-channel rearing areas is medium because Action Q4 is of moderate magnitude and high uncertainty since it is unknown if the off-channel rearing areas would be used by Chinook salmon. The risk associated with Action Q4 is medium because creation of off-channel habitat may alter flow or connection with groundwater, but it is unlikely to adversely affect existing habitat. Action Q4 is considered cost prohibitive in terms of reversibility. Based upon the results of routing Action Q4 through the decision tree, a small-scale implementation is recommended.
- **Data Needs and Monitoring:** Data will be needed to assess use of off-channel habitats for Chinook salmon rearing. Specifically, the number and condition (i.e., length, weight, and food content) of juveniles present the following year would need to be identified. To obtain this information, presence and condition of fry and smolts in the created habitat and the number of juveniles reaching the smolt life stage within the restored habitat would be monitored.
- **Potential Triggers and Adaptive Responses:** It is uncertain as to whether off-channel rearing areas will be used by Chinook salmon juveniles in all water year types and inter-annual variability needs to be factored in to the post-implementation monitoring and assessment. If juveniles are not found in the off-channel rearing areas the following year, the morphological conditions would be evaluated and recommendations made to increase juvenile abundance or discontinue the creation of off-channel habitats.

Action Q5: Simultaneously fill gravel pits and create floodplain salmon rearing habitat.

- **H_A:** Filling gravel pits and creating floodplain rearing habitat will result in the creation of salmon rearing habitat.
- **Decision Tree Routing:** The worth of this action is medium because although this action has the potential to reduce significant limiting factors associated with excessive predation and in addition create floodplain rearing habitat and have a large magnitude, it has high uncertainty due to unknown results associated with the creation of floodplains in gravel pit

areas. The risk associated with this activity is high due to construction activities needed to construct floodplain habitat. Action Q5 is considered cost prohibitive in terms of reversibility yet has a high opportunity to learn. Based on the results of routing this action through the decision tree, targeted studies are recommended.

- **Data Needs and Monitoring:** Data will be needed to assess use of off-channel habitats for Chinook salmon rearing. Specifically, the number and condition (i.e., length, weight, and food content) of juveniles present the following year would need to be identified. To obtain this information, presence and condition of fry and smolts in the created habitat and the number of juveniles reaching the smolt life stage within the restored habitat would be monitored.

- **Potential Triggers and Adaptive Responses:** It is uncertain as to whether off-channel rearing areas will be used by Chinook salmon juveniles in all water year types and inter-annual variability needs to be factored in to the post-implementation monitoring and assessment. If juveniles are not found in the off-channel rearing areas the following year, the morphological conditions would be evaluated and recommendations made to increase juvenile abundance or discontinue the creation of off-channel habitats.

Action Q6: Create structural elements to provide floodplain rearing habitat.

- **H_A:** Creating floodplain rearing habitat with structural elements (e.g., large woody debris, boulders, undercut bank, root wads) will result in the creation of salmon rearing habitat.

- **Decision Tree Routing:** The worth of this action is medium because although this action has the potential to create floodplain rearing habitat and have a large magnitude, it has high uncertainty due to unknown impacts to the stream ecosystem. The risk associated with this activity is high due to the potential impacts of construction activities. Action Q6 has a high opportunity to learn. Based on the results of routing this action through the decision tree, targeted studies are recommended.

- **Data Needs and Monitoring:** Data will be needed to assess use of created floodplain habitats for Chinook salmon rearing. Specifically, the number and condition (i.e., length, weight, and food content) of juveniles present the following year would need to be identified. To obtain this information, presence and condition of fry and smolts in the created habitat and the number of juveniles reaching the smolt life stage within the restored habitat would be monitored.

- **Potential Triggers and Adaptive Responses:** It is uncertain as to whether the creation of floodplains with structures will be used by Chinook salmon juveniles in all water year types and inter-annual variability needs to be factored in to the post-implementation monitoring and assessment. If juveniles are not found in the rearing areas the following year, the morphological conditions would be evaluated and recommendations made to increase juvenile abundance or discontinue the creation of structures.

5.2.15 Limited Food Availability

It is unknown what role food availability will play in regulating Chinook salmon production in the Restoration Area. Actions for improving food availability and growth/development rates are routed below.

Goal R

Ensure favorable conditions for food availability, growth, and development

The physical and chemical characteristics of streams that are optimal for macroinvertebrate communities can be related to optimal conditions for life stages and species of salmon (Plotnikoff and Polayes 1999). Species composition and abundance are indications of overall stream health. Invertebrate production plays a key role between primary producers and higher trophic levels (Rader 1997). The growth and survival of salmonids vary between rivers, and studies suggest that the differences in invertebrate biomass contribute to some of this variation (Cada et al. 1987, Filbert and Hawkins 1995).

Species composition of invertebrates affects prey availability for juvenile salmonids (i.e., some invertebrate taxa are highly vulnerable to salmonid predation while others are not). The current state of invertebrate production and conditions for growth and development are unknown. It will be necessary to evaluate and monitor food conditions, growth, and development to provide a measure of what effect in-river conditions may have on the fishery and measure SJRRP restoration success.

Life stages affected by limited food availability and reduced growth/development rates are fry, juvenile, smolt, and yearlings.

Food conditions in Reach 1 are considered of high importance as this reach is expected to support most life-history stages of Chinook salmon for the greatest period of time. Food conditions in Reaches 2 through 5 are considered to be of moderate importance to accommodate other life-history requirements, though likely for a shorter temporal period.

Two competing hypotheses exist regarding how to increase the availability of food in the Restoration Area. The two hypotheses are: (1) adding salmon derived nutrients will increase growth of juvenile Chinook salmon, and (2) restoring the riparian habitat will increase invertebrate production. Each hypothesis is routed below.

Action R1: Increase invertebrate production.

- **H_{A1}:** Adding salmon-derived nutrients (i.e., salmon carcasses) to the river will increase invertebrate production in the Restoration Area.
- **Decision Tree Routing:** The worth of adding salmon derived nutrients is medium because Action R1 is of moderate magnitude and high uncertainty (specific nutrient limitations in the Restoration Area are unknown). The risk associated with Action R1 is medium because it could impact existing water-quality conditions. Action R1 is not reversible, but may be discontinued if the desired outcome is not achieved. Action R1 should provide an opportunity to learn about limited food resources and nutrient inputs in the San Joaquin River. A small-scale implementation is recommended for Action R1.
- **Data Needs and Monitoring:** Data will be needed to assess changes in food resources associated with added nutrients. Specifically, information regarding invertebrate assemblage, diversity, and abundance following Action R1 is needed. The presence and abundance of invertebrate species in the study reach would be monitored.
- **Potential Triggers and Adaptive Responses:** It is uncertain whether adding salmon derived nutrients will result in increased food resources for juvenile Chinook salmon. If increased invertebrate diversity and abundance following restoration are not observed, nutrient levels and recommendations for further actions will be assessed. New actions will be routed.
- **H_{A2}:** Restoration of riparian habitat in Reach 1 will result in increased invertebrate production.
- **Decision Tree Routing:** The worth of restoring riparian habitat is medium because Action R1 is of moderate magnitude and high uncertainty since it is unknown if the restored riparian habitat would result in increased food resources. The risk associated with Action R1 is medium because restoration of riparian habitat may alter flow conditions, but it is unlikely to adversely affect existing habitat. Action R1 is considered cost prohibitive in terms of reversibility, but should provide an opportunity to learn about the effects of restored riparian habitat on food resources. Based upon the results of routing this action through the decision tree, a small scale implementation is recommended.
- **Data Needs and Monitoring:** Data will be needed to assess changes in food resources associated with restored riparian habitat, specifically information regarding invertebrate assemblage, composition, and abundance following restoration. The presence and abundance of

invertebrate species in the restored habitat and the number of juveniles using the area adjacent to the riparian restoration would be monitored.

- **Potential Triggers and Adaptive Responses:** It is uncertain whether restoring riparian habitat will result in increased food resources for juveniles. If invertebrate diversity and abundance do not increase following restoration, the morphological conditions would be assessed and recommendations made to increase invertebrate production or discontinue the restoration of riparian habitats.

Action R2: Restore floodplain habitat (see Action Q3).

5.2.16 Excessive Predation

Excessive predation has been identified as a potential limiting factor for Chinook salmon and other native fishes. The following goals and associated actions to reduce the impacts of excessive predation are described below.

Goal S

Reduce predation of Chinook salmon by nonnative fishes and other aquatic organisms

The potential for predation to limit success of the restored fishery is currently unknown. Surveys will need to be conducted to identify predatory species and determine potential for predation to adversely affect restored native fish. Chinook salmon life stages potentially affected by excessive predation are fry, parr, smolt, juvenile and yearlings.

Predation in Reach 1 is considered to have high importance as this reach is expected to support most life-history stages of Chinook salmon for the greatest period of time.

Predation in Reaches 2 through 5 is considered to be of moderate importance to accommodate other life-history requirements, though likely for a shorter period of time.

Action S1: Fill and isolate the highest priority mining pits (see Action D4).

Action S2: Construct a low-flow channel (see Action A1).

Action S3: Restore floodplain habitat (see Action Q3).

Action S4: Reduce the number of nonnative predatory fishes in the Restoration Area.

> Reducing the numbers of nonnative fishes, particularly piscivores, is one way to reduce predation pressure on juvenile Chinook salmon. Implementing one of several actions intended to reduce the threat of nonnative fishes to Chinook salmon as well as identifying levels of management needed to achieve and sustain recovery will be necessary. Competing hypotheses are: (1) removing nonnative piscivores (using passive or active sampling gears, or pheromone-based trapping) will reduce nonnative fish and ultimately increase Chinook salmon survival, and (2) increasing catch limits of nonnative piscivores will have the same effect as active removal.

- **H_{A1}:** Capture and removal of nonnative predatory fish will result in increased survival of early Chinook salmon life stages.

- **Decision Tree Routing:** The magnitude of Action S4 is low because it is unlikely removal of predatory fish in the Restoration Area would benefit Chinook salmon because of the large numbers of piscivores located outside the Restoration Area. The uncertainty of Action S4 is high because it is unclear what lasting effect Action S4 would have on Chinook salmon survival or how much effort would be required to maintain this level of increased survival. The worth of this action is low. The risk of Action S4 is medium. This action would not be reversible. A targeted study is recommended for Action S4.

- **Data Needs and Monitoring:** Data needed to evaluate Action S4 would be the change in density of predators after removal and over what spatial and temporal scale. Data needs indicate monitoring will need to take place pre- and post-targeted study to estimate density of predators and their diet. Additionally, a cost estimate for maintenance would need to be established as well as a time-line (i.e., how often would this need to be completed). Monitoring would have to take place over a spatial scale large enough to determine how far upstream/downstream of the targeted study benefits would occur and how long it would take for predators to recolonize the area.

- **Potential Triggers and Adaptive Responses:** If the hypothesis is accepted and removing predators relates to increased Chinook salmon survival, a cost estimate and implementation plan will be created so new actions can be routed. If removal of predators does not effectively reduce densities, different alternatives to address excessive predation would be evaluated (see Actions A1 and Q3).

- **H_{A2}:** Increasing the recreational limit, and/or reducing size limits of nonnative predatory fish will result in increased survival of early Chinook salmon life stages.

- **Decision Tree Routing:** The magnitude of Action S4 is low because it is unlikely removal of predatory fish via fishing in the Restoration Area would benefit Chinook salmon because of the large numbers of piscivores located outside the Restoration Area. The uncertainty of Action S4 is high because it is unclear what lasting effect this measure would have on Chinook salmon survival or how much effort would be required to maintain this level of increased survival. The worth of Action S4 is low, and the risk is medium. Action S4 would not be reversible. A targeted study is recommended for Action S4.

- **Data Needs and Monitoring:** Data needed to evaluate Action S4 would be the change in density of predators after implementing regulation changes. Data needs indicate monitoring will need to take place pre- and post-targeted study to estimate density of predators. Monitoring would have to take place over a spatial scale large enough to determine how far upstream and downstream from the targeted study benefits would occur and how long it would take for predators to recolonize the area.

- **Potential Triggers and Adaptive Responses:** If the hypothesis is accepted and altering recreational fishing limits relates to increased Chinook salmon survival, an implementation plan will be created so route new actions can be routed. If removal of predators does not effectively reduce densities, different alternatives to address excessive predation would be evaluated (see Actions A1 and Q3).

Action S5: Create an increase in turbidity during juvenile downstream migration to reduce detection and therefore predation by piscivore fishes.

Salmonid juveniles may benefit from turbid waters (via increases in suspended sediment) in certain instances if their predators are less successful in detecting and pursuing them. However, this effect is countered if adequate cover exists (no effects of increased turbidity; Gregory and Levings 1996). To further complicate matters, differences in reaction distances to prey by predators alters predator-prey interactions under different visual conditions (i.e., light) (Mazur and Beauchamp 2003). Salmonids may also experience decreased feeding efficiency and other negative consequences (e.g., clogged gills and impaired respiration) as a result of increased turbidity. Important invertebrate prey may also experience negative consequences of increasing suspended sediments (McCabe and O’Brien 1983).

- **H_{A1}:** Increasing suspended sediment (by cleaning fine deposited sediment from spawning habitat and releasing it into the water column) over a relatively short period of time will reduce predation on juvenile Chinook salmon by site-feeding piscivore fishes.

- **Decision Tree Routing:** The magnitude of Action S5 is unknown because little information is available from field studies documenting the benefits (decreased predation) of increasing suspended sediment. The uncertainty of this action is high because it is unclear under what environmental conditions (i.e., discharge, temp), at what time of year, and at what concentration and duration that this action would be effective. In addition, the risk of this action is high because of the potential negative biotic and abiotic impacts of this action. The worth of this action is therefore low and a targeted study is recommended. This action would also benefit spawning habitat for salmon.

- **Data Needs and Monitoring:** Data needed to evaluate Action S4 include: a thorough literature review on the impacts of suspended sediment on fish (determine concentrations, duration of exposure, etc.) and a laboratory study designed to test the questions associated with appropriate concentrations, duration, and effects under different environmental and habitat conditions. Monitoring during this period should be conducted to evaluate the current suspended sediment conditions in the San Joaquin River under different discharge and environmental conditions.

- **Potential triggers and adaptive responses:** If the hypothesis is supported by available literature and a preliminary laboratory study, a small-scale implementation plan will be constructed using test fish to confirm laboratory results under field conditions. If monitoring actions do not support the hypothesis, new actions will be considered.

Action S6: Use pulse flows to displace nonnative predatory fishes in the Restoration Area.

By using pulse flows, the numbers of nonnative fishes, particularly piscivores, may be reduced in an effort to reduce predation pressure on juvenile Chinook salmon.

- **H_{A1}:** Pulse flows reduce abundance of nonnative predatory fish resulting in decreased juvenile Chinook salmon predation.

- **Decision Tree Routing:** The magnitude of Action S4 is medium because although the magnitude is potentially high, removal of predatory fish in the Restoration Area would, if effective, likely only be temporary. There is high uncertainty whether this action would be effective (i.e., reported results of similar actions have been inconsistent), and if it were effective, what the likelihood would be of this action resulting in long-term changes in predatory populations. The worth of this action is low. The risk of Action S4 is medium. This action would not be reversible. A targeted study is recommended for Action S4.

- **Data Needs and Monitoring:** Data needed to evaluate Action S4 would be the change in density of predators after pulse flow implementation. Data needs indicate monitoring will need to take place pre- and post-targeted study to estimate density of predators and their diet. Additionally, a frequency of occurrence would need to be established (i.e., how often would this need to be completed). Monitoring would have to take place over a spatial scale large enough to determine how far upstream/downstream from the targeted study benefits would occur and how long it would take for predators to recolonize the area.

- **Potential Triggers and Adaptive Responses:** If the hypothesis is accepted and pulse flows help to displace predators resulting in increased Chinook salmon survival, a cost estimate and implementation plan will be created so new actions can be routed. If the action does not result in reducing predation, different alternatives to address excessive predation would be evaluated (see Actions A1 and Q3).

Chapter 6 Program Planning

As stated in Chapter 1, the FMP lays out a structured approach to adaptively manage the reintroduction of Chinook salmon and other fish to the Restoration Area. The FMP is a program-level document and subsequent plans describing site-specific monitoring and assessments will be developed as the restoration program continues. The 2010 Fisheries Implementation Plan (available at: www.restore sjr.net) and its development as well as a brief description are provided in this Chapter. In addition, a general schedule is provided illustrating the sequence and periodicity of fisheries-related actions.

6.1 2010 Planning

Potential actions including Settlement actions and additional actions considered as a means to meet the fish restoration goals are described and routed through the Adaptive Management Approach in Chapter 5. Specific information needs before implementation of actions are also described in Chapter 5. The general process described in this FMP will translate into specific scientific studies and monitoring plans via future recommendations. This section summarizes the process of developing special study and monitoring recommendations.

The development of the 2010 Fisheries Implementation Plan was a four-step process. First, the FMWG reviewed the program’s goals and specific objectives as identified in this FMP. The Restoration timeline was matched to the objectives and members of the FMWG were assigned to write general proposals for specific plans. Next, proposals were drafted so the FMWG could prioritize specific work plans, and help ensure specific work plans would have objectives that matched the objectives of the FMP. The third step included an FMWG review of each draft, and suggested revisions to the author. Finally, revised proposals were prioritized based on: implementation date, phase status, and work plan status. Specific implementation plans were written for the proposals receiving the highest priority ranking. These work plans were elevated to the Program Management Team for funding. Table 6-1 lists the pertinent Settlement requirements, corresponding primary limiting factors, and recommended evaluation or assessment. The following sections summarize recommendations by Settlement categories: Phase I actions, Paragraph 12 actions, and Phase II actions.

Paragraph 15 of the Settlement requires Interim Flows start no later than October 1, 2009, to “collect relevant data concerning flows, temperatures, fish needs, seepage losses, recirculation, recapture and reuse.” To collect relevant data relating to fish needs in a timely manner, particularly in time to influence the planning and design of Phase I projects, the focus of the 2010 recommendations was primarily related to monitoring, with detailed and prioritized work plans outlining the suggested monitoring and special studies to begin on October 1, 2009. Phase I actions, or those identified as Paragraph 11(a) items in the Settlement require substantial fisheries information for successful implementation. For example, Paragraph 11(a)(2) requires the flow capacity enhancement to 4,500 cfs in Reach 2B of the Restoration Area. The setback of levees and associated conveyance improvements can offer significant fisheries benefits in terms of floodplain and instream structure; however, a better understanding of existing floodplain and instream structure in the entire Restoration Area is needed before Reach 2B floodplain construction. The FMWG recommends numerous evaluations during 2010 to acquire the necessary information for Phase I action implementation (Table 6-1). For a detailed description of the proposed evaluations, the reader is referred the work plans in the Fisheries Implementation Plan (available at www.restoresjr.net). Because the emphasis of the Interim Flow period, the 2010 Implementation Plan primarily consists of monitoring elements to collect important information regarding fisheries. It is anticipated that future implementation plans will consist of a higher proportion of special studies and evaluations addressing specific hypothesis evaluating restoration actions as part of the Adaptive Management Approach.

These plans were determined by the FMWG to be necessary for the success of the fisheries program. The 2010 Fisheries Implementation Plan consist of work plans describing existing agency monitoring programs as well as new work plans; some may or may not change, depending on funding priorities, agency requirements, etc.

Table 6-1.
Pertinent Settlement Requirement, Corresponding Primary Limiting Factors, and Approximate Year of Evaluation or Assessment

Settlement Requirement	Limiting Factor(s)	Evaluation/Monitoring
Phase I		
11(a)(1), Mendota Pool Bypass	Impaired Fish Passage, Entrainment	2010 Interim Flow Evaluation (H)
11(a)(2), Reach 2B conveyance to 4,500 cfs	Insufficient Floodplain and Riparian Habitat	2010 Interim Flow Evaluation (E)
11(a)(3), Reach 4B conveyance to 475 cfs	Insufficient Floodplain and Riparian Habitat, Impaired Fish Passage	2010 Interim Flow Evaluation (E)
11(a)(4), Reach 4B headgate modification	Impaired Fish Passage	2010 Interim Flow Evaluation (H)
11(a)(5), Modifications to Sand Slough Control Structure	Impaired Fish Passage	2010 Interim Flow Evaluation (H)
11(a)(6), Screen Arroyo Canal	Entrainment	Site-Specific Project
11(a)(7), Modify Sack Dam	Entrainment	Site-Specific Project
11(a)(8), Eastside and Mariposa Bypass passage mod	Impaired Fish Passage	2010 Interim Flow Evaluation (H)
11(a)(9), Eastside and Mariposa Bypass low-flow modifications	Impaired Fish Passage	2010 Interim Flow Evaluation (H)
11(a)(10), Salt and Mud Slough barriers	Excessive Straying	Future Site-Specific Project
Paragraph 12		
12, Implement trap-and-haul	Impaired Fish Passage, Inadequate Streamflow	2010 Interim Flow Evaluation (H)
12, Modify Channels to provide spawning habitat	Excessive Redd Superimposition, Limited Gravel Availability	2010 Interim Flow Evaluation (J)
12, Fish passage	Impaired Fish Passage	2010 Interim Flow Evaluation (H)
12, Modify Hills Ferry Barrier *	Reduced Genetic Viability, Excessive Redd Superimposition	2010 Interim Flow Evaluation (F)
12, Construct settling basins	Excessive Sedimentation	2011 Interim Flow Evaluation
12, Restore floodplain habitat	Insufficient Floodplain and Riparian Habitat	2010 Interim Flow Evaluation (E)
12, Create off-channel rearing areas	Insufficient Floodplain and Riparian Habitat	2010 Interim Flow Evaluation (E)
12, Macroinvertebrate Assessment	Degraded Water Quality	2010 Interim Flow Evaluation (G)
12, Water Quality Assessment	Degraded Water Quality	2010 Interim Flow Evaluation (K,L)
12, Fisheries Management Peer Review	Adaptive Management Requirement	2010 Interim Flow Evaluation (I)
12, Spawning Gravel Assessment	Limited Gravel Availability	2010 Interim Flow Evaluation (J)

Table 6-1.
Pertinent Settlement Requirement, Corresponding Primary Limiting Factors, and Approximate Year of Evaluation or Assessment (contd.)

Settlement Requirement	Limiting Factor(s)	Evaluation/Monitoring
Phase II		
11(b)(1), Reach 4B conveyance to 4,500 cfs	Inadequate Streamflow	2010 Interim Flow Evaluation (E)
11(b)(2), Modifications to Chowchilla Bifurcation Structure	Entrainment	2010 Interim Flow Evaluation (E)
11(b)(3), Fill and/or isolating highest priority gravel pits	Excessive Straying, Unsuitable Water Temperature, Excessive Predation	2010 Interim Flow Evaluation (L)
11(b)(4), Modify Sand Slough Control Structure for up to 4,500 cfs	Impaired Fish Passage	2010 Interim Flow Evaluation (H)
Paragraph 14		
14(a), Reintroduction Application	Reduced Genetic Viability	2010 Interim Flow Evaluation (C)
14(a), Reintroduction Decision by NMFS	Environmental Compliance Requirement	2010 Interim Flow Evaluation (D)
14, Reintroduce Chinook Salmon	Reduced Genetic Viability	2010 Interim Flow Evaluation (A,B)

Notes:
The Work Plan reference (A through J) in 2010 Fisheries Implementation Plan (available at: www.restore sjr.net) is noted in the Evaluation/Monitoring column.
* This action is also addressed in the San Joaquin River Restoration Settlement Act.
Key:
cfs = cubic feet per second
NMFS = National Marine Fishery Service

6.2 Fisheries Schedule

Table 6-2 is a generalized schedule between 2009 and 2016. The following text describes the various components of the schedule and should be used to accompany Table 6-2.

Conceptual Models: Draft conceptual models of stressors and limiting factors for San Joaquin River Chinook salmon were completed in 2008 and the first public draft FMP was distributed in June 2009. The February 2010 FMP (this document) incorporates comments and feedback from the Implementing Agencies, Settling Parties, and the Fisheries Technical Feedback Group. The FMWG recommends a thorough independent peer review of the February 2010 FMP in late 2010. The FMP is a living document and it will be updated frequently as new information from monitoring, modeling, and implementation is acquired. Table 6-2 indicates the recommended review period and document revision time frames.

Quantitative Models: Ecosystem Diagnosis and Treatment was the first modeling approach selected for use in the SJRRP because it provides a framework that views Chinook salmon as the diagnostic species for the ecosystem. The EDT framework was designed so that analyses made at different scales (i.e., from tributary watersheds to successively larger watersheds) can be related and linked. The FMWG also recommends that an individual based model (IBM) be used initially in conjunction with the EDT, and then at a later time incorporated into the EDT. The EDT model would be used to provide a population-level analysis, whereas the IBM would be applied at the scale of specific reaches and/or life stages. Neither the EDT nor the IBM precludes or requires the use of the other model for the FMWG to assess the potential success of the SJRRP.

Independent Review: The FMWG recommends acquiring policy and technical experts to successfully integrate new knowledge into the management of the SJRRP. The results of such integration can affect the SJRRPs goals, objectives, models, actions, and monitoring. Such continual assimilation of new information requires internal and external processes, operating at multiple time scales. It is recommended that short-term assessments are completed every 2 years, and long-term assessments every 5 years.

Fisheries Monitoring: Program monitoring and evaluation is designed to measure the overall success of the SJRRP in meeting the objectives established in the FMP and is generally at the fisheries population level, consisting of the measurement of elements such as escapement levels, viability values, and genetic fitness. While most program monitoring will not begin until salmon are reintroduced, a significant amount of monitoring and evaluation during the Interim Flows period will provide valuable background information and be very useful in establishing long-term monitoring for evaluation of the SJRRP.

Restoration Implementation: The Phase I and Phase II projects have specific completion dates per the Settlement. Many of the monitoring and special projects recommended by the FMWG are related to the overall project schedule.

Table 6-2.
Primary Fisheries Program Tasks and the Implementation Sequence/Schedule Recommended by the FMWG

Task	2009				2010				2011				2012				2013				2014				2015				2016			
Develop FMP			■	■											U							U								U		
– Conceptual models	■	■			U																											
– First Draft FMP	■	■			U																											
– Independent Peer Review							■	■			U																					
Quantitative Modeling																																
– EDT	■	■	■	■																												
– IBM					■	■	■	■																								
Program Assessment																																
– Short-term											■	■							■	■							■	■				
– Long-term																											■	■	■	■		
Initial Recommendations																																
– WQ Assessment				■	U	■	■	■	■	■		■	■	■		■	■	■		■	■	■		■	■	■		■	■	■		
– Macroinvert Assess													■	■			■	■			■	■										
– Benthic Macroinverts				■	■	■	■	■	■	■	■	■	■	■	■																	
– Fish Community Assess						■	■	■	■	■	■	■	■	■	■	■	■															
– Passage Assessment				■	■	■	■	■	■	■	■	■	■	■	■																	
– Entrainment Assessment										■	■	■	■	■	■	■	■	■	■	■	■											
– Water Temperature Mon				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
– Streamflow Monitoring				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
– Public Outreach						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
– Macrohabitat Assess				■	■	■	■	■	■	■	■	■	■	■	■																	
– Predator Distribution						■	■	■	■	■	■	■	■	■	■	■	■															
– Assess Gravel Pit Temp				■	■	■	■	■	■	■	■	■	■	■	■																	
– Predater Rate Study									■	■	■	■	■	■	■	■	■	■	■	■												

Table 6-2.
Primary Fisheries Program Tasks and the Implementation Sequence/Schedule Recommended by the FMWG (contd.)

Task	2009				2010				2011				2012				2013				2014				2015				2016			
– Gravel Pit Prioritization															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨						
– Recreation Assessment									▨	▨	▨	▨																				
– Hills Ferry Barrier Evaluation				▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																	
– Spawning Gravel Assess				▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																	
– Sediment Management Plan											▨	▨	▨	▨	▨																	
Monitoring and Evaluation																																
– Population Objectives																	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
– Habitat Objectives																	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Phase I Actions									▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨												
Phase II Actions																					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

Notes:
Shaded Boxes Indicate Project Duration.
In Most Cases, Contracts Indicate a 3-Year Duration (a Programmatic Limitation); However, Actual Duration May Vary.
Key:
EDT = Ecosystem Diagnosis and Treatment
FMP = Fisheries Management Plant
FMWG = Fisheries Management Work Group
IBM =
U = Document update
WQ = water quality

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Chapter 7 Program Monitoring and Evaluation

Monitoring is a critical component in the adaptive management process and will be used to assess the performance of the SJRRP. In Chapter 5, actions were developed and routed and action-specific monitoring was identified for individual actions. These actions were developed to address specific limiting factors. Therefore, the monitoring of these actions will allow for evaluation of how well specific actions ameliorated the limiting factors identified. Action-specific monitoring will ultimately lead to refinement of existing actions or development of new actions.

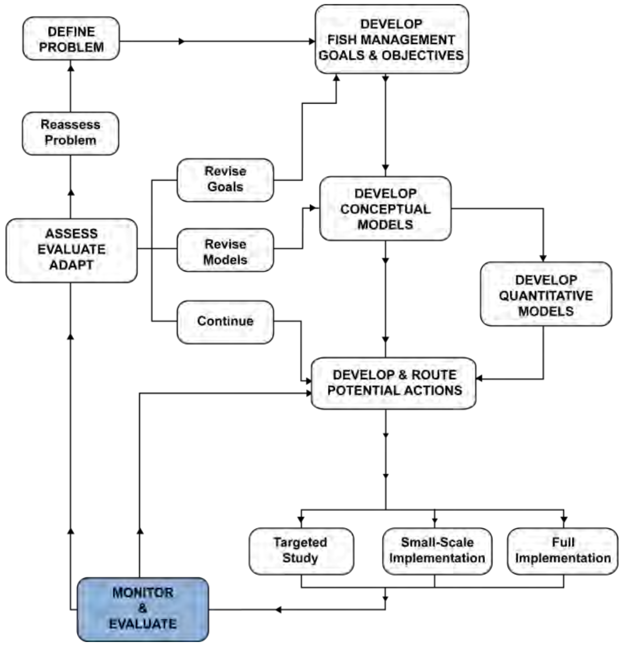

Figure 7-1. Fisheries Management Plan Adaptive Management Approach – Monitor and Evaluate

Program-level monitoring is designed to measure the overall success of the SJRRP in meeting the objectives established in Chapter 3. Program-level monitoring is generally at the fisheries population level, and consists of the measurement of elements such as escapement levels, viability values, and genetic fitness. The use of program-level monitoring is denoted by the rectangle titled “Monitor and Evaluate” in Figure 7-1. It can be very difficult to assess many of the metrics described below, making an evaluation of program success difficult. For example, because salmon will be migrating in and out of the Restoration Area, it is difficult to assess metrics like ‘juvenile survival’ because of imprecise monitoring methods. In Chapter 3, population and habitat objectives were identified for the SJRRP. In this chapter, each of the population objectives is listed and potential monitoring methods are provided under each objective.

The recommended monitoring and evaluations described in this chapter are general in nature for several reasons. First, the specifics of monitoring programs are typically agency dependant due to differing requirements and laws. Second, monitoring techniques and technology is a quickly evolving science and describing specific monitoring elements at this time would not be appropriate. Detailed descriptions of monitoring and evaluations will be included in agency work plans and Implementation Plans as they are developed.

7.1 Population Objectives Monitoring

The following describes the population-level objectives and the monitoring and evaluation methodology recommendations.

Population Objective 1: A 3-year target of a minimum of 2,500 naturally produced adult spring-run Chinook salmon and 2,500 naturally produced adult fall-run Chinook salmon.

- **Recommended monitoring and evaluation** – Escapement is defined as the number of adult salmon that return from the ocean and are available to spawn. A long-term monitoring program will be developed to estimate the annual escapement of Chinook salmon measured at the spawning grounds of Reach 1 of the Restoration Area.

  To adequately assess progress toward meeting population recovery objectives, any monitoring program used will need to be evaluated for statistical power and bias. Standard techniques have been established (e.g., mark-recapture carcass surveys, split-beam hydroacoustics, visual surveys, fish counting stations), but should be validated using more than one monitoring method. Special consideration will also be given to the location of monitoring stations and collection methods for real-time data collection. Annual reviews of monitoring data will allow timely revisions of the adaptive management program.

Population Objective 2: Each year, a minimum of 500 naturally produced adult spring- and fall-run Chinook salmon each should be in adequate health to spawn successfully. Thus, the minimum annual effective population target would be 500 Chinook salmon of each run. The expectation is there will be a 50-percent sex ratio. Additional objectives related to genetics will be further described in the Hatchery and Genetics Management Plan currently under development.

- **Recommended monitoring and evaluation** – The Hatchery and Genetics Management Plan will address methodologies used to distinguish hatchery-derived fish from naturally produced fish. A long-term monitoring program will be developed to estimate the number of fish reproducing in the San Joaquin River (e.g., redd counts), the hatchery/instream contributions (via deoxyribonucleic acid (DNA) contributions), and the sex ratio of reproducing fish. In addition, to characterize the inbreeding, heterozygosity and genetic variance of the population the effective population size of salmon on the San Joaquin River will be evaluated as part of genetic studies.

Population Objective 3: Ten years following reintroduction, less than 15 percent of the Chinook salmon population should be of hatchery origin. Additional objectives related to genetics will be further described in the Hatchery and Genetics Management Plan currently under development.

- **Recommended monitoring and evaluation –** The Genetics Management Plan (and Hatchery Management Plan as a subset of that document) will address monitoring and evaluation protocols related to this objective.

Population Objective 4: A Growth Population Target of 30,000 naturally produced adult spring-run Chinook salmon and 10,000 naturally produced fall-run Chinook salmon.

- **Recommended monitoring and evaluation –** Same methods as described under Population Objective 1 would be used for Population Objective 4.

Population Objective 5: Adult Chinook salmon should be regularly tested for common diseases and health afflictions. Pre-spawn mortality related to any disease should not exceed 15 percent.

- **Recommended monitoring and evaluation –** Adult Chinook salmon should be regularly evaluated for general health, occurrence of parasites, virulent diseases, and systemic bacterial infection. The purpose of the fish disease monitoring program will be to obtain information about the relative health of populations and the suitability of habitat conditions. A well-designed monitoring program should provide a diagnosis (i.e., what disease), be able to provide information on whether the condition is attributable to hatchery influence or the presence of fish pathogens, should be related to mortality rates, and be temporally stratified. The specifics of this monitoring program will be informed by the Genetics Management Plan currently under development.

Population Objective 6: Mean egg production per spring-run female Chinook salmon should be 4,200, and egg survival should be greater than or equal to 50 percent.

- **Recommended monitoring and evaluation –** Egg production, defined here as the mean number of viable eggs produced per female salmon, and egg survival defined as the mean viability of eggs produced per salmon redd will be important to estimating overall salmon survival rates. The egg monitoring program will address the objective above, and also relate egg survival with associated habitat conditions (e.g., velocity, substrate, intragravel temperature, vertical hydraulic gradients) to address action-specific goals. Egg production and survival may be estimated using a variety of direct or indirect methods including use of histological criteria for classification of gonads, redd pump sampling, use of incubation baskets, redd excavation, or artificial redd construction and placement. Likely, several techniques will be used and serve as a comparison for techniques since each comes with specific biases. Further, the establishment of a length-fecundity relationship and fecundity-at-age estimates will be useful to estimate potential egg production and deposition in non-sampling years. The initial recommendation would be the establishment of a long-term monitoring program that samples every 3 to 5 years.

Population Objective 7: A minimum annual production target of 44,000 spring-run Chinook salmon juveniles and 63,000 fall-run Chinook salmon juveniles and maximum annual production target of 1,575,000 spring-run Chinook salmon juveniles and 750,000 fall-run juveniles migrating from the Restoration Area. Juvenile production includes fry, parr, subyearling smolts, and age 1+ yearling smolts. Estimated survival rate from fry emergence until they migrate from the Restoration Area should be greater than or equal to 5 percent. Ten percent of juvenile production for spring-run Chinook salmon should consist of age 1+ yearling smolts.

- **Recommended monitoring and evaluation –** A long-term monitoring program will be developed to estimate the outmigration of juvenile Chinook salmon in the Restoration Area. To adequately assess progress toward meeting population recovery objectives, any monitoring program used will need to be evaluated for statistical power and bias. Standard techniques have been established to monitor juvenile salmonids (e.g., motorized or nonmotorized rotary screw traps, seining, hydroacoustics, fish counting stations), but should be validated using more than one monitoring method or by determining the effectiveness of the gear chosen using field experiments. This monitoring will likely emphasize primary migration corridors in the Restoration Area and include some monitoring in the bypasses and other channels for stranding (e.g., Chowchilla Bypass). Combining information obtained from Population Objective 5 and Population Objective 6 will allow survival of fry through the outmigration period to be determined. Population modeling should also be useful for predicting survival rates. Special consideration will also be given to the location of monitoring stations and collection methods for real-time data collection. Annual reviews of monitoring data will allow timely revisions of the adaptive management program.

Population Objective 8: Juvenile Chinook salmon should be regularly tested for common general health and diseases. The incidence of highly virulent diseases should not exceed 10 percent in juvenile Chinook salmon.

- **Recommended monitoring and evaluation –** Juvenile salmon should be regularly evaluated for general health, physiological condition related to smolt development, stress, plasma osmolarity, virulent diseases, and systemic bacterial infection. The purpose of the fish health monitoring program will be to obtain information about the relative health of populations and the suitability of habitat conditions. This monitoring program will employ tactics described for Population Objective 4, but will target the juvenile life-history phase.

Population Objective 9: A minimum growth rate of 0.4 g/d during spring and 0.07 g/d during summer should occur in juvenile Chinook salmon in the Restoration Area.

- **Recommended monitoring and evaluation –** A monitoring program will be established to estimate the growth rates of juvenile Chinook salmon in the Restoration Area. Different approaches have been established to estimate the growth rates of fishes. Once validated, indices indicating short-term growth (e.g., DNA-ribonucleic acid (RNA) ratios) are often useful. An alternative recommendation is to use recent advance in biotelemetry (a remote measure of physiological or energetic data) to allow the development of bioenergetics models and the identification of stressors (e.g., predict the likelihood of outmigration success related to river flow and temperature conditions). These models may be used in conjunction to evaluate specific actions (e.g., how channel reconfiguration affect Chinook salmon behavior). Estimating growth through time may also be accomplished using PIT (i.e., passive integrated transponder) or acoustic tagging technologies. Regardless of method, studies addressing growth rates of juveniles should establish growth standards for different temporal periods and the technique used should be validated.

Population Objective 10: Document the presence of the following assemblage structures in the Restoration Area: rainbow trout assemblage (Reach 1), pikeminnow-hardhead-sucker assemblage (Reaches 2 through 5), and deep-bodied fish assemblage (Reaches 2 through 5).

- **Recommended monitoring and evaluation –** Metrics are commonly used to evaluate fish community structure. For example, the health of a fish community can be evaluated by documenting the spatial and annual variation of fish populations in the Restoration Area based on such criteria as the proportion of native and nonnative fish, the diversity of types of fish, or with indices of biotic integrity. A monitoring program will be established to document the presence of particular assemblages and the diversity and guild structure in established reaches of the Restoration Area. Presence-absence is a very useful measure for large-scale studies, but not as useful for detecting more subtle differences in more homogenous areas. This objective focuses on the presence of species within assemblages, but as more information is obtained, more quantitative objectives will likely be established (e.g., species diversity and richness).

7.2 Habitat Objectives Monitoring

The following describes the habitat objectives and the monitoring and evaluation method recommendations.

Habitat Objective 1: A minimum of 30,000 m^2 of high-quality spring-run Chinook salmon holding pool habitat.

- **Recommended monitoring and evaluation –** The distribution of pools with respect to spawning habitat and their potential use as holding habitat by spring-run Chinook salmon will be evaluated. In addition, holding pool habitat characteristics such as pool depth, structure, and associated riparian cover as well as water quality measurements will be evaluated in the monitoring program.

Habitat Objective 2: A minimum of 78,000 m^2 of quality spawning gravel in the first 5 miles of Reach 1 should be present for spring-run Chinook salmon.

- **Recommended monitoring and evaluation –** A course sediment management evaluation will be conducted, including an evaluation of existing Chinook salmon spawning habitat quality and quantity, potential gravel sources, and potential reintroduction sites and methods.

Habitat Objective 3: A minimum of 88,000 m^2 of floodplain rearing habitat for spring-run subyearling parr/smolts and 126,000 m^2 of floodplain rearing habitat for fall-run subyearling parr/smolts.

- **Recommended monitoring and evaluation –** A long-term monitoring program will be developed in conjunction with Population Objective 8 to estimate growth rates (see recommended monitoring under Population Objective 8) of juveniles and densities of juveniles using floodplain habitat. This information alone will not allow us to address the issue of how much floodplain habitat is enough to support juvenile rearing, but it will provide adequate information to allow modeling to assist in answering this question. Modeling approaches can be used to estimate a carrying capacity on floodplain habitat. Additionally, information on growth rates should be compared between juveniles using river habitat and juveniles using floodplain habitat for rearing to assess the fitness benefits of using one habitat versus another.

Habitat Objective 4: Provide passage conditions that allow 90 percent of migrating adult and 70 percent of migrating juvenile Chinook salmon to successfully pass to suitable upstream and downstream habitat respectively, during all base flow schedule component periods and water year types of the Settlement, except the Critical-Low water year type.

- **Recommended monitoring and evaluation –** Passage may be impeded for migrating adult and juvenile salmon if design, operation and maintenance at some facilities and locations do not afford passage under a range of flows. In addition, passage can be impaired by lack of water, poor water quality, poor habitat, natural occurrences, waterfalls, boulder cascades, and other structures. Impacts of fish barriers may include impaired passage and injury to fish, resulting in reduced numbers of fish reaching suitable spawning areas and low survival for juvenile life stages. All potential passage sites will be evaluated for potential barriers using common passage criteria (i.e., depth, velocity, and discharge) under a variety of flow conditions. The dimensions of the physical features of the structures that affect fish passage will also be measured and thoroughly described. Potential impediments to fish passage will be evaluated and, if necessary, hydraulic modeling will be conducted to assess fish passage under a variety of flow conditions.

Habitat Objective 5: To provide appropriate flow timing, frequency, duration and magnitude, enabling the viability of 90 percent of all life-history components of spring-run Chinook salmon.

- **Recommended monitoring and evaluation –** An analysis of streamflow and fish distribution and survival is recommended. Flow and stage measurement will occur in real-time, according to procedures based on the U.S. Geological Survey publication *Stream-Gaging Program of the U.S. Geological Survey – U.S.*

Geological Survey Circular 1123 (Wahl et al. 1995) and will be available publicly to support the restoration program. Flow will be measured at a minimum of six sites; Friant Dam, Gravelly Ford, below Chowchilla Bifurcation Structure, below Sack Dam, top of Reach 4B, and the Merced River confluence. Population Monitoring Objectives 1, 2, and 6 described above will provide spring-run Chinook salmon viability.

Habitat Objective 6: Water temperatures for spring-run Chinook salmon adult migrants should be less than 68°F (20°C) in Reaches 3, 4, and 5 during March and April and less than 64°F (18°C) in Reaches 1 and 2 during May and June (Exhibit A).

- **Recommended monitoring and evaluation –** Water temperature will be monitored real-time at two locations in Reach 1, two locations in Reach 2, one location in Reach 3, two locations in Reach 4, and two locations in Reach 5.

Habitat Objective 7: Water temperatures for spring-run Chinook salmon holding adults should be less than 59°F (15°C) in holding areas between April and September (Exhibit A).

- **Recommended monitoring and evaluation –** Water temperature will be monitored real-time at two locations in Reach 1, two locations in Reach 2, one location in Reach 3, two locations in Reach 4, and two locations in Reach 5.

Habitat Objective 8: Water temperatures for spring-run Chinook salmon spawners should be less than 57°F (14°C) in spawning areas during August, September, and October (Exhibit A).

- **Recommended monitoring and evaluation –** Water temperature will be monitored real-time at two locations in Reach 1, two locations in Reach 2, one location in Reach 3, two locations in Reach 4, and two locations in Reach 5.

Habitat Objective 9: Water temperatures for spring-run Chinook salmon incubation and emergence should be less than 55°F (13°C) in spawning areas between August and September (Exhibit A).

- **Recommended monitoring and evaluation –** Water temperature within the hyperemic zone have been found to be significantly higher than in the water column in other rivers of the Central Valley (pers. comm. Joe Merz, S.P. Cramer Fish Sciences). Hyperemic zone water temperatures should be occasionally evaluated and correlated if possible to water column temperatures in the spawning areas. In addition, as part of the water quality monitoring program, water temperature will be monitored real-time at two locations in Reach 1, two locations in Reach 2, one location in Reach 3, two locations in Reach 4, and two locations in Reach 5.

Habitat Objective 10: Water temperatures for spring-run Chinook salmon juveniles should be less than 64°F (18°C) in the Restoration Area when juveniles are present (Exhibit A).

- **Recommended monitoring and evaluation –** Water temperature will be monitored real-time at two locations in Reach 1, two locations in Reach 2, one location in Reach 3, two locations in Reach 4, and two locations in Reach 5.

Habitat Objective 11: Selenium levels should not exceed 0.020 mg/L or a 4-day average of 0.005 mg/L in the Restoration Area (Exhibit B).

- **Recommended monitoring and evaluation –** Selenium levels will periodically be monitored in five locations as part of a short list of water quality parameters using laboratory analysis.

Habitat Objective 12: DO concentration should not be less than 5.0 mg/L when Chinook salmon are present (Exhibit B).

- **Recommended monitoring and evaluation –** DO will be monitored real-time at the same locations as water temperature: two locations in Reach 1, two locations in Reach 2, one location in Reach 3, two locations in Reach 4, and two locations in Reach 5. Additional sampling sites for DO may be added, as needed.

Habitat Objective 13: Total ammonia nitrogen should not exceed 30-day average of 2.43 mg N/L when juvenile Chinook salmon are present or exceed a 1-hour average of 5.62 mg N/L when Chinook salmon are present (Exhibit B).

- **Recommended monitoring and evaluation –** Total ammonia nitrogen will be monitored weekly to every other week in two locations in cooperation with the Grassland Bypass Project. Additional sampling sites for ammonia nitrogen may be added, as needed.

Habitat Objective 14: Ecological integrity of the Restoration Area should be restored as a result of improved streamflow, water quality conditions and status of aquatic communities. Over 50 percent of the total target river length should be estimated to be in “good condition” B-IBI = 61-80) or “very good condition” (B-IBI=81-100). In addition, none of the study sites should be in “very poor condition” (B-IBI=0-20).

- **Recommended monitoring and evaluation –** Ecological integrity of in-stream habitat in the Restoration Area will be evaluated with a benthic macroinvertebrate assessment, using an approach described by the California’s Surface Water Ambient Monitoring Program (SWAMP). This study will provide information about species richness and community composition (Ephemeroptera, Plecoptera, and Trichoptera taxa), response to perturbation and tolerance/intolerance to environmental conditions in the Restoration Area. In addition, the study will help establish baseline measures to evaluate the impact of restoration actions on ancillary water quality parameters and other physical habitat characteristics.

7.3 Real-Time Monitoring

Paragraph 18 of the Settlement describes the roles and responsibilities of the RA and the Technical Advisory Committee (TAC) with respect to Exhibit B of the Settlement. The RA "*shall make recommendations to the Secretary concerning the manner in which the hydrographs shall be implemented and when the Buffer Flows are needed to help in meeting the Restoration Goal.*" The RA is to consult the TAC in making such recommendations and the Secretary "*shall consider and implement these recommendations to the extent consistent with applicable law, operational criteria (including flood control, safety of dams, and operations and maintenance), and the terms of this Settlement.*"

The TAC is to make recommendations to the RA for the RA's recommendation to the Secretary, and is equipped to make decisions regarding flow releases. The Implementing Agencies responsible for monitoring are a part of the TAC as either non-voting members (DFG and DWR) or Liaisons (Reclamation, NMFS, and USFWS). To facilitate real-time flow decisions, the Implementing Agencies will be available to the TAC to compile and assesses current information regarding water operations, Chinook salmon, and other fish conditions, such as stages of reproductive development, geographic distribution, relative abundance, and physical habitat conditions.

It is expected that the monitoring framework includes program-level monitoring for population objectives and monitoring for physical habitat parameters will enable the collection of information required for real-time decision making, as well as to collect information to evaluate the success of the SJRRP and its objectives.

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Chapter 8 SJRRP Assessment, Evaluation, and Adaptation

A key value of the Adaptive Management Approach is the revision of management actions as new information becomes available. The assessment, evaluation, and adaptation process described below is used to revise management actions as new knowledge is acquired and scientific understanding improves. New knowledge must appropriately affect the governance and management of the SJRRP, enabling change in management actions and implementation. For example, new water temperature information from either modeling or quantitative studies could change the emphasis on the spatial extent of floodplain construction for juvenile Chinook salmon. This new information could change the physical habitat goals for Chinook salmon and other fishes. Changes in the goals can lead to revised objectives and a new suite of actions designed to achieve those objectives. The assessment, evaluation, and adaptation component of the Adaptive Management Approach is highlighted in Figure 8-1.

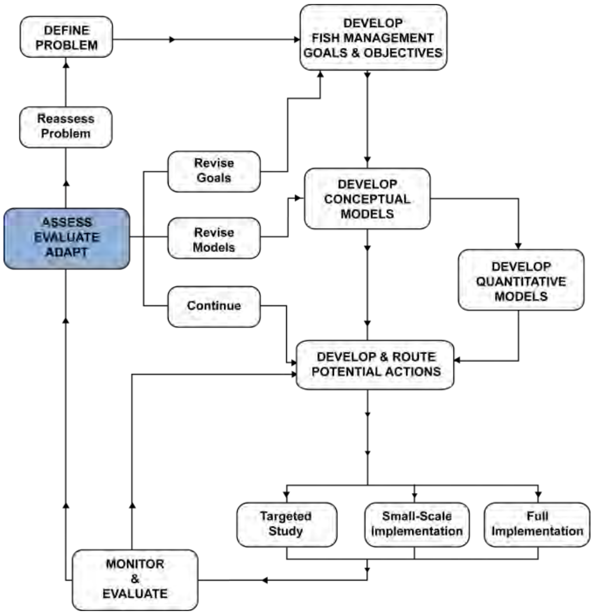

Figure 8-1.
Fisheries Management Plan Adaptive Management Approach – Assess, Evaluate and Adapt

Both policy and technical expertise are needed to achieve successful integration of new knowledge into the management of the SJRRP. The results of such integration can affect the SJRRPs goals, objectives, models, actions, and monitoring. Such continual assimilation of new information requires internal and external processes, operating at multiple time scales. Following is a description of the process that will be used to assess, evaluate, and adapt the SJRRP to new information.

8.1 Short-Term and Long-Term Evaluation

A core SJRRP team designated by management with representation of all the SJRRP Work Groups will assist the science advisory group (SAG) in a semiannual, short-term evaluation of implementation activities. These short-term evaluations will begin as soon as possible and will ensure the incorporation of new knowledge into the SJRRP. This will lead to change occurring gradually over time or on relatively short time-steps. For example, new information will be collected during the Interim Flows period and will result in a substantial amount of learning. This new information will be assimilated into the fisheries management planning process as it becomes available, which could impact many aspects of the SJRRP.

Some aspects of the SJRRP will require long-term assessments, such as an evaluation of the progress toward meeting the Restoration Goal in terms of Chinook salmon escapement or the restoration of habitat. An external adaptive management review panel will review the progress toward achieving the goals of the SJRRP and in incorporating new and accumulating knowledge on a long-term basis. This long-term evaluation will begin biennially in 2010 and more intensive efforts will occur every 5 and 10 years starting in 2010. The core SJRRP team and SAG will assist in the preparation and presentation of information to the review panel.

Short- and long-term assessments will also be useful in fulfilling the evaluation requirements of Paragraph 20(d)1. Many of the requirements of Paragraph 20(d)1 will require substantial interpretation and review to inform all parties of progress toward meeting the Restoration Goal.

8.1.1 Review and Coordination

Review and coordination are important components of the Adaptive Management Approach that will be used to rehabilitate the San Joaquin River and to manage its fishes and other aquatic ecosystem resources. External review will benefit the SJRRP by providing mechanisms for obtaining: (1) peer review of draft reports, (2) technical oversight of Restoration Area and reach-specific actions, (3) independent scientific advice, recommendations and evaluations of models, monitoring plans, experimental designs and other elements of SJRRP planning, implementing, and reporting, and (4) independent assessment of the progress toward meeting the Restoration Goal. Coordination with other programs that might affect or be affected by the SJRRP will help eliminate unnecessary duplication of effort, reduce potential conflicts, and promote cooperation and information exchange. This section describes the main features of the external review processes that will be used to inform planning, implementing, and reporting, and the measures that will be taken to ensure adequate coordination with other SJRRP activities, which are critical components in adaptive management.

External Review Processes

External review serves two overarching goals: (1) improve the quality of the science and engineering that informs SJRRP planning, implementation, and reporting, and (2) to provide stakeholders and the public with some assurances that the main elements of the SJRRP have undergone independent scrutiny by qualified experts. Over the life of the SJRRP, there will be a need for at least four types of review processes that will differ in their scope, goals, and duration and in the number and qualifications of the independent reviewers they will require. The four types of review processes include: (1) peer review of written materials for public dissemination, (2) technical review of discrete program elements, (3) scientific review by a permanent SAG, and (4) periodic evaluation of SJRRP progress by an independently constituted scientific review panel.

Peer Review Process. Peer review of draft reports and other written materials for public dissemination will be the most narrowly focused and frequently used of the review processes and will involve the fewest number of reviewers at any given time. This process will bring fresh perspectives to the questions under consideration in any given report and the benefit of knowledge gained through experiences in other river systems. This process will help distinguish generally accepted facts from locally derived professional judgment, improve the quality of the analyses, and suggest alternative ways to approach a problem or additional analyses to perform. Peer review comments often provide citations for other written materials, data sources, or Web sites not included in the document under review. When divergent opinions are offered, peer review should provide another way to document uncertainty, or to more precisely define the uncertainties with the greatest potential to impede progress or lead to serious mistakes. Where appropriate, reviewers will be asked to provide advice on the reasonableness of judgments made from the scientific evidence. This process should also provide an avenue for innovative ideas to enter into the planning process.

Peer review panels will generally consist of one to three individuals with the appropriate expertise and are independent of the SJRRP. The composition of the panel will depend on the document under review, but could include agency personnel, consultants, and academics. Any manuscripts written about the SJRRP, or components therein, submitted for publication in journals would be subject to the journal's peer review process.

Technical Review Committee Process. Technical review committees will be assembled on an as-needed basis to provide project-level advice, recommendations, or independent reviews of discrete program elements requiring specialized knowledge and experience. For example, Central Valley Project Improvement Act's (CVPIA) Anadromous Fish Screen Program (AFSP) will be an important technical review resource as they will review plan formulation, engineering designs, and other planning documents related to fish screen projects. Other examples include review of the preparation of genetic and hatchery management plans, design and construction of fish passage structures, and large channel-floodplain alteration projects. Technical review committee members will have practical experience.

Precisely how and by whom these groups will be constituted and disbanded will be described in detail in future planning efforts. In general, however, these committees will be temporary, lasting just long enough to see a discrete undertaking through all phases of its design and implementation. Deliverables will be in the form of verbal advice during meetings, revisions to drawings, plans and specifications, written comments, or formal reviews of documents.

Science Advisory Group Process. The SAG will be formed to provide SJRRP-level scientific advice, recommendations, and a technical review of annual work plans. It should consist of about six members selected primarily for their scientific and technical knowledge and their experience with restoration projects in other river systems. Although members will likely change over time, the SAG itself will be a permanent body. The SAG will have a chairperson who is responsible for synthesizing all the comments and recommendations from the SAG members.

The SAG's principal responsibilities will be to (1) assess and make recommendations on the study designs used to evaluate project performance, (2) review and comment on the performance of the models used to inform the planning process, and (3) assess and comment on the design and performance of the monitoring network. The SAG will (1) attend the annual technical workshop (see below), (2) provide a written scientific review of the SJRRP's annual Work Plan, and (3) meet annually with a core team designated by management. The core team will include representatives from all the SJRRP Work Groups. This core team will be responsible for organizing the workshop and preparing a detailed response to the comments and recommendations of the SAG.

SJRRP Review Panel Process. The SJRRP may establish an independent review panel convened by a body, such as the National Academy of Sciences, to review the SJRRP's progress in achieving the goals and objectives of the FMP. The panel would have members representing multiple disciplines related to Chinook salmon restoration in the San Joaquin River (e.g., fish biology, hydrology, hydraulics, fluvial geomorphology, aquatic, wetland and terrestrial ecology, monitoring, statistics, and data management). The panel could include individuals working in academia, government, consulting firms, public interest organizations, and private enterprise. A special effort would be made to ensure most of the panel members will be individuals who have practical experience designing and implementing complex aquatic ecosystem restoration efforts. The panel should include some members familiar with the San Joaquin River and some with no previous knowledge of the system. To prevent any potential for conflict of interest, panel members would not be eligible to receive SJRRP funds for any research, monitoring, or implementation actions in the San Joaquin River.

The panel's sole purpose would be to review and assess progress toward achieving the Restoration Goals of the SJRRP. The panel would have full independence to evaluate and report on issues as it sees fit within the general charge of progress assessment. Panel members will not be asked to perform any other tasks besides assessing the progress of the SJRRP. The panel would produce a written triennial report to Congress, the Secretary, and the Governor that includes an assessment of ecological indicators and other measures of progress toward restoring self-sustaining Chinook salmon populations in the San Joaquin River.

The panel may meet about four times annually to receive briefings on the current status of the SJRRP, discuss scientific and engineering issues arising from implementation of the FMP, and to review draft protocols and reports addressing the assessment of the FMP's progress in meeting the goals. Two or three meetings would be open to the agencies and the public, whereas one or two meetings would be closed for purposes of working on the triennial report. The panel would provide: (1) an assessment of progress in restoring spring-run Chinook salmon to the San Joaquin River and in meeting the other goals of the SJRRP, (2) discussion of significant accomplishments of the SJRRP, (3) discussion and evaluation of specific scientific and engineering issues that may impede progress, and (4) independent review of monitoring and assessment protocols to be used for evaluation of SJRRP progress (e.g., performance measures, annual assessment reports, assessment strategies).

Coordination

The SJRRP is committed to coordinating its efforts with ecosystem restoration, monitoring, and special studies programs operating within and downstream from the Restoration Area and with local and regional initiatives to alter land and water use within the Restoration Area. The SJRRP team consists of multiple Work Groups that are made up of agency personnel and their consultants, and coordination with other programs enables communication with their counterparts in other programs. Consequently, an important responsibility of each Implementing Agency's Work Group representative will be to remain informed about what initiatives the agency is pursuing in other programs Examples of downstream programs likely to affect or be affected by the SJRRP include State programs for anadromous fish restoration in the San Joaquin River tributaries, the Anadromous Fish Restoration Program, the CALFED Ecosystem Restoration Program, the Bay-Delta Conservation Program, and the Delta Vision Initiative. There will also be opportunities to coordinate with other monitoring and special studies programs, especially the Interagency Ecological Program, the AFSP, the CALFED Science Program, and the Vernalis Adaptive Management Program.

Participation in scientific workshops and conferences will also be valuable to ensure coordination with other programs. Each year, the SJRRP will conduct an all-day workshop consisting primarily of presentations by Work Group members and their cooperators. The presentations will encompass all aspects of program implementation, including modeling, monitoring, project planning, construction, and evaluation. Each presentation will summarize the accomplishments to date, problems encountered, and a proposed plan for the coming year. Work Group members will also be encouraged to attend the annual workshop of the Interagency Ecological Program and the biennial conference of the CALFED Science Program. In both cases, it may be possible to organize a session devoted primarily to the SJRRP.

The incorporation of public involvement in the adaptive management process of large-scale restoration projects is critical to achieving success. The SJRRP is committed to coordinating its efforts with interested stakeholders and the public. This coordination will be performed primarily by the FMWG through a continuation of the Technical Feedback Meeting format used in the development of this FMP. In addition, and to the greatest extent possible, all external review and coordination meetings described above will be conducted in a public forum. Documents and deliverables prepared as part of these external review and coordination meetings will also be made available to the public on the SJRRP's Web site, www.restoresjr.net.

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Chapter 9 References

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Exhibits

Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program

November 2010

Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program

Exhibits

Exhibit A	Conceptual Models of Stressors and Limiting Factors for San Joaquin River Chinook Salmon
Exhibit B	Water Quality Criteria
Exhibit C	Spawning Habitat Characterization
Exhibit D	Stock Selection Strategy: Spring-run Chinook Salmon
Exhibit E	Ecological Goals of the Restoration Flows
Exhibit F	EDT Proof of Concept

Exhibit A

Conceptual Models of Stressors and Limiting Factors for San Joaquin River Chinook Salmon

Fisheries Management Plan:
A Framework for Adaptive Management in the San Joaquin River Restoration Program

SAN JOAQUIN RIVER
RESTORATION PROGRAM

November 2010

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Definitions

Alevin	The life stage of a salmonid between hatching from the egg and emergence from stream gravels as a fry. Alevins are characterized by the presence of a yolk sac, which provides nutrition while the alevin develops in the redd.
Apparent Velocity	The horizontal vector of interstitial flow that is a function of permeability and hydraulic gradient.
Conceptual Model	Conceptual models are verbal or graphic depictions of how scientists believe that ecological, hydrological, and managerial systems in the San Joaquin River Basin will function and respond to SJRRP actions. They will be used to help identify actions that should have a high likelihood of achieving SJRRP objectives and help identify key knowledge gaps and hypotheses that will be addressed by an adaptive management process. The conceptual models will also be used to help develop quantitative models that will facilitate the development of testable hypotheses.
D_{50}	The median diameter of gravel at a site (e.g., spawning bed).
Diel	A daily cycle, usually encompassing 1 day and 1 night.
Escapement	The number of adults that successfully —escape” the ocean fishery and return to freshwater habitats to spawn.
Fry	Fry are young salmonids that have absorbed their yolk sac and emerged from the redd. They typically use low velocity, shallow habitats near the river banks. In the Central Valley, fry are frequently defined as juveniles smaller than 50 millimeters in fork length.
Grilse	A precocious salmon or anadromous trout that has matured at a much smaller size and usually younger age (2-year-old) than that of the fully grown adult fish (3-year-old and older).
Limiting Factors	Stressors that significantly influence the abundance and productivity of Chinook salmon populations.

Parr	The life stage for salmon that is distinguished by its dark parr marks, and when the salmon is large enough to use mid-channel habitats. In the Central Valley, parr are defined as juveniles between 50 and 70 millimeters in fork length.
Permeability	The ease with which water passes through gravel, depending on the composition and degree of packing of the gravel and viscosity of the water.
Restoration Area	The San Joaquin River between Friant Dam and the Merced River confluence.
Redd	A nest prepared by a female salmon in the stream bed gravel where she deposits her eggs.
Restoration Flow Schedule	The schedule of flow releases from Friant Dam as prescribed in the Settlement.
Smolt	A young salmonid that is undergoing physiological and morphological changes for life in seawater. Subyearling smolts are generally between 70 and 120 millimeters in fork length, whereas yearling smolts are usually larger than 180 millimeters in fork length.
Stressors	Physical, chemical, or biological perturbations to a system that adversely affect ecosystem processes, habitats, and species. Examples include altered flows, blocked passage, blocked sediment recruitment, instream habitat alteration, invasive species, contaminants, and excessive salmon harvest.

Abbreviations and Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	microgram per liter
AChE	acetylcholinesterase
BKD	bacterial kidney disease
CalEPA	California Environmental Protection Agency
CALFED	CALFED Bay-Delta Program
Central Valley Water Board	Central Valley Regional Water Quality Control Board
cfs	cubic feet per second
cm	centimeter
cm/hr	centimeter per hour
CVI	Central Valley Index
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CWT	coded-wire-tag
D_{50}	median particle diameter for gravel
DDT	dichloro-diphenyl-trichloroethane
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
DO	dissolved oxygen
DPR	California Department of Pesticide Regulation
DWR	Department of Water Resources
ENSO	El Niño Southern Oscillation
EPA	U.S. Environmental Protection Agency
ESU	Evolutionarily Significant Unit
FL	fork length
FMP	Fisheries Management Plan
FMWG	Fisheries Management Work Group
ft/hr	foot per hour
ft/s	foot per second
H_2S	hydrogen sulfide
IWM	instream woody material
MEI	Multivariate El Niño Southern Oscillation Index

mg/L	milligram per liter
MID	Modesto Irrigation District
mm	millimeter
NAWQA	National Water Quality Assessment Program
NH_3	ammonia
NMFS	National Marine Fisheries Service
NO_2	nitrogen dioxide
NO_3	nitrate
NPDES	National Pollutant Discharge Elimination System
OP	organophosphorus
PDO	Pacific Decadal Oscillation
PEIS/R	Program Environmental Impact Statement/Report
PKD	proliferative kidney disease
ppt	parts per thousand
RBDD	Red Bluff Diversion Dam
RM	river mile
Settlement	Stipulation of Settlement
SJRRP	San Joaquin River Restoration Program
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TID	Turlock Irrigation District
TKN	total Kjeldahl nitrogen
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VAMP	Vernalis Adaptive Management Plan

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Chapter 1 Introduction

The Fisheries Management Work Group (FMWG) prepared this document for the San Joaquin River Restoration Program (SJRRP) to describe the life history requirements and the environmental factors that will most likely affect the abundance of San Joaquin River spring- and fall-run Chinook salmon (*Oncorhynchus tshawytscha*) in the Restoration Area (San Joaquin River between Friant Dam and the Merced River confluence) (Figures 1-1 and 1-2), and downstream from the Restoration Area, including the lower San Joaquin River, Sacramento-San Joaquin Delta (Delta), San Francisco Estuary, and Pacific Ocean. Included are Chinook salmon conceptual models and supporting information intended to serve as key components of the Fisheries Management Plan (FMP) for the SJRRP. The models assume that all restoration actions prescribed in the Settlement will be implemented.

The conceptual models will be used to assist in guiding flow management, and identifying key habitat restoration needs. The models will also help identify key knowledge gaps to be addressed through a rigorous and comprehensive monitoring and adaptive management program. As part of the adaptive management process, monitoring data will be used to continually refine the conceptual models and management and restoration priorities. The conceptual models also assist in developing quantitative population models to refine the hypotheses to be tested under the Adaptive Management Approach defined in the FMP. As new information becomes available and restoration actions begin, the conceptual models will be revised accordingly.

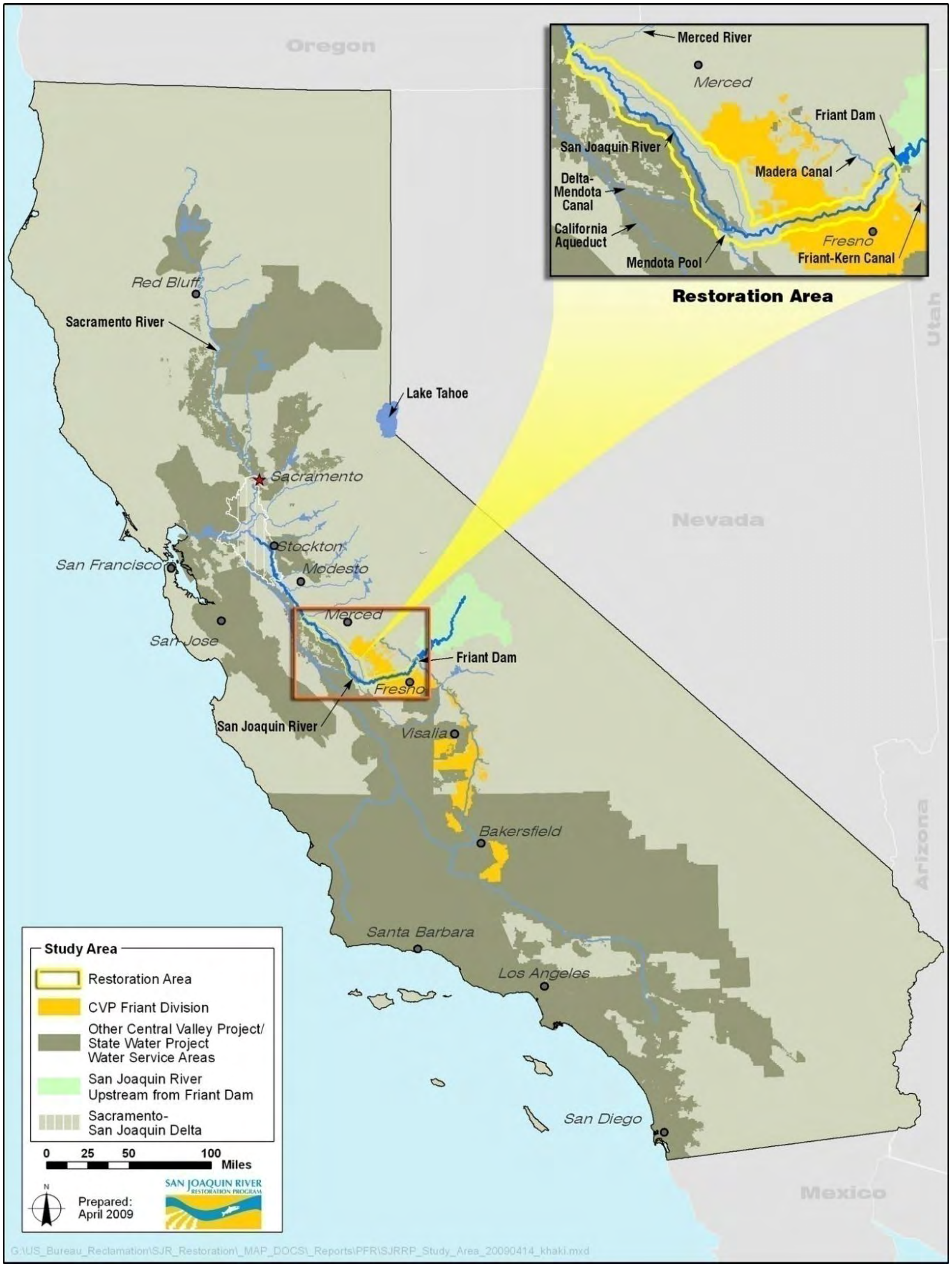

Figure 1-1.
San Joaquin River Restoration Program Study Area

Figure 1-2.
San Joaquin River Restoration Area and the Defined River Reaches

1.1 Document Organization

The information herein is the result of a thorough and in-depth review of background literature, reports, and existing models describing the life history and biology of Central Valley spring- and fall-run Chinook salmon. In addition, Central Valley late fall-run may be introduced through the SJRRP if their life history tactics prove to be more successful than fall-run Chinook salmon. The following components are described in detail:

- Historical population status of Chinook salmon in the San Joaquin River before and immediately after construction of Friant Dam (Chapter 2)
- Review of background literature on the basic life history and habitat requirements of Chinook salmon in the San Joaquin River Basin, including the Merced, Tuolumne, and Stanislaus rivers, the greater Central Valley, and other Pacific Coast river systems, where appropriate (Chapter 3)
- Discussion of stressors, including human activities and environmental conditions that affect Chinook salmon survival (Chapter 4)
- Conceptual models of the mechanisms likely to influence the abundance and recovery of spring- and fall-run Chinook salmon populations in the San Joaquin River (Chapter 5)
- Data needs (i.e., knowledge gaps) for spring- and fall-run Chinook salmon in the San Joaquin River Basin (Chapter 6)
- Sources used to prepare this document (Chapter 7)

1.2 Scope

The Restoration Goal is to ―restore and maintain fish populations in ‗good condition‘ in the mainstem of the San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally producing and self-sustaining populations of salmon and other fish…" (Settlement). While many fish species will benefit from actions to meet the Restoration Goal, such as the incorporation of Restoration Flows, the emphasis of the Restoration Goal primarily is on spring-run Chinook salmon, and secondarily fall-run or late fall-run Chinook salmon. Therefore, the scope of this document is limited to spring-, fall-, and late fall-run Chinook salmon.

1.3 Coordination

This document and the conceptual models herein are based on existing salmonid models for the California Central Valley, scientific literature, and the opinions of experts working in the San Joaquin River Basin. It will be further developed through extensive coordination and collaboration with various salmonid experts, restoration ecologists, modelers, as well as groups working in the basin, and Work Groups of the SJRRP. The Chinook salmon conceptual models are intended to aid in the facilitation, negotiation, and coordination of quantitative Chinook salmon population models, monitoring metrics, potential adaptive management strategies, and various regulatory review processes.

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Chapter 2 Historical Population Dynamics in the San Joaquin River

Considerable historical documentation exists regarding the presence of Chinook salmon in the San Joaquin River and its tributaries, although the identification of race is often difficult to ascertain. The first documentation of Chinook salmon in the San Joaquin River comes from Spanish explorers and missionaries of Old California (Yoshiyama et al. 2001). Large schools of adult Chinook salmon were observed in the pools near Friant during May, June, and the first part of July by the U.S. Fish Commission (Yoshiyama et al. 2001). The anectdotal history of Native American inhabitants contains references to salmon being harvested seasonally upstream to Graveyard Meadows (Lee 1998). Salmon were also encountered in upper San Joaquin River tributaries such as the North San Joaquin River, Fine Gold Creek, Cottonwood Creek, and Whiskey Creek (Yoshiyama et al. 2001) and in valley floor tributaries such as the Chowchilla and Fresno rivers.

The California Fish and Game Commission noted dramatic salmon declines in the late 1800s (Yoshiyama et al. 2001). Gold mining, agricultural development, deforestation, and water development such as dam construction and flood conveyance activities adversely impacted salmon habitat. By the late 1800s and early 1900s, numerous impediments to anadromous fish passage were present in the San Joaquin River. These included Mendota Pool (River Mile (RM) 205) and Kerckhoff Dam (approximately RM 291) After Kerckhoff Dam was constructed in 1920, it permanently blocked spring-run Chinook salmon from spawning areas upstream and seasonally affected the flow in 14 miles of river with pools that provided over-summering habitat.

Clark (1929) reported that in the early 1900s there were primarily spring-run fish and relatively few fall-run. He said that the spring-run Chinook salmon was —very good” in 1916 and 1917, —fairly good” in 1920 and 1926, but in 1928, very few Chinook salmon were seen in the river. By the 1920s, reduced autumn flows in the mainstem San Joaquin River nearly eliminated the fall run, although a small run did persist.

2.1 Spring-Run Chinook Salmon

Spring-run Chinook salmon once occupied all major river systems in California where there was access to cool reaches that would support over-summering adults. Historically, spring-run Chinook salmon were widely distributed in streams of the Sacramento-San Joaquin River basins, spawning and rearing over extensive areas in the upper and middle reaches (elevations ranging 1,400 to 5,200 feet (450 to 1,600 meters)) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud, and Pit rivers (Myers et al. 1998). Only two evolutionarily significant units (ESU) of spring-run Chinook salmon remain in California: a Central Valley population and a Klamath-Trinity population

(Moyle et al. 1995). Spring-run Chinook salmon in the San Joaquin River were extirpated in the mid- to late 1940s following the construction of Friant Dam and diversion of water for agricultural purposes to the San Joaquin Valley.

After Friant Dam was constructed, numerous spring-run Chinook salmon returned to the river below the dam during the years when the river flowed below Sack Dam (Table 2-1) (DFG 1946, Warner 1991). Clark (1943) noted that Friant Dam first prevented upstream passage in 1942, although the dam did not begin storing water until February 21, 1944. Clark (1943) estimated that there were about 5,000 spring-run fish in a holding pool immediately below the dam in 1942, but no complete count was made that year. There was a “poor” run in 1944, when flows below Sack Dam were low and many fish were killed by —spearing” (DFG 1946). In 1945, daytime counts indicated that at least 56,000 spring-run fish passed through the Mendota Dam fish ladder or jumped over the dam (DFG 1946); it is likely that the Mendota Dam counts were low because many adults migrate at night. Flows below Sack Dam were low from spring 1948 through 1950 (Table 2-1) when only a portion of the runs were salvaged (Warner 1991). Escapement surveys were not conducted after 1950.

Table 2-1.
Spring-Run Chinook Salmon in the San Joaquin River from 1943 to 1950

Year	Number Counted	Counting Method	Flows at Sack Dam (cfs)
1943	35,000	Mendota Dam Ladder	4,086
1944	5,000	Mendota Dam Ladder	83
1945	More than 56,000	Mendota Dam Ladder	3,066
1946	30,000	Mendota Dam Ladder	1,138
1947	6,000	Mendota Dam Ladder	98
1948	More than 1,915	Hills Ferry Weir Trap	23
1950	36	Ladder from Salt Slough	3

Key:
cfs = cubic feet per second

2.2 Fall-Run/Late Fall-Run Chinook Salmon

The San Joaquin River likely supported relatively few fall-run Chinook salmon after diversions began at Sack Dam, some time between 1860 and 1880 (http://are.berkeley.edu/courses/EEP162/spring2007/documents/SJRcasehistory.pdf). Clark (1929) reported that there were few fall-run Chinook in the San Joaquin River since the early 1900s because of inadequate fall flows. During all but wet years, the river was nearly completely dewatered downstream from Sack Dam until late November (Hatton 1940, Clark 1943), by which time it was too late for most fall-run Chinook salmon to migrate upstream in the San Joaquin River Basin. However, Hatton (1940) reported that in some years, fall-run fish migrated through natural sloughs and irrigation canals to the San Joaquin River above the Mendota weir. No escapement surveys were made to document the abundance of fall-run fish in the San Joaquin River.

Since the 1950s, some San Joaquin River fall-run Chinook salmon have continued up the mainstem San Joaquin River into Salt and Mud sloughs, and their tributaries on the west side of the valley (DFG 2001). These sloughs conveyed poor quality water and had no suitable Chinook salmon spawning habitats (DFG 2001). In response to these events, the California Department of Fish and Game (DFG) has installed and operated a temporary fish barrier (Hills Ferry Barrier) just upstream from the confluence with the Merced River since 1992 (DFG 2001, 2005). Adult Chinook salmon were observed at the barrier and above the barrier between late October and mid-November in 2000 and 2004 (DFG 2001, 2005).

It is also likely a population of late fall-run Chinook salmon was present historically in the San Joaquin River basin although appreciable numbers are currently only present in the Sacramento River Basin (Williams 2006).

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Chapter 3 Life History Requirements

Central Valley Chinook salmon exhibit two general freshwater life-history-types, ―stream-type” and “ocean-type” (Healey 1991). The evolution of stream-type and ocean-type life histories is an adaptation to the seasonal flow and temperature regimes in the rivers where Chinook salmon spawn and rear. Central Valley spring- and late fall-run Chinook salmon are generally classified as stream-type because the adults migrate into mid-elevation watersheds where they spend several months while they mature sexually, and because juveniles typically spend at least 1 year rearing in fresh water. However, in the Central Valley and Oregon, spring-run Chinook salmon juveniles often migrate to the ocean within a few months after emerging from the gravel in the redd. In Butte Creek, California, the contribution of the subyearling life stage to adult production is approximately four times that of the yearling life stage (Ward et al. 2002). In contrast, Central Valley fall-run Chinook salmon are considered ocean-type, because the adults spawn in the lower watersheds within a few weeks of entering fresh water, and juveniles typically migrate to the ocean within a few months.

Adult and juvenile Chinook salmon express temporal and spatial variations in life-history patterns allowing adaptations to diverse and variable riverine environments (Moyle 2002). Both adult and juvenile salmon exhibit variable life-history expressions on both a temporal and spatial scale. Sufficient life-history diversity must exist to sustain a population through environmental perturbations and to provide for evolutionary processes. Thus, it is important to preserve as much life-history diversity as possible to maintain healthy Chinook salmon populations (Williams 2006). To promote the long-term success of Chinook salmon populations, restoration should provide sufficient habitat for several life-history types of spring-run Chinook salmon in the Restoration Area.

Whereas adult spring-run Chinook salmon returning to the San Joaquin River are expected to exhibit various life-history patterns on both temporal and spatial scales, the juvenile stage typically exhibits more life-history variability than adults. In addition, juvenile salmon have a stronger dependence on riverine habitat for successful survival than adults and many of the restoration actions required by the Settlement focus on the juvenile phase. Improving passage, migratory habitat, and holding habitat will be important to ensure long-term success for adult spring-run Chinook salmon. The following discussion focuses on the juvenile stage of spring-run Chinook salmon. It is expected that fall- and late-fall-run Chinook salmon juveniles will also benefit from the preservation of habitats that support multiple life-history types as well.

There is substantial variation between the stream-type and ocean-type life-history categories, particularly regarding spring-run Chinook salmon. Many subtypes of the ocean-type and stream-type migrant designations have been described (Gilbert 1912, Reimers 1973, Schluchter and Lichatowich 1977, Fraser et al. 1982). Specific patterns of juvenile migrants have been observed in Butte, Mill, and Deer creeks and are described in

Chapter 3. The Butte Creek population consists of fry migrants that primarily disperse downstream from mid-December through February, subyearling smolts that primarily migrate between late-March and mid-June, and yearlings that migrate from September through March (Hill and Webber 1999, Ward and McReynolds 2001, Ward et al. 2002). Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill Creek and Deer Creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley et al. 2004).

Before and shortly after Friant Dam was constructed, numerous spring-run Chinook salmon fry from the San Joaquin River entered the estuary. Before construction of Friant Dam, seasonal downstream migrations of juvenile Chinook salmon occurred following periods of high discharge (Hallock and Van Woert 1959). In 1944, peak migration at Mendota was between late January and June, peaking in February. At Mossdale, sampling indicated the greatest numbers emigrated during January and February (Hallock and Van Woert 1959). Juveniles captured at Mendota before 1949 were —for all practical purposes the progeny of spring-run Chinook salmon adults only, since very few fall-run fish spawned in the upper San Joaquin" (Hallock and Van Woert 1959). Based on this information, it is likely that fry-sized spring-run Chinook salmon from the San Joaquin River Basin historically used the lower San Joaquin River and the Delta for rearing.

The FMWG expects three general life-history types may be present in the San Joaquin River following restoration: 1) yearling, 2) fry migrant, and 3) transient fry migrant (Figure 3-1). There are many variations of these general life-history types, but these basic strategies are presented as a guideline. Similar to spring-run Chinook salmon observed in tributaries to the Sacramento River, the Fry Migrant category exhibits an early outmigration life history, using downstream rearing areas, such as Reaches 4 and 5. The Transient Fry Rearing life-history category would be expected to rear in upper reaches of the Restoration Area (i.e., Reach 2B), and migrate out of the Restoration Area in late spring. As found in the Sacramento River Basin, the Yearling life-history category of spring-run Chinook salmon expected in the San Joaquin River would use the upper reaches of the Restoration Area (Reach 1) for rearing and migrate downstream during fall or winter. The contribution of these life-history types to spring-run recruitment success is unknown.

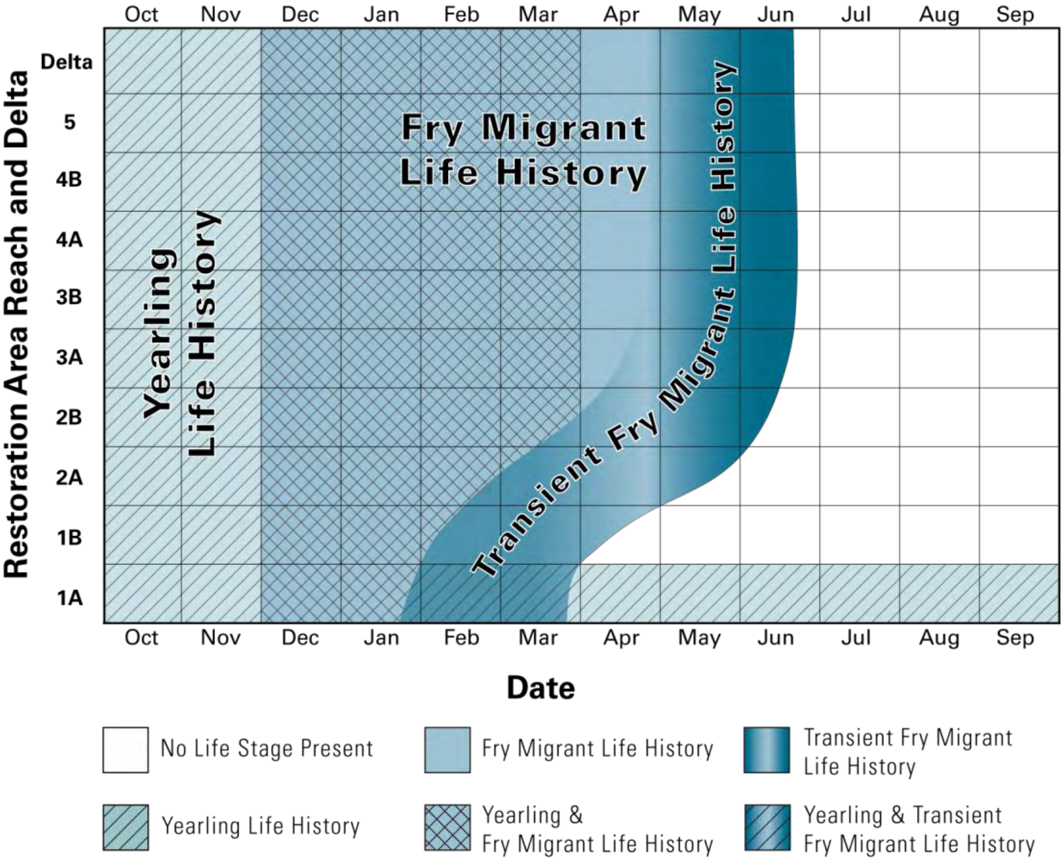


Figure 3-1.
General Representation of Three Life-History Types of Juvenile Spring-Run Hypothesized to Be Expressed in the Restoration Area and Delta Following Restoration Actions

The underlying biological basis for differences in juvenile life history appear to be both environmental and genetic (Randall et al. 1987). Distance of migration to the marine environment, stream stability, stream flow and temperature regimes, stream and estuary productivity, and general weather regimes have been implicated in the evolution and expression of specific emigration timing. Juvenile stream- and ocean-type Chinook salmon have adapted to different ecological niches. Ocean-type Chinook salmon tend to use estuaries and coastal areas more extensively for juvenile rearing. In general, the younger (smaller) juveniles are at the time of emigrating to the estuary, the longer they reside there (Kjelson et al. 1982, Levy and Northcote 1982, Healey 1991). Brackish water areas in estuaries also moderate physiological stress during parr-smolt transition. In the Sacramento River and coastal California rivers, subyearling emigration is related to the avoidance of high summer water temperatures (Calkins et al. 1940, Gard 1995). Ocean-type Chinook salmon may also use seasonal flood cycles as a cue to volitionally begin downstream migration (Healey 1991). Migratory behavior in ocean-type Chinook salmon juveniles is also positively correlated with water flow (Taylor 1990a).

Barriers to life-history expression include flow truncation or alteration, passage barriers, lack of appropriate habitat, water quality and temperature, ocean conditions, etc. Given the uncertainties with stock selection and adaptation to the San Joaquin River environment, we intend to manage and restore habitats to promote expression of several life-history variations exhibited in other spring-run populations.

A critical life-history requirement for all life-history stages of Chinook salmon is water temperature. Available literature frequently describes the suitability of water temperatures as optimal, suitable, not suitable, stressful, and lethal for fish. These definitions are not standardized to represent particular physiological responses and the definition of these frequently used terms often varies among authors. For these reasons, temperature requirements will be defined as either optimal, critical, or lethal. Optimal water temperatures are defined as those that provide for normal feeding activity, normal physiological response, and behavior void of thermal stress symptoms (McCullough 1999). Critical water temperatures are defined as causing some level of thermal stress. Thermal stress is defined as any water temperature that alters the biological functions of fish and decreases the probability of survival (McCullough 1999). Lethal levels are defined as resulting in substantial mortality. Water temperatures below optimal levels may also cause thermal stress or mortality, but the San Joaquin River system is not expected to experience thermally stressful low water temperatures, so those will not be addressed in this document.

Table 3-1 provides an overview of the water temperature objectives as identified by the FMWG for Chinook salmon. Optimal, critical, and lethal temperatures are cited. Optimal temperatures are defined using ecological and physiological optimum criteria. These criteria are threshold levels for long term population sustainability and signify optimum growth and survival under natural ecological conditions including the existence of predation pressure, competition, variability in food availability, etc. (EPA 2003). Because optimal temperatures represent a range, they are defined as ―less than or equal to” the upper limit of the optimal range. Critical and lethal temperatures are cited from a number of independent studies evaluating thermal stress on salmonids in both laboratory and natural settings. Critical temperatures are expressed as a range of stress-inducing temperatures. The primary sources for water temperature criteria listed in Table 3-1 are the U.S. Environmental Protection Agency‘s (EPA) Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality (EPA 2003), Rich (2007) Impacts of Water Temperature on Fall-Run Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) in the San Joaquin River System, and Pagliughi (2008), Lower Mokelumne River Reach Specific Thermal Tolerance Criteria by Life Stage for Fall-Run Chinook Salmon and Winter-Run Steelhead. All of these sources represent broad literature reviews of temperature thresholds and requirements for salmonids on the west coast.

Table 3-1.
Temperature Objectives for the Restoration of Central Valley Chinook Salmon

Monthly Water Temperature Objectives for the San Joaquin River Restoration Program

Spring-Run and Fall-Run Chinook Salmon

Life Stage	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Adult Migration			Optimal: ≤ 59°F (15°C) Critical: 62.6 – 68°F (17 – 20°C) Lethal: >68°F (20°C)									
Adult Holding (Spring-Run Only)				Optimal: ≤55°F (13°C) Critical: 62.6 – 68°F (17 – 20°C) Lethal: >68°F (20°C)								
Spawning								Optimal: ≤ 57°F (13.9°C) Critical: 60 – 62.6°F (15.5 – 17°C) Lethal: 62.6°F or greater (17°C)				
Incubation and Emergence								Optimal: ≤55°F (13°C) Critical: 58 – 60°F (14.4 – 15.6°C) Lethal: >60°F (15.6°C)				
In-River Fry/Juvenile	Optimal: ≤60°F (15.6°C), young of year rearing; ≤62.6°F (18°C), late season rearing (primarily spring-run) Critical: 64.4 – 70°F (18-21.1°C) Lethal: >75 °F (23.9°C), prolonged exposure											
Floodplain Rearing*	Optimal: 55 – 68°F (13 – 20°C), unlimited food supply											
Outmigration	Optimal: ≤60°F (15.6°C) Critical: 64.4 – 70°F (18 – 21.1°C) Lethal: >75°F (23.9°C), prolonged exposure											

Sources: EPA 2003, Rich 2007, Pagliughi 2008, Gordus 2009.

Note:

* Floodplain rearing temperatures represent growth maximizing temperatures based on floodplain condition. No critical or lethal temperatures are cited assuming fish have volitional access and egress from floodplain habitat to avoid unsuitable conditions.

Shaded box indicates life stage is present

Key:

°F = degrees Fahrenheit

°C = degrees Celsius

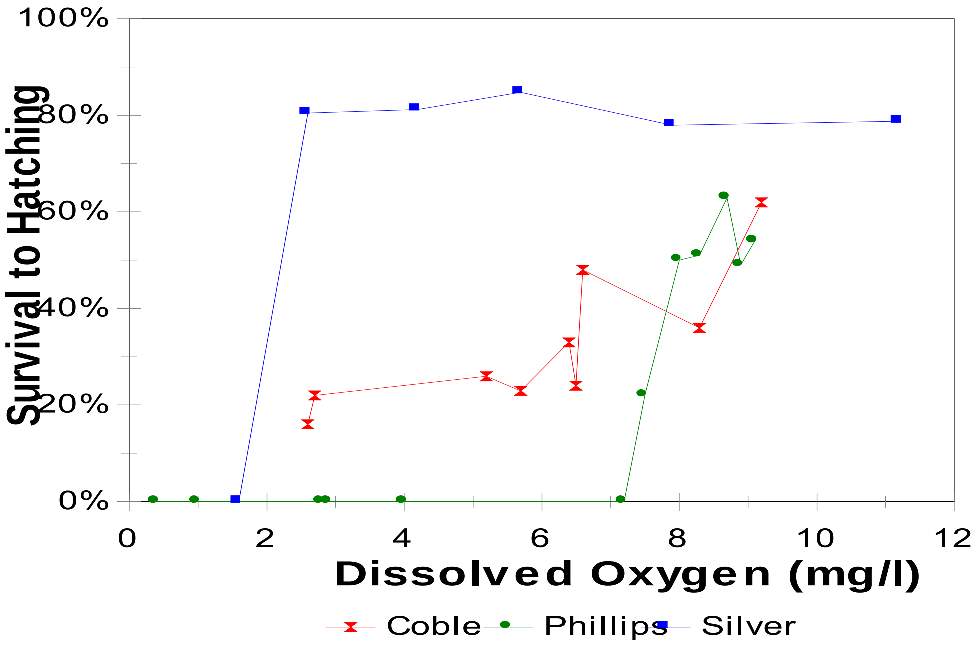
3.1 Egg Survival and Emergence

Salmon eggs incubate in nests called redds in gravel beds at depths of 12 to 18 inches under the surface of the bed until the alevins hatch in 40 to 50 days at a water temperature of 50 degrees Fahrenheit (°F) (10 degrees Celsius (°C)). Normal embryo development and emergence of the fry from the gravel require suitable water temperatures, high concentrations of dissolved oxygen (DO), sufficient intragravel flow to deliver oxygenated water and flush metabolic wastes from the egg pocket, and a minimal amount of fine sediments that would otherwise block their emergence. In the Sacramento River and its tributaries, the egg incubation period for spring-run Chinook salmon extends from August to March (Fisher 1994, Ward and McReynolds 2001), whereas the incubation period for fall-run Chinook salmon in the San Joaquin River Basin extends from late October through February. Late fall-run Chinook salmon eggs incubate through April to June.

This discussion focuses on factors that affect egg survival to the hatching stage and the factors that affect the ability of fry to emerge from the gravels. Gravel type, velocities, and specific spawning preferences of Chinook salmon are described in Section 3.5, Spawning.

3.1.1 Dissolved Oxygen and Turbidity

Numerous field and laboratory studies indicate that egg survival to hatching is greatly dependent on high concentrations of DO (Chapman 1988, Kondolf 2000). Excessive concentrations of substrate fines smaller than 1 millimeter (mm) in diameter are usually correlated with reduced DO (Chapman 1988, Kondolf 2000). There is a strong possibility that turbidity also affects egg survival as a result of clay-sized particles adhering to an egg‘s membrane (Stuart 1953), reducing the egg‘s ability to absorb DO. This effect provides a good explanation of why salmonid eggs survive at high rates under low DO concentrations under clean laboratory conditions but not under natural settings with higher turbidity levels. When steelhead eggs were incubated on clean, porous ceramic plates under highly controlled levels of DO and flow in a laboratory, survival was high (about 80 percent) at DO levels as low as 2.5 milligrams per liter (mg/L) (Silver et al. 1963) (Figure 3-2). In contrast, a field study by Coble (1961), during which steelhead eggs were placed in plastic mesh sacks with gravel, indicates that egg survival gradually declined as DO declined from 9.2 mg/L to 2.6 mg/L (Figure 3-2). Another field study by Phillips and Campbell (1962), during which eggs were placed in perforated metal boxes with glass beads, indicates that no eggs survived at DO levels at or below 7.2 mg/L (Figure 3-2).



Sources: Silver et al. 1963 Coble 1961, and, Phillips and Campbell 1962.

Figure 3-2.
Relationship Between Dissolved Oxygen Concentration and Survival to Hatching of Steelhead Trout Eggs During Laboratory and Field Studies

Studies with other salmonid species show similar results. Eggs of chum salmon (*O. keta;* Alderdice et al. 1958), Chinook salmon (Silver et al. 1963), and coho salmon (*O. kisutch;* Shumway et al. 1964) incubated under clean laboratory conditions hatched at high rates at DO concentrations as low as 2.0 to 2.5 mg/L. Chum salmon eggs that were deposited in natural redds in an experimental stream channel with washed gravels also exhibited relatively high survival rates (50 percent) at DO levels as low as 2.5 mg/L (Koski 1975). Conversely, the survival of coho salmon eggs incubated in natural streams either in natural redds (Koski 1966) or in experimental chambers (Phillips and Campbell 1962) were reduced at DO concentrations below 9.0 mg/L and 8.3 mg/L, respectively. Although the adhesion of fines to the egg‘s membranes was not evaluated in the field studies, it is the most likely explanation for why eggs require greater concentrations of DO in natural streams than in a laboratory or in washed gravel.

The DO requirement for Chinook salmon eggs has not been accurately determined under natural field conditions. Gangmark and Bakkala (1960) studied the hatching survival of Chinook salmon eggs in artificial redds in Mill Creek, Tehama County, relative to DO concentrations. Their results were questionable, however, because individual test results were not presented and the authors referred to their earlier studies for a description of the methods (Gangmark and Broad 1955). The egg-handling mortalities averaged 53 percent, possibly because the eggs were not allowed to water-harden before handling and because fungal infections caused by egg contact with the plastic mesh net bag resulted in mortality (Gangmark and Broad 1955). Furthermore, an evaluation of a portion of their raw data presented in Gangmark and Bakkala (1958) indicated that they obtained a poor relationship between survival and DO concentration, possibly due to variable rates in handling mortality among replicates. Without better direct evidence, it is assumed that Chinook salmon eggs have a relatively high DO requirement compared to coho and chum salmon and steelhead trout because Chinook salmon produce relatively large eggs. Large eggs generally require high DO concentrations because they have a relatively small surface-to-volume ratio (Beacham and Murray 1985).

In addition to the effects of low DO concentrations on survival of eggs to hatching, any reduction in DO below the saturation level results in slowly developing embryos that emerge at a small size and before the complete absorption of yolk (Phillips and Campbell 1962, Silver et al. 1963, Shumway et al. 1964, Mason 1969, Wells and McNeil 1970, Koski 1975). It is likely that small alevins are relatively weak and less able to emerge through sand layers covering the egg pocket than are large relatively healthy alevins incubated at high DO concentrations. Furthermore, Mason (1969) reported that small coho salmon fry subjected to low DO levels during incubation could not compete successfully with larger fry and emigrated from experimental channels. Chapman (1988) suggested that any reduction in DO levels from saturation probably reduces survival to emergence or postemergent survival.

3.1.2 Intragravel Flow

Intragravel flow is correlated with egg survival. Intragravel flow is measured as either permeability or apparent velocity during egg survival studies. Permeability is the ease with which water passes through gravel, and depends on the composition and degree of packing of the gravel and viscosity of the water (Pollard 1955). Apparent velocity is the horizontal vector of interstitial flow and is a function of permeability and hydraulic gradient (Pollard 1955, Freeze and Cherry 1979). It is measured as the rate of flow through a standpipe, which is called apparent yield, divided by the porosity of the surrounding gravel. The actual velocity of flow through interstitial spaces, which is called the true or pore velocity, is faster than the apparent velocity because flow travels around substrate particles whereas apparent velocity assumes that the flow path is linear. Laboratory studies, such as Silver et al. (1963), that incubate eggs without a gravel medium, measure true velocity, whereas all field studies measure apparent velocity with standpipes.

The survival of steelhead and coho salmon egg to hatching in natural streams has been correlated with apparent velocity but not as strongly as with DO concentration, whereas there were no correlations with permeability (Coble 1961, Phillips and Campbell 1962). The size of coho salmon and steelhead embryos at hatching was reduced at low velocities, regardless of DO concentration in the laboratory (Shumway et al. 1964), whereas Chinook salmon and steelhead egg survival was not correlated with true velocity under the same laboratory conditions (Silver et al. 1963). Koski (1966) reported that survival to emergence of coho salmon eggs in natural redds was not correlated with a permeability index (milliliters per second). Sowden and Power (1985) reported that rainbow trout egg survival in a groundwater-fed stream was strongly correlated with DO and apparent velocity, but not with the percentage of fines less than 2 mm, the geometric-mean particle size, also called the fredle index.

Although egg survival and apparent velocity have been highly correlated in several studies, there is no consistent critical apparent velocity for egg survival, possibly because of the influence of different levels of DO and the adhesion of clay-sized particles to the egg‘s membrane among the studies. The results of five studies are listed below as evidence that the critical apparent velocity necessary for high rates of egg survival can vary from 0.65 foot per hour (ft/hr) (20 centimeters (cm) per hour (cm/hr)) to 50.9 ft/hr (1,550 cm/hr), depending on the DO concentration.

- Gangmark and Bakkala (1960) reported that the mean survival to hatching for newly fertilized Chinook salmon eggs planted in 220 artificial redds in Mill Creek, Tehama County, exceeded 87 percent where apparent velocity was at least 1.5 ft/hr and DO exceeded 5 mg/L. Mean survival was 67 percent at 14 sites where apparent velocity ranged between 0.5 and 1.0 ft/hr during the same study. However, the results of their study are questionable because individual test results were not presented and the methods were not described (see the above discussion on egg DO requirements).

- Coble (1961) reported that steelhead egg survival to hatching was high, 48 to 62 percent, at artificial redds with mean apparent velocities that exceeded 1.52 ft/hr (46.5 cm/hr) and mean DO levels greater than 6.4 mg/L.

- Phillips and Campbell (1962) reported that steelhead egg survival was high, 49 to 63 percent, in artificial redds with apparent velocities that exceeded 0.65 ft/hr (20 cm/hr) and mean DO levels that exceeded 8.3 mg/L.

- Reiser and White (1988) reported that Chinook salmon egg survival to hatching was highly correlated ($r = 0.797$) with apparent velocity and the percentage of two size classes of substrate fines during laboratory tests that maintained DO levels between 6.2 and 7.7 mg/L. These results suggest that at low DO levels tested, apparent velocity less than 50.9 ft/hr (1,550 cm/hr) resulted in reduced egg survival. They also reported that fines less than 0.84 mm in diameter affected survival to a much greater degree than did sediment between 0.84 and 4.6 mm in diameter, presumably due to greater influence of intragravel flow.
- Deverall et al. (1993) reported apparent velocities in natural Chinook salmon redds exceeded 16.4 ft/hr (500 cm/hr) at 45 of 49 redds in the Waitaki River, New Zealand, and that egg survival to hatching was between 75 and 98 percent at three redds where apparent velocity ranged between 6.56 ft/hr (200 cm/hr) and 9.84 ft/hr (300 cm/hr) and DO levels were near saturation.

3.1.3 Water Temperature

A review of numerous studies suggests that 42 to 55°F (5.5 to 13°C) is the optimum temperature range for incubating Chinook salmon (Donaldson 1955, Combs and Burrows 1957, Combs 1965, Eddy 1972, Bell 1973, Healey 1979, Reiser and Bjornn 1979, Garling and Masterson 1985). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards provides an optimum temperature threshold of less than 55°F (13°C) for incubation of salmonid eggs based on an extensive review referencing 41 sources that included five issue papers. The issue papers, in turn, referenced approximately 700 citations. As temperatures rise above this range the results can be increased incidence of disease, and mortality. Rich (2007) indicate, through a compilation of available studies that a range 58°F (14.4°C) to 60°F (15.6°C) contributes to increased mortality greater than 20 percent but less than 100 percent mortality. Seymour (1956) showed a rapid increase in Chinook salmon egg mortality as temperatures increased above 57°F (13.9°C), and 100 percent mortality in the yolk-sac stage when temperatures were increased to 60°F (15.6°C). Alderdice and Velsen (1978) estimated that the upper temperature limit for 50-percent mortality of Chinook salmon eggs was near 61°F (16°C); Healey (1979) found that water temperatures higher than 57°F (13.9°C) caused greater than 82-percent mortality of Chinook salmon eggs in the Sacramento River. These eggs appear to be no more tolerant of high water temperatures than the more Northern California races. Myrick and Cech (2001) likewise concluded that there appears to be very little variation in thermal tolerance of Chinook salmon eggs among geographic races.

Chinook salmon egg survival also declines at water temperatures below 42°F (5.6°C) and mortality is about 100 percent at a constant temperature of 35°F (1.7°C) (Leitritz 1959). Eggs can tolerate temperatures below 42°F (5.6°C) for about 6 days without mortality (Leitritz 1959). Gangmark and Bakkala (1958) reported water temperatures between 34 and 36.5°F (1.1 and 2.5°C) in January 1957 in artificial redds with planted eggs in Mill Creek, the North Fork of Mill Creek, and the Sacramento River. The duration of the cold temperatures was not reported but there was no indication that egg survival rates were affected. Cold water temperature tolerance limits are not specified in Table 3-1 due to the assumption that cold water impacts are not a limiting factor for Chinook salmon in the San Joaquin River.

3.1.4 Emergence

After hatching, alevins remain buried in the gravel for an additional period of development during which time nutrition is provided by absorption of the yolk sac. After yolk sac absorption by the alevins has been completed, fry begin the process of emerging from the gravel. In the Sacramento River Basin, spring-run Chinook salmon alevins remain in the gravel for 2 to 3 weeks after hatching and emerge from the gravels into the water column from November to March (Fisher 1994, Ward and McReynolds 2001). In the Tuolumne River, the period of fall-run Chinook salmon alevin development has been estimated to last between 35 and 55 days (mean 47 days) at 50 to 55°F (10 to 13°C), based on the timing from redd completion to peak emergence at five fall-run Chinook salmon redds monitored in fall 1988 (TID and MID 1992).

3.2 Juvenile Rearing and Migration

Upon emergence, Chinook salmon fry swim or are displaced downstream (Healey 1991). Active downstream movement of fry primarily occurs at night along the margins of the river. After this initial dispersal, fry may continue downstream to the estuary and rear, or may take up residence in the stream for a period of time from weeks to a year (Healey 1991). Although juvenile spring-run Chinook salmon are known to exhibit a stream-type life-history pattern wherein they remain in freshwater until the spring following their emergence from the gravel in the redd, they are also known to migrate from spawning areas in their first year. Populations in Oregon (Healey 1991) and California (e.g., Butte Creek) primarily migrate to the ocean as subyearling smolts within a few months after emergence. The duration of juvenile freshwater residency may be influenced by water temperature and river outflow. Nicholas and Hankin (1989) found that the duration of freshwater rearing in Oregon coastal streams is tied to water temperatures, with juvenile Chinook salmon remaining longer in rivers with cool water temperatures. Moyle (2002) suggests that the propensity for Chinook salmon fry and smolts to emigrate to the ocean increases as high flows cause reduced water temperatures and increased turbidity.

River-rearing Chinook salmon fry occupy low-velocity, shallow areas near stream margins, including backwater eddies and areas associated with bank cover such as large woody debris or large substrate (Lister and Genoe 1970, Everest and Chapman 1972, McCain 1992). Juvenile Chinook salmon often seek refuge in low velocity habitats where they can rest and feed on drifting invertebrates with minimum expenditure of energy. Because of the energetic demands of both retaining position within the water column and obtaining prey items, as well as the metabolic demands on ectotherms (organisms that regulate their body temperatures based on their surrounding environment) as water temperatures increase, feeding and growth in rivers depend on a number of factors working in concert. Energy required to maintain position within the water column is generally a function of body size (Chapman and Bjornn 1969, Everest and Chapman 1972). For example, small fish and newly emerged fry typically inhabit slower water habitats, often found at the margins of mainstem channels, backwaters, or side channels. Larger fish typically move into swifter flowing habitats, where larger prey are usually available (Lister and Genoe 1970). This shift is also energetically more economical, since larger fish would require more prey items, and capturing one prey item is energetically more efficient than capturing many.

Juvenile salmonids larger than 2 inches (50 mm) in length in the Sacramento-San Joaquin system also rear on seasonally inundated floodplains. Sommer et al. (2001) found higher growth and survival rates of Chinook salmon juveniles that reared on the Yolo Bypass than in the mainstem Sacramento River, and Moyle (2000) observed similar results on the Cosumnes River floodplain. Sommer et al. (2001) found that drifting invertebrates, the primary prey of juvenile salmonids, were more abundant on the inundated Yolo Bypass floodplain than in the adjacent Sacramento River. Bioenergetic modeling suggested that increased prey availability on the Yolo Bypass floodplain was sufficient to offset increased metabolic demands from higher water temperatures (9°F (5°C)) higher than in the mainstem). Gladden and Smock (1990) estimated that annual invertebrate production on two Virginia floodplains exceeded river production by one to two orders of magnitude. In the Virginia study, annual production on the floodplain continuously inundated for 9 months was 3.5 times greater than on the floodplain inundated only occasionally during storms (Gladden and Smock 1990).

Sommer et al. (2001) suggested that the well-drained topography of the Yolo Bypass may help reduce stranding risks when floodwaters recede. Most floodplain stranding occurs in pits or behind structures (e.g., levees or berms) that impede drainage (Moyle et al. 2005). Additionally, research in the Cosumnes River (Moyle et al. 2005) and Tuolumne River

(Stillwater Sciences 2007) suggests that flow-through of water on inundated floodplains appeared to be more important for providing suitable habitat for Chinook salmon and other native fish species than the duration of inundation or other physical habitat characteristics. Thus, configuration of restored floodplains to promote active flow-through of river water (i.e., creation of conveyance floodplains) would likely maximize habitat value for juvenile Chinook salmon.

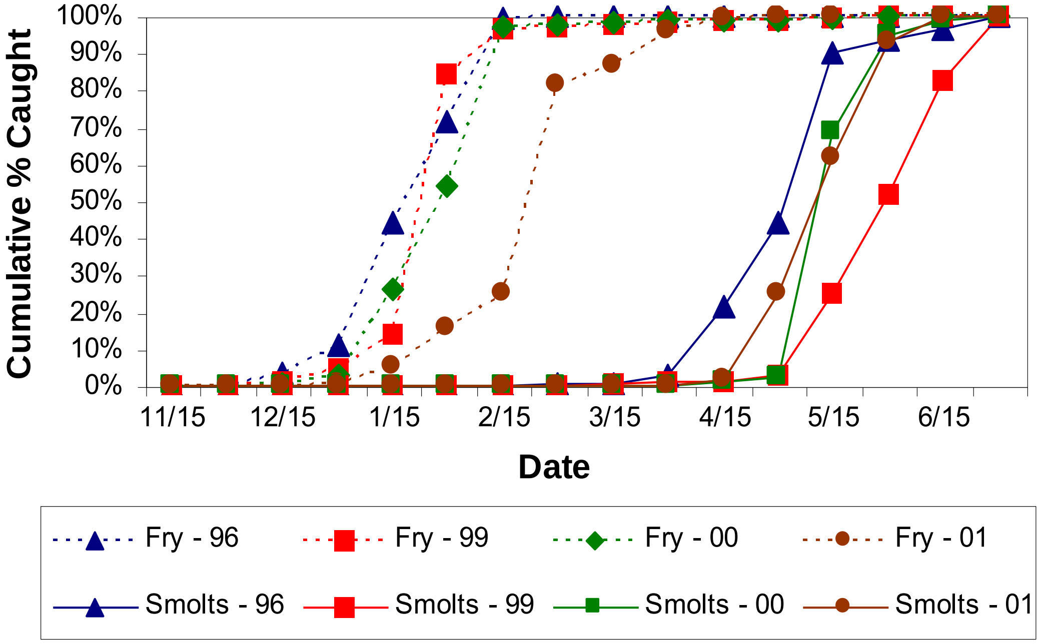
Considering the historical extent of floodplain inundation in the San Joaquin River Basin, and tule (*Scirpus acutus*) marsh habitat along the San Joaquin River before land development, it is possible that juvenile Chinook salmon and steelhead reared on inundated floodplains in the San Joaquin River in Reaches 2 through 5. These downstream reaches were inundated for a good portion of the year in normal and wetter years, providing suitable water temperatures for juvenile rearing from January to at least June or July in most years, and perhaps extending into August in wetter years. As snowmelt runoff declined, and ambient temperatures increased, water temperatures in slow-moving sloughs and off-channel areas probably increased rapidly. The extent to which juvenile salmonids would have used the extensive tule marshes and sloughs historically found in Reaches 2, through 5 is unknown.

The quality of juvenile rearing habitat is highly dependent on riparian vegetation. Riparian vegetation provides shading which may slightly affect river temperatures and provide cover; provides allochthonous organic matter that drives the Chinook salmon‘s food web; contributes woody debris for aquatic habitat complexity, bank stability through root systems, and filtration of sediments and nutrients in storm runoff (Helfield and Naiman 2001).

3.2.1 Migration Timing

Juvenile Chinook salmon in the Central Valley move downstream at all stages of their development: most as newly emerged fry dispersing to downstream rearing habitats and others that migrate toward the ocean as they undergo smoltification. Smoltification is the physiological process that increases salinity tolerance and preference, endocrine activity, and gill Na^+-K^+ ATPase activity. It usually begins in late March when the juveniles reach a fork length between 70 and 100 mm; however, a few fish delay smoltification until they are about 12 months old (yearlings) when they reach a fork length between 120 and 230 mm. Environmental factors, such as stream flow, water temperature, photoperiod, lunar phasing, and pollution can affect the onset of smoltification (Rich and Loudermilk 1991).

Rotary screw trap studies at the Parrott-Phelan Diversion Dam in Butte Creek probably provide the best available information on the migratory behavior of a natural spring-run Chinook salmon population in the Central Valley, because hatchery fish are not planted in Butte Creek and the fall-run Chinook salmon do not spawn above the study site. In Butte Creek, at least 95 percent of the juvenile spring-run Chinook salmon migrate as fry from the spawning areas upstream from Parrott-Phelan Diversion Dam into the Sutter Bypass where they rapidly grow (0.5 to 0.7 mm/day) to a subyearling smolt size (60- to 100-mm fork length (FL) (Ward et al. 2002). The Butte Creek fry primarily disperse downstream from mid-December through February (Figure 3-3) whereas the subyearling smolts primarily migrate between late-March and mid-June (Figure 3-3). Spring-run yearlings in Butte Creek migrate from September through March (Hill and Webber 1999, Ward and McReynolds 2001, Ward et al. 2002). Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill Creek and Deer Creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley et al. 2004).



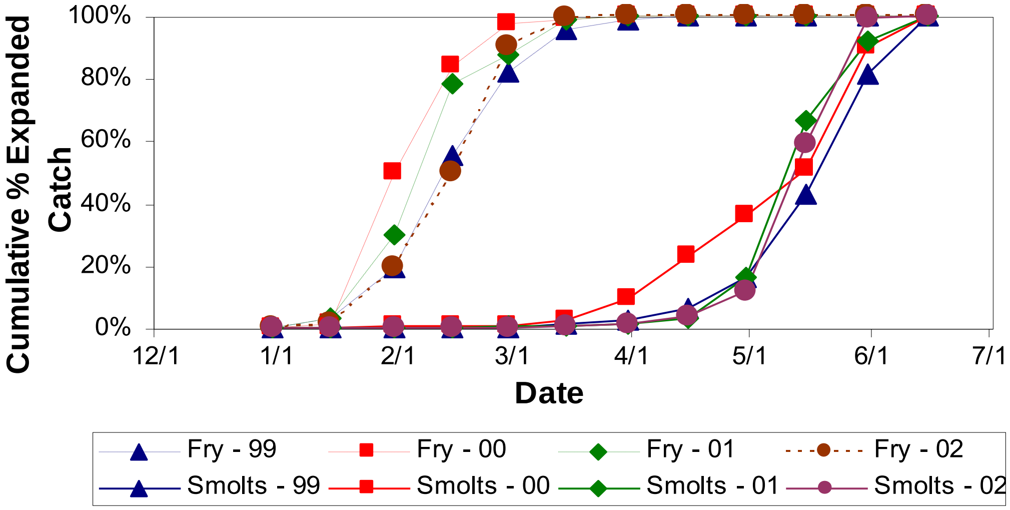
Sources: Hill and Webber 1999, Ward and McReynolds 2001, Ward et al. 2002.

Notes:

1. The data are plotted in 2-week intervals relative to the last date of capture in each interval.
2. Fry less than or equal to 50-mm fork length.
3. Subyearling smolt greater than or equal to 70 mm fork length

Figure 3-3.
Cumulative Percent of Spring-Run Chinook Salmon Fry and Subyearling Smolt-Sized Fish Caught with Rotary Screw Trap at Parrott-Phelan Diversion Dam on Butte Creek, California, in 1996, 1999, 2000, and 2001

Fall-run Chinook salmon fry disperse downstream from early January through mid-March, whereas the smolts primarily migrate between late March and mid-June in the Stanislaus River (Figure 3-4), which is nearly identical to the timing of spring-run smolt outmigration in Butte Creek. Fall-run yearlings are caught during all months that the rotary screw traps are operating at Oakdale on the Stanislaus River; this occurs from December through June, regardless of flow (http://www.sanjoaquinbasin.com/fishbio-san-joaquin-basin-newsletter.html).



Source: http://www.sanjoaquinbasin.com/fishbio-san-joaquin-basin-newsletter.html.

Notes:

1. The data are plotted in 2-week intervals relative to the last date of capture in each interval.
2. Fry less than or equal to 50-mm fork length.
3. Smolt greater than or equal to 70-mm fork length.

Figure 3-4.
Cumulative Percent of Expanded Number of Fall-Run Chinook Salmon Fry and Smolt-Sized Fish Passing Rotary Screw Trap at Oakdale on the Stanislaus River, California, in 1999, 2000, 2001, and 2002

3.2.2 Delta and Estuary Rearing

In many systems, an important life-history strategy of juvenile salmonids is to take up residence in tidally functioning estuaries. While this is a common life-history strategy among Chinook salmon on the Pacific Coast, fry often appear most abundant 2 to 3 months earlier in the Delta than in other Pacific Coast estuaries, perhaps in response to the warmer temperatures in the Delta (Healey 1980, Kjelson et al. 1982). Juvenile Chinook salmon less than 70-mm FL are abundant in the Delta from February to April (MacFarlane and Norton 2002). Work in other West Coast estuaries indicates estuarine rearing by fry is important for Chinook salmon development (Levy and Northcote 1981). Fyke trapping and trawling studies conducted by the U.S. Fish and Wildlife Service (USFWS) in the Sacramento River and in the Delta suggest small juvenile Chinook salmon use the shoreline and larger juveniles typically use the center of the channel (USFWS 1994a). Other studies along the Pacific Coast also indicate a preference for nearshore areas by less mature juvenile Chinook salmon (Dauble et al. 1989, Healey 1991). The diet of fry and juvenile Chinook salmon in the San Francisco Estuary consists of dipterans, cladocerans, copepods, and amphipods (Kjelson et al. 1982). Thus, the nearshore habitats in the Delta and San Francisco Bay are probably valuable to juvenile Chinook salmon for rearing, whereas the main deepwater channels are used for migration.

Numerous spring-run Chinook salmon fry from the San Joaquin River entered the estuary before and shortly after Friant Dam was constructed. Before construction of Friant Dam, seasonal downstream migrations of juvenile Chinook salmon occurred following heavy outflow events (Hallock and Van Woert 1959). Peak migration at Mendota was between late January and June, peaking in February 1944. Additional sampling at Mossdale also found the greatest numbers emigrating during January and February (Hallock and Van Woert 1959). Juveniles captured at Mendota before 1949 were ―for all practical purposes the progeny of spring-run Chinook salmon adults only, since very few fall-run fish spawned in the upper San Joaquin" (Hallock and Van Woert 1959). Based on this information, it is highly likely that fry-sized spring-run Chinook salmon from the San Joaquin River Basin historically reared in the lower San Joaquin River, Delta, and San Francisco Bay.

3.2.3 Smoltification and Estuary Presence

Juvenile salmon undergo complex physiological changes, called smoltification, in preparation for their life in saltwater (summarized in Quinn 2005). These include changes in osmoregulation (salt balance), body shape and color, energy storage, and migratory behavior. A change in osmoregulation is critical because in the freshwater environment, juvenile salmon must keep from losing their essential electrolytes (salts that regulate body functions) and absorbing too much water. To do this, they minimize water intake, excrete dilute urine, and actively acquire salts with their gills. In saltwater, which is saltier than their body fluids, fish drink, but must excrete salts from their gills and produce concentrated urine. The smolting process is metabolically demanding and juveniles release hormones, including cortisol, that trigger the use of their energy reserves. Cortisol inhibits the immune system, making smolts more vulnerable to disease and other stress. The juveniles Chinook salmon also undergo morphological changes which camouflage them in streams to the blue-green backs, silver sides, and white bellies that are typical of pelagic marine fishes. The smolting process is triggered by a combination of conditions, including body size, rate of growth, increasing day length, and increasing water temperatures. There is a smoltification window during spring, after which slow-growing, small individuals lose their ability to smoltify.

As Chinook salmon begin smoltification, they tend to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (ppt) (Healy 1980, Levy and Northcote 1981). Smolts enter the San Francisco Estuary primarily in May and June (MacFarlane and Norton 2002) where they spend days to months completing the smoltification process in preparation for ocean entry and feeding (Independent Scientific Group 1996). Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levy and Northcote 1981, Healey 1991). Kjelson et al. (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school during the day into the upper 9.843 feet (3 meters) of the water column.

Decaying marsh vegetation forms the basis of the juvenile Chinook salmon‘s food web in the Columbia River (Bottom 2007). Juveniles, 40- to 60-mm fork length, primarily used shallow, nearshore, and wetland habitats. They fed on insects (adult dipterans), amphipods (*Corophium salmonis*, *C. spinicome)*, and water fleas (*Cladocera*) that were produced in wetland habitats. Juveniles spent an average of 73 days (10 to 219) in the Columbia River estuary growing an average of 0.5 mm per day in 2004 (Bottom 2007).

In the San Francisco Estuary, insects and crustaceans dominate the diet of juvenile Chinook salmon (Kjelson et al. 1982, MacFarlane and Norton 2002). Larval fish become increasingly important in the diet as juvenile Chinook salmon approach and enter the ocean (MacFarlane and Norton 2002). Juvenile Chinook salmon spent an average of about 40 days migrating through the Delta to the mouth of San Francisco Bay in spring 1997, but grew little in length or weight until they reached the Gulf of the Farallon Islands (MacFarlane and Norton 2002). After passing through Suisun Bay, juvenile Chinook primarily fed on the hemipteran *Hesperocorixa* sp., the calanoid copepod *Eucalanus californicus*, the mysid *Acanthomysis* sp., fish larvae, and other insects (MacFarlane and Norton 2002). In San Pablo Bay, marine crustaceans in the order Cumacea were the dominant prey of juvenile Chinook salmon. In the Central Bay, the juvenile Chinook salmon fed on insects, fish larvae, *Ampelisca abdita* (a gammaridean amphipod), and cumaceans (MacFarlane and Norton 2002). Based on the mainly ocean-type life history observed (i.e., fall-run Chinook salmon), MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show relatively little estuarine dependence and may benefit from expedited ocean entry. It is possible that the absence of extensive marsh habitats outside Suisun and San Pablo bays, and the introduction of exotic species of zooplankton, limit important food resources in the San Francisco Estuary that are present in other Pacific Northwest estuaries (MacFarlane and Norton 2001).

3.2.4 Ocean Phase

All Chinook salmon use the ocean to achieve maximum growth, although this growth is a tradeoff with high mortality, and all races of Chinook salmon deal with this tradeoff differently (Pearcy 1992). Central Valley Chinook salmon typically spend between 2 and 4 years at sea (Mesick and Marston 2007a). Most mortality experienced by salmonids during the marine phase occurs soon after ocean entry (Pearcy 1992, Mantua et al. 1997). Typically, Chinook salmon time their ocean entry to minimize predation and maximize growth; however, Chinook salmon appear to use the ―bet-hedging” strategy, adopting diverse ocean entry patterns that do not correspond to major ocean events (Pearcy 1992).

Because of the small size of juveniles entering the ocean, their movements are greatly influenced by currents during this time. Most head in a northerly direction along the coastal shelf during the first year of their life (Pearcy 1992). Williams (2006) notes that in the summer, juveniles are found in slow eddies at either side of the Golden Gate, but that their distribution shifts north beyond Point Reyes later in the fall. Knowledge of California salmon life in the ocean is extremely limited. MacFarlane and Norton (2002) were the first to describe their physiology and feeding behavior in coastal waters of central California. They compared the feeding rates and condition of fall-run Chinook salmon in the lower end of the Delta (Chipps Island), at the Golden Gate Bridge (representing the end of the San Francisco Bay), and in the Gulf of the Farallones. Results indicated that feeding and growth were reduced in the estuary, but increased rapidly in the coastal shelf in the Gulf of the Farallones (MacFarlane and Norton 2002). Fish larvae were the most important prey of juvenile Chinook salmon in the coastal waters of the Gulf of the Farallones (MacFarlane and Norton 2002). Euphausiids and decapod early life stages were also consumed in significant numbers.

Maturing Chinook salmon are abundant in coastal waters ranging from southeastern Alaska to California and their distribution appears to be related to their life-history type (stream-type or ocean-type), race, and physical factors such as currents and temperature (Healey 1991, Williams 2006). Unfortunately, little information exists on the geographic distribution of Chinook salmon in the sea. Williams (2006) reported coded-wire-tag (CWT) recoveries by fisheries management area from the Regional Mark Information System database. Results indicated that Central Valley Chinook salmon are primarily distributed between British Columbia and Monterey, California, with the highest percentages found off the coasts near San Francisco and Monterey.

Subadults feed on northern anchovy, juvenile rockfish, euphausiids, Pacific herring, osmerids, and crab megalopae along the Pacific Coast (Hunt et al. 1999). Northern anchovies and rockfish appear to be the most important prey items off the San Francisco coast (Hunt et al. 1999). It is likely that prey items change seasonally, and Chinook salmon take advantage of such changes with opportunistic feeding (Williams 2006).

3.3 Adult Migration

As Chinook salmon near sexual maturity, they attempt to return to their natal stream to spawn. Adults, particularly the stream-type fish that migrate long distances in the ocean to feed, use geomagnetic orientation in ocean and coastal waters to locate the mouth of their natal stream, where they switch to olfactory clues (Quinn 1990). The mechanism of compass orientation and the transition from compass orientation in coastal waters and estuaries to olfactory-based upriver homing appear to be very complicated and not well understood (Quinn 1990). Furthermore, ocean-type populations of Pacific salmon, such as the fall-run Chinook populations in the San Joaquin River tributaries, may not have a well-developed means of navigation by compass orientation since they do not migrate far from the coast to feed.

Adult Pacific salmon primarily rely on olfactory cues to guide the upstream migration to their natal stream, although other factors may be involved (Quinn 1990). It is generally believed that as juveniles rear and migrate downriver, they imprint on the olfactory cues at every major confluence and retrace the sequence as adults when they return to spawn (Harden-Jones 1968, Quinn et al. 1989, Quinn 1990). Few adult coho (Wisby and Hasler 1954) and Chinook salmon (Groves et al. 1968) that had their olfactory pits plugged (to prevent them from sensing waterborne odors) were able to home to their natal stream. Most (67 percent and 89 percent) of the control fish in those studies were able to home to their natal stream. Blinded fish were able to home more successfully than were fish with occluded olfactory pits. Experiments have also shown that juvenile coho salmon exposed to artificial waterborne odors while they were reared in hatcheries homed to waters that contained those artificial odors (Cooper et al. 1976, Johnsen and Hasler 1980, Brannon and Quinn 1990, Dittman et al. 1994, Dittman et al. 1996). Normal homing rates for Chinook salmon are not precisely known, but probably range between 84 percent and 99 percent, which are the homing rates calculated for hatchery-reared Chinook salmon in New Zealand (Unwin and Quinn 1993) and the Cowlitz River Hatchery, Washington (Quinn and Fresh 1984).

There is contradictory evidence that hereditary factors may also influence homing behavior. Bams (1976) and McIsaac and Quinn (1988) provided proof that a high proportion of displaced Chinook salmon offspring homed to their ancestral spawning area even though the juvenile fish were never exposed to their ancestral waters. However, Donaldson and Allen (1957) provided evidence that coho juveniles relocated to two different locations before smolting would home to their release sites and not to their original hatchery site. The scent from siblings (population-specific odors) did not affect adult coho salmon homing behavior in Lake Washington (Brannon and Quinn 1990), and no other mechanism to account for a hereditary factor has been discovered.

When adult Pacific salmon do not return to their natal stream, they appear to select a new river for spawning based on the magnitude of stream flow. Two field studies conducted by Quinn and Fresh (1984) in Washington and Unwin and Quinn (1993) in New Zealand determined that adult Chinook salmon strays selected rivers with the highest stream flow. An experimental study conducted by Wisby and Hasler (1954) also showed that when the scent of the fishes‘ natal river was not present, coho salmon moved into the arm of a forked channel with the greatest flow.

3.3.1 San Francisco Bay and Sacramento-San Joaquin Delta

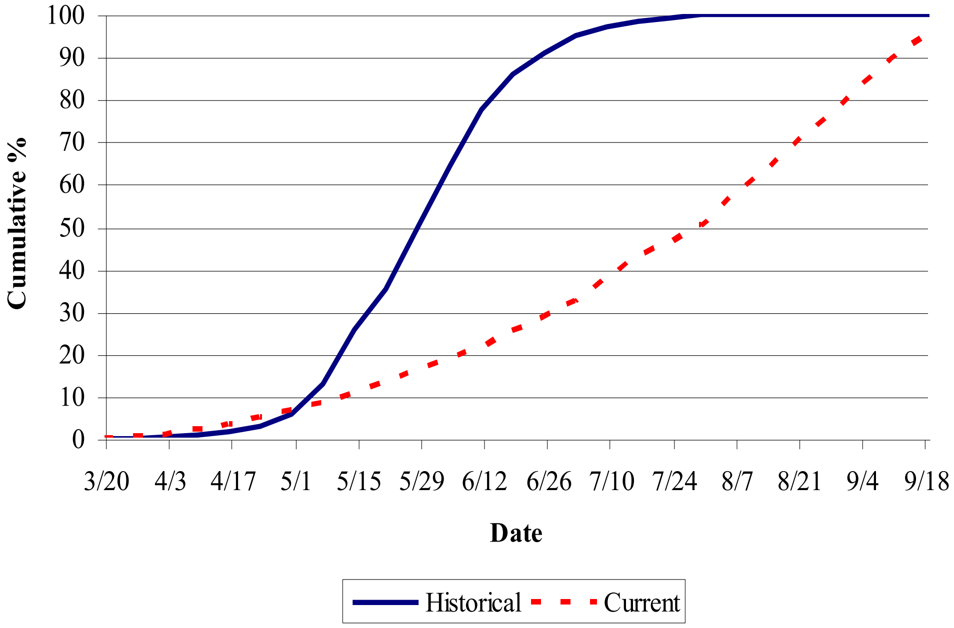
Chinook salmon runs are designated on the basis of adult migration timing as the fish enter San Francisco Bay; however, runs also differ in the degree of maturation at the time of river entry, thermal regime and flow characteristics of their spawning site, and the actual time of spawning (Myers et al. 1998). Spring-run Chinook salmon migrate upstream during the spring before they have fully reached sexual maturity, whereas fall-run Chinook salmon are sexually mature when they enter fresh water between June and December (Moyle 2002) and spawn shortly thereafter. Adult spring-run Chinook salmon begin entering San Francisco Bay in late January and early February (DFG 1998). Adult San Joaquin River Basin fall-run Chinook salmon have been collected in the Delta near Prisoners Point primarily during September and October (Hallock et al. 1970).

As adult Chinook salmon migrate through the Delta, they cease feeding (Higgs et al. 1995). Merkel (1957) found a high percentage of empty stomachs of salmon captured in North San Francisco Bay, particularly during the beginning of the spring-run Chinook salmon migration period (February and March). Merkel found no Chinook salmon in North San Francisco Bay with immature gonads, and presumed that samples from the San Francisco Bay were farther along in sexual maturity as opposed to offshore samples and as a result, the fish had ceased feeding, unlike the offshore samples (Merkel 1957). Recent study continues to verify the cessation of feeding on estuary entrance and gonadal development (DFG 1998).

Adult Chinook salmon inserted with sonic tags and tracked throughout the Delta and lower Sacramento and San Joaquin rivers were observed exhibiting substantial upstream and downstream movement in a random fashion while migrating upstream (CALFED 2001) several days at a time. Adult salmonids migrating upstream are assumed to make greater use of pool and mid-channel habitat than channel margins, particularly larger salmon such as Chinook salmon (Hughes 2004).

3.3.2 River

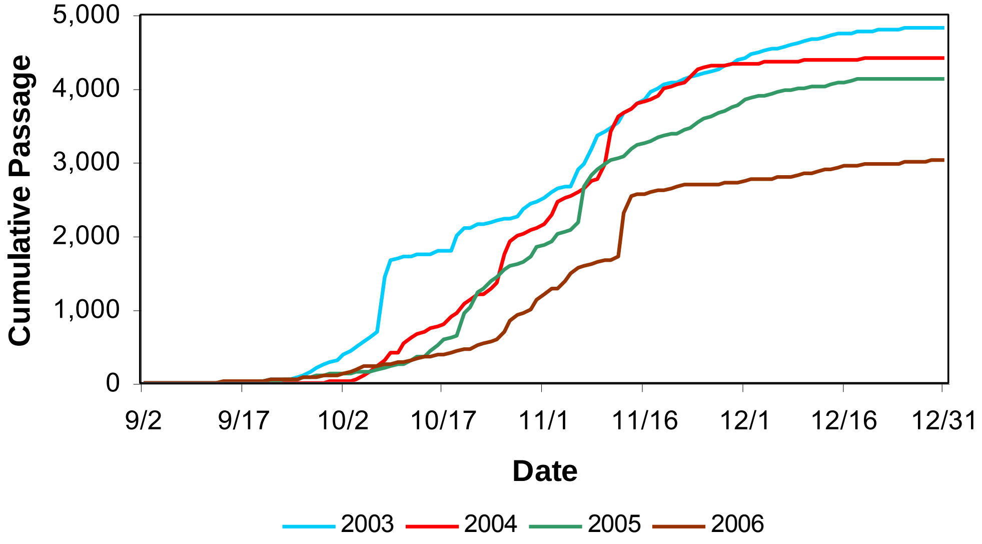
In the Sacramento River watershed (the closest population of spring-run Chinook salmon to the San Joaquin River), adult spring-run Chinook salmon historically returned to fresh water between late March and early July (Figure 3-5) (DFG 1998). The spring-run populations in Mill (Johnson et al. 2006) and Butte creeks (McReynolds 2005, personal communication) still exhibit this historical migration timing. However since 1970, most spring-run salmon in the Sacramento River upstream from the Red Bluff Diversion Dam (RBDD) migrate during the summer (Figure 3-5) (DFG 1998).



Source: DFG 1998.

Figure 3-5.
Timing of Adult Spring-Run Chinook Salmon Migrating Past Red Bluff Diversion Dam from 1970 to 1988 (Current) and Composite Data from Mill and Deer Creeks, Feather River, and Upper Sacramento River Before Construction of Shasta Dam (Historical)

Weir counts in the Stanislaus River suggest that adult fall-run Chinook salmon in the San Joaquin River Basin typically migrate into the upper rivers between late September and mid-November (Figure 3-6) (S.P. Cramer and Associates 2004, 2005; Cramer Fish Sciences 2006, 2007).



Sources: S.P. Cramer and Associates 2004, 2005; Cramer Fish Sciences 2006, 2007.

Figure 3-6.
Cumulative Number of Adult Fall-Run Chinook Salmon Counted in Stanislaus River near Riverbank (RM 31.4) with a Weir and Vaki RiverWatcher Digital Infrared Recording System from 2003 to 2006

3.4 Adult Holding

When adult spring-run Chinook salmon begin their migration to their natal streams, they are sexually immature. After they arrive in their natal streams in the spring, they hold in deep pools through the summer, conserving energy until the fall when their gonads ripen and they spawn. In the Sacramento River system, adult spring-run Chinook salmon typically hold between April and July (Yoshiyama et al. 1998) or September (Vogel and Marine 1991) and then begin spawning in late August at the higher elevations, and in October at the lower elevations (DFG 1998). While holding during the summer, spring-run adults minimize their activity, which is thought to lower metabolic rates and therefore conserve energy for eventual reproductive activities (NRC 1992, as cited in Bell 1986).

Spring-run Chinook salmon adults generally require deep pools with relatively slow water velocities as holding habitat. Deep pools remain cooler during warm summer months, and provide refuge from avian and terrestrial predators. Instream cover (e.g., undercut banks, overhanging vegetation, boulders, large wood, and surface turbulence) also provides refuge from predation. For spring-run Chinook salmon in the

Sacramento River system, Marcotte (1984) reported that the suitability of holding pools declines at depths less than 8 feet. Airola and Marcotte (1985) found that spring-run Chinook salmon in Deer and Antelope creeks avoided pools less than about 6 feet deep. In the John Day River in Oregon, adults usually hold in pools deeper than 5 feet that contain cover from undercut banks, overhanging vegetation, boulders, or woody debris (Lindsay et al. 1986). Marcotte (1984) reported that water velocities in holding pools used by spring-run Chinook in Deer and Antelope creeks ranged from 0.5 ft/s to 1.2 ft/s.

A temperature of 55°F (13°C) is considered optimal for adult holding salmonids according to the EPA (2003). Conclusions from Moyle et al. (1995) support this finding and reports water temperatures for adult Chinook salmon holding are optimal when less than 60.8ºF (16°C), and lethal when above 80.6°F (27°C) (Moyle et al. 1995). In Butte Creek, prespawn adult mortalities were minimal when average daily temperatures were less than 66.9°F (19.4°C) with only brief periods of high temperatures up to about 70°F (21°C) in July between 2001 and 2004 (Ward et al. 2006). According to Marine (1992) chronic exposures of 62.6 to 68°F (17°C to 20°C) is an incipient upper lethal water temperature limit for pre-spawning adult salmon (Marine 1992). Coutant (1970) as cited in Rich (2007) cites temperatures at 69.8 to 71.6°F (21 to 22°C) for a 1-week period as upper incipient lethal levels.

In the Stanislaus River, fall-run Chinook salmon probably do not hold for more than 1 or 2 weeks before spawning, based on the time between when they pass the Riverbank weir (S.P. Cramer and Associates 2004, 2005; Cramer Fish Sciences 2006, 2007) and the initiation of spawning (DFG 1991-2005).

3.5 Spawning

Most Chinook salmon spawn in the mainstem of large rivers and lower reaches of tributaries, although spawning has been observed over a broad range of stream sizes, from small tributaries less than 10 feet wide (Vronskiy 1972) to large mainstem rivers (Healey 1991). The adults migrate upstream until they locate a bed of gravel where water temperatures and DO concentrations are suitable for egg incubation. Adult Chinook salmon typically spawn at the tails of pools (also referred to as heads of riffles), where the fish have access to both suitably sized gravel and refuge provided by the depth of the pool (Vronskiy 1972, Chapman 1943, Mesick 2001a). Pool tails may also provide optimum conditions for egg incubation, because surface water tends to downwell into the gravel at pool tails, thereby delivering high DO concentrations to incubating eggs, and transporting metabolic wastes from the egg pocket.

Gravel suitable for spawning consists of a mixture of particle sizes from sand (0.1 to 6.0 inches (0.25 to 15.24 cm)) diameter cobbles, with a median diameter (D_{50}) of 1 to 2 inches (2.54 to 5.08 cm). D_{50} values of gravel for spring-run Chinook have been found to range from 0.4 to 3.1 inches (10.8 to 78 mm) (Platts et al. 1979, Chambers et al. 1954, 1955, all as cited in Kondolf and Wolman 1993).

Chinook salmon are capable of spawning within a wide range of water depths and velocities (Healey 1991). The water depths most often recorded over Chinook salmon redds range from 0.4 to 6.5 feet and velocities from 0.5 feet per second (ft/s) to 3.3 ft/s, although criteria may vary between races and stream basins. For example, fall-run Chinook salmon, because of their larger size, are generally able to spawn in deeper water with higher velocities (Healey 1991) than spring-run Chinook salmon, which tend to dig comparatively smaller redds in finer gravels (Burner 1951). Similarly, 4- and 5-year-old fish are generally larger than the average 3-year-old fish, and can spawn in deeper, faster water with larger gravels and cobbles.

On arrival at the spawning grounds, adult female Chinook salmon dig pits in the gravel bed that are typically 12 inches deep and 12 inches in diameter. During spawning, the female deposits about 1,500 eggs in a pit and then covers them with gravel. Over a period of 1 to several days, the female gradually digs several egg pits in an upstream direction within a single redd (Burner 1951, Healey 1991). By disturbing the gravel that surrounds the egg pocket, the female loosens the bed material and cleans some of the fine sediment from the gravel, thereby improving interstitial water flow. Females can remove from 2 percent to 15 percent of fine sediment smaller than 0.04 inch (less than or equal to1 mm) during the redd-building process, depending on the initial proportion of fines in the gravel (Kondolf 2000). Before, during, and after spawning, female Chinook salmon defend the redd area from other potential spawners (Burner 1951). Defense of a constructed redd helps to prevent subsequent spawners from constructing redds in the vicinity of an egg pocket, which can dislodge the eggs and increase egg mortality. Adult Chinook salmon females generally defend their redd until they die, usually within 1 to 2 weeks of spawning.

3.6 Adult Carcasses

There is substantial evidence that adult Pacific salmon carcasses provide significant benefits to stream and riparian ecosystems. In the past, the large numbers of salmon that returned to streams contributed large amounts of nutrients to the ecosystem (Pearsons et al. 2007, Bilby et al. 1998, Hocking and Reimchen 2002). The carcasses provide nutrients to numerous invertebrates, birds, and mammals, and nutrients from decaying salmon carcasses are incorporated into freshwater biota (Helfield and Naiman 2001, Bilby et al. 1998), including terrestrial invertebrates (Hocking and Reimchen 2002). Helfield and Naiman (2001) found that nitrogen from carcasses is incorporated into riparian vegetation. Merz and Moyle (2006) found marine-derived nitrogen incorporated into riparian vegetation and wine grapes. Merz and Moyle (2006) also compared relative nitrogen contribution rates between salmon-abundant and salmon-deprived rivers. The results indicated that salmon-abundant rivers had much more marine-supplied nitrogen than nonsalmonid-bearing rivers (Merz and Moyle 2006). This nutrient supply is a positive feedback loop in which nutrients from the ocean are incorporated into riparian growth that in turn provides ecosystem services by providing additional growth and development of the riparian system. Carcass nutrients are so important to salmonid stream ecosystems that resource managers spread ground hatchery salmon carcasses in Washington streams (Pearsons et al. 2007).

Chapter 4 Stressors

A number of documents have addressed the history of human activities, current environmental conditions, and factors contributing to the decline of Chinook salmon in the Central Valley. The San Joaquin River Restoration Study Background Report (McBain and Trush 2002) describes the changes in habitat and likely stressors that will affect Chinook salmon in the Restoration Area. The Final Restoration Plan adopted for the Anadromous Fish Restoration Program in 2001 (USFWS 2001) identifies many stressors that affect spring-run and fall-run Chinook salmon in the Central Valley. The Final Program Environmental Impact Statement/Report (PEIS/R) for the CALFED Bay-Delta Program (CALFED) (CALFED 2000) and the Final PEIS for the Central Valley Project Improvement Act (CVPIA) provide summaries of historical and recent environmental conditions for Chinook salmon and steelhead in the Central Valley. National Marine Fisheries Service (NMFS) prepared range-wide status reviews and recovery plans for West Coast Chinook salmon (Myers et al. 1998, NMFS 2009)). NMFS also assessed the factors for Chinook salmon decline in a supplemental document (NMFS 1996). The following summarizes the information from these documents as well as more recent research on Chinook salmon and their habitats in the Central Valley and other West Coast rivers.

Stressors are defined as physical, chemical, or biological perturbations to a system that adversely affects ecosystem processes, habitats, and species. Examples include altered flows, blocked passage, blocked sediment recruitment, instream habitat alteration, invasive species, contaminants, and excessive salmon harvest. Stressors that significantly influence the abundance and productivity of Chinook salmon populations are considered limiting factors for that particular population.

Stressors are discussed here according to each life history stage of Chinook salmon: (1) egg survival and emergence, (2) juvenile rearing, (3) smoltification and downstream migration, (4) ocean survival, (5) adult migration, (6) adult holding for spring-run Chinook salmon, and (7) spawning. In addition, the potential effects of releasing hatchery-reared juvenile Chinook salmon and climate change are discussed in terms of recovering naturally spawning populations. The following discussion generally pertains to both spring- and fall-run Chinook salmon, particularly for the juvenile stages, which typically use the same habitats at the same times. The discussion of stressors that affect adult stages will include issues specific for each run.

4.1 Egg Survival and Emergence

Stressors that may affect the survival of eggs and emergence of alevins in the San Joaquin River include high water temperatures, sedimentation (fines deposited in the substrate), turbidity (suspended clay-sized particles), and redd superimposition. Chinook salmon egg mortality rapidly increases as water temperatures exceed 57°F (13.9°C). High rates of sedimentation of the spawning gravels reduce intragravel flows and potentially entomb alevins. High levels of turbidity can coat the egg membrane with clay-sized particles that inhibit its ability to absorb oxygen or excrete metabolic wastes.

Other potential stressors for incubating eggs, such as predation, anglers walking on redds, and streambed scour, are not expected to be significant within the Restoration Area. Eggs incubating in natural gravels in the San Joaquin River Basin are probably protected from large invertebrate (e.g., crayfish) or fish (e.g., sculpin) predators because the interstitial spaces in the gravel are too small for predators to reach the egg pockets. Sculpin and crayfish are capable of penetrating deeply into streambeds to feed on salmon eggs and alevins but only where the gravel is coarse and free of fine sediments (McLarney 1964, Phillips and Claire 1966, Vyverberg 2004, pers. comm.). It is also unlikely that walking on redds would harm incubating eggs because the eggs are typically 12 inches below the surface of the gravel and natural gravel beds do not shift easily or otherwise move when walked upon. Montgomery et al. (1996) reported that the tops of chum salmon (*O. keta*) egg pockets were below the level of scour depth that occurred during frequent, bankfull flows in a small West Coast stream. It is likely that Chinook salmon bury their eggs at greater depths than chum salmon (DeVries 1997), therefore, streambed scour should be an unlikely source of mortality for incubating eggs in the Restoration Area.

4.1.1 Excessive Sedimentation and Turbidity

Koski (1966) reported that a majority of mortality in redds was caused by the inability of alevins to emerge due to excessive amounts of fine sediments in the redd. He found numerous dead coho salmon alevins that were completely buttoned-up but extremely emaciated at a depth of 8 inches. Beschta and Jackson (1979) showed that in a flume, fines 0.5 mm in diameter tend to form a barrier in the upper 10 cm of the gravel bed that ―seals” against intrusion of fines into the egg pocket but also creates a barrier to emergence. This barrier has been described in salmon redds as a mixture of coarse sand and fines 6 to 12 inches above the egg pocket (Hawke 1978) that has a geometric mean diameter (d_g) lower than the substrate above and below the middle layer (Platts et al. 1979). Bams (1967) reported that when sockeye salmon alevins confronted a sand barrier, they ―butted” upward to loosen sand grains and form an open passage to the substrate surface. Koski (1966) reported that the number of days for the first coho salmon alevins to emerge was unaffected by the amount of fines, but that the total duration of emergence for all alevins was longer in redds with high percentages of fines.

Quantification of alevin entombment relative to the amount of fines has been difficult. Researchers who evaluated emergence rates by capping natural redds with nets, such as Koski (1966, 1975), Tagart (1976), and Tulock Irrigation District (TID) and Merced Irrigation District (MID) (1991), cannot accurately estimate egg survival to emergence (Young et al. 1990) because they did not estimate egg viability, fertilization success, the loss of eggs during deposition in the egg pocket (Young et al. 1990), or escapement of fry that migrate under the trap‘s netting (Garcia De Leaniz et al. 1993).

Laboratory studies suggest that alevin entombment occurs over a range of substrate particle sizes, including those less than or equal to 0.85 mm (Shelton and Pollock 1966), less than or equal to 3.3 mm (Koski 1966), less than or equal to 4.67 mm (Tapple and

Bjornn 1983), and less than or equal to 6.4 mm (McCuddin 1977). However, these studies tested the ability of large, healthy alevins to emerge under high concentrations of sand, which is an abnormal condition considering that high concentrations of sand typically result in low DO levels and small, weak alevins.

Flood events, and land disturbances resulting from logging, road construction, mining, urbanization, livestock grazing, agriculture, fire, and other uses may contribute sediment directly to streams or exacerbate sedimentation from natural erosive processes (California Advisory Committee on Salmon and Steelhead Trout 1988, NMFS 1996). High permeability measurements in Reach 1A approximately 5 years ago suggest that sedimentation has not been a problem (Stillwater Sciences 2003). Furthermore, turbidity levels are usually low in the San Joaquin River Basin until high rates of runoff occur in January or February, which is after a majority of the eggs have hatched.

4.1.2 Excessively High Water Temperatures

Target incubation temperatures for Chinook salmon are daily maximums of less than 55°F (13°C) (EPA 2003). Water released from Friant Dam should be less than 58°F (14°C) throughout the spawning period as long as the cold water pool in Millerton Lake is not exhausted. The HEC 5Q water temperature model developed for the Restoration Area (Deas and Smith 2008) suggests that implementing the Restoration Flow Schedule could result in maximum temperatures of the Friant release flows of under 62°F (16.7°C) in October or November (Figure 4-1). Using hydrologic and climatic conditions from 1980 to 2005, the temperature of the release flows would exceed 60°F during 20 years of the 26-year period (Figure 4-1). It is possible that these temperatures could result in Chinook salmon egg mortality rates of about 50 percent.

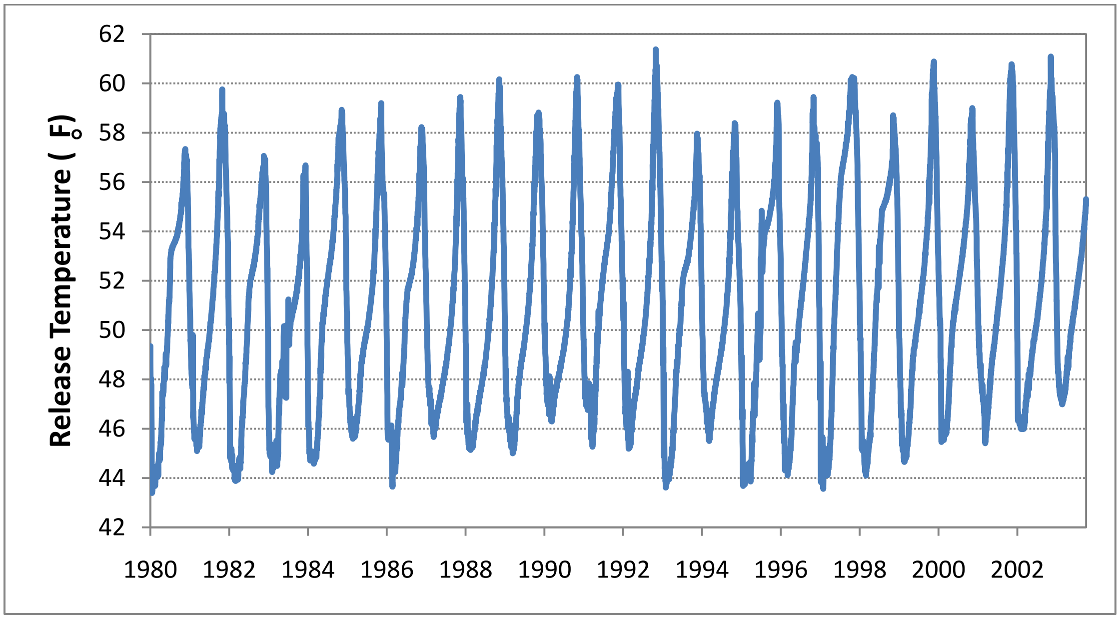


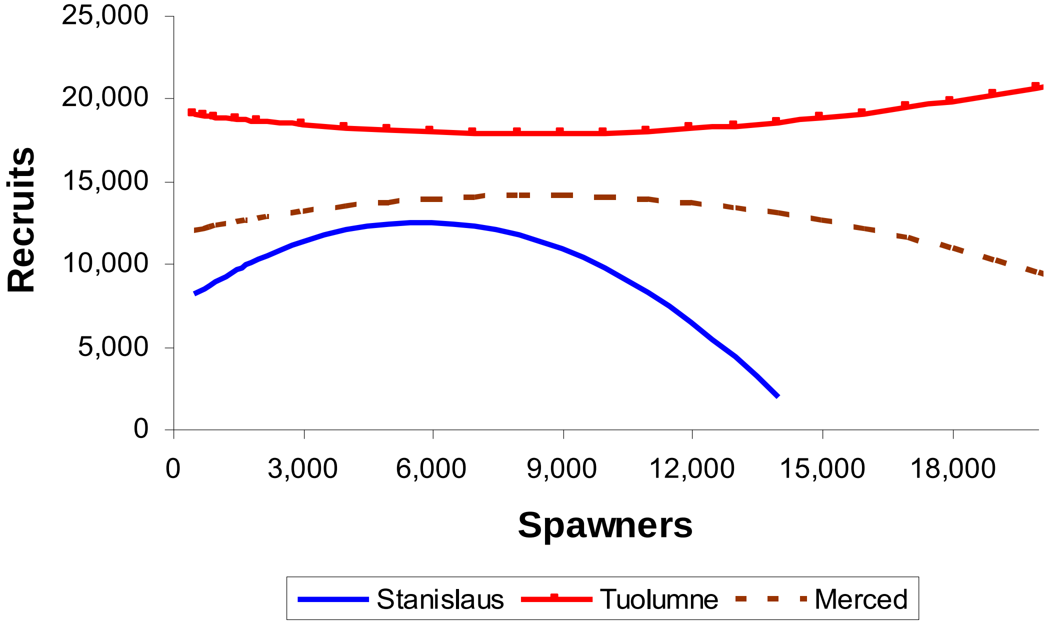
Figure 4-1.
Results of HEC 5Q Water Temperature Model Showing Predicted Water Temperatures of Releases from Friant Dam if Restoration Hydrograph Releases Were Made Under Hydrologic and Climatic Conditions from 1980 to 2004

4.1.3 Redd Superimposition

Redd superimposition occurs when spawning fish construct new redds on top of preexisting redds such that either the eggs in the preexisting redd are either destroyed (dug up) or buried under fines that prevent most of the fry from emerging. Redd superimposition has been reported for the Stanislaus River (Mesick 2001a), American River (Vyverberg 2004, pers. comm.), and the Tuolumne River (TID and MID 1991). Redd superimposition can occur at low escapements and in areas with ample high-quality spawning habitat (Mesick 2001a), presumably because spawners prefer to dig redds in the loose gravels provided by preexisting redds that are no longer guarded by the original female. Redd superimposition does not necessarily kill the eggs or entomb the alevins in the original egg pocket, because most superimposing redds are not constructed exactly on top of preexisting redds but rather several feet to the side as well as several feet upstream or downstream from the original redd. Entombment would only occur in superimposed redds constructed in spawning beds where the concentration of fines was relatively high.

Redd superimposition rates in the Stanislaus River were estimated during fall 2000 when escapement was relatively high by monitoring superimposition at 82 artificial redds that were constructed in late October before most of the fall-run fish had begun to spawn (Carl Mesick Consultants 2002). In this study, redd superimposition completely disturbed 15 percent of the artificial egg pocket areas (presumably with 100 percent egg mortality) and buried another 23 percent of the artificial egg pocket areas with gravel and fines that could entomb some or all of the alevins.

It is unlikely that redd superimposition limits adult recruitment in the Stanislaus, Tuolumne, and Merced rivers because many more fry are produced at high spawner densities than can be sustained by the quality of the rearing habitat. Spawner-recruitment relationships for the Tuolumne and Merced rivers are relative flat (Figure 4-2) (Mesick and Marston 2007b), which suggests that high densities of spawners do not reduce adult recruitment to a significant degree. Although a high density of adult spawners has reduced adult recruitment in the Stanislaus River (Figure 4-2), rotary screw trap evidence indicates that many more fry were produced than the number of smolt outmigrants from 1998 to 2004 when spawner abundance ranged between 2,400 and 11,650 fish (Mesick and Marston 2007b).



Source: Mesick and Marston 2007b.
Note:
A categorical variable called "Population Shift" was used for all three rivers to account for a shift in recruitment that occurred sometime between 1987 and 1994.
The relationships are based on regression models of recruits, quadratic spawner terms (a2 +a +c), and a mean Vernalis flow of 7,000 cubic feet per second from March 1 to June 15.

Figure 4-2.
Spawner-Recruit Relationships for Stanislaus, Tuolumne, and Merced Rivers

4.2 Juvenile Rearing and Migration

Likely stressors for juvenile Chinook salmon rearing in and migrating through the Restoration Area include inadequate food resources, high water temperatures, predation, entrainment at unscreened diversions, contaminated runoff from agriculture and housing development, and disease. These stressors are primarily influenced by flow diversions, agricultural practices, urban development, and gravel excavations.

Except during flood years, a relatively small number of Chinook salmon fry that migrate into the lower San Joaquin River (below the confluence with the Merced River) from the San Joaquin River tributaries and Delta are thought to survive. Ocean recovery rates of the fry obtained from the Coleman National Fish Hatchery and tagged with coded wire half tags indicate that fry survival was lower in the Central Delta near the mouth of the Mokelumne River than in the North Delta near Courtland, Ryde, or Isleton during dry years, although the difference was not statistically significant (Brandes and McLain 2001). However, during flooding in 1982 and 1983, tagged fry survived at similar rates in the Central Delta and South Delta in the Old River compared to the North Delta (Brandes and McLain 2001). The poor survival of juveniles rearing in the Delta in dry and normal water years may be caused by predation, entrainment at numerous small, unscreened diversions, unsuitable water quality, high water temperatures, inadequate food resources, and direct mortality at the Federal and State pumping facilities in the Delta. Entrainment at the Delta pumping facilities may be minimal during very wet years because tagged fry were collected at the pumping facilities only during the dry years whereas none were collected in wet years (Brandes and McLain 2001). Although the fry migration life stage does not appear to contribute as much to current production of the population in San Joaquin River tributaries and the Delta, it may be an important life stage in rivers with functional floodplain habitats in downstream reaches, such as Sutter Bypass on Butte Creek (Ward and McReynolds 2001, Ward et al. 2002) and possibly in restored floodplain and wetland habitats in the lower Restoration Area, where fry can rapidly grow to a smolt size because of warmer water temperatures and abundant food resources.

4.2.1 Food Resources

The survival of juvenile Chinook salmon to the adult stage partially depends on their ability to grow rapidly enough to begin their downstream migration as smolts early in the spring when their chances are highest to survive their migration through the Delta and estuary to the ocean. In addition, it is highly likely that large, healthy smolts will survive their migrations at higher rates than would smaller, poorly fed smolts.

Food resources in the Restoration Area may be adversely affected by a combination of factors:

- Reduced flows or dikes that substantially reduce the contribution of organic matter and prey-sized invertebrates from inundated floodplains
- Sedimentation and gravel extraction that affects the production of in-river, prey-sized invertebrates
- Lack of nutrients provided by low numbers of adult Chinook salmon carcasses
- Reduced native riparian and wetland vegetation that is the primary basis of the aquatic food web
- Lack of organic matter and prey-sized invertebrates from upstream reservoirs
- Pesticides and other contaminants that reduce the abundance of food organisms
- Competition for food with native and introduced species

Floodplain Inundation and River Connectivity

Most of the energy that drives aquatic food webs in rivers is derived from terrestrial sources (Allan 1995), and aquatic productivity is related to flood magnitude and the area inundated in some rivers (Large and Petts 1996). Flooding, particularly the rising limb of the hydrograph (i.e., period of increasing flow), typically results in high concentrations of both dissolved and particulate organic matter being released into the river (Allan 1995). High flows that inundate floodplains also provide food for juvenile fish that rear in floodplain habitats. Research in other river systems has shown that production of invertebrates, the most important prey resource for many fishes, on inundated floodplains can far exceed river production. Sommer et al. (2001) found that drift invertebrates, the primary prey of juvenile salmonids, were more abundant on the inundated Yolo Bypass floodplain than in the adjacent Sacramento River. As a result, feeding success, growth, and survival, of juvenile Chinook salmon were higher in the Yolo Bypass, the primary floodplain of the lower Sacramento River, than in the adjacent mainstem channel in 1998 and 1999 (Sommer et al. 2001). Gladden and Smock (1990) estimated that annual invertebrate production on two Virginia floodplains exceeded river production by one to two orders of magnitude.

Floodplain habitats tend to produce small invertebrates with short life cycles such as chironomids and cladocerans (McBain and Trush 2002). However, the duration and frequency of floodplain inundation can be an important determinant of invertebrate production and community structure. In the Virginia floodplains, annual production on the floodplain continuously inundated for 9 months was 3.5 times greater than on the floodplain inundated only occasionally during storms (Gladden and Smock 1990). On Cosumnes River floodplains, Grosholz and Gallo (2006) found that the invertebrate community structure was regulated by the timing and duration of inundation of the floodplain. Planktonic crustaceans emerged first, followed by insect macroinvertebrates. Importantly, juvenile fish diets tracked the species composition of the emerging invertebrate community subsequent to inundation of the floodplain.

Lateral connectivity of river channels to adjacent floodplains has been shown to be an important control on the timing, composition, and total invertebrate biomass in a river. In the Rhone River Basin, Castella et al. (1991) showed, using a series of connectivity indices, that invertebrate diversity and biomass in the river can be linked to the connectivity of the river to its floodplain. The mainstem San Joaquin River is bordered by San Joaquin River Flood Control District levees and individual landowner levees (McBain and Trush 2002) resulting in a separation of much of the river from its historic floodplain.

Invertebrate colonization of a rewatered river channel or newly inundated floodplain is regulated by three primary mechanisms: proximity to a source of colonists, the *in situ* invertebrate ―seedbank” in the substrate, and the timing and duration of inundation. In Alabama‘s Sipsey River, Tronstad et al. (2005) showed that invertebrate species composition and the timing of recolonization is controlled by the frequency of inundation of invertebrate ―seedbanks” in floodplain soils: recently inundated soils had faster rates of emergence and greater species diversity than soils with a longer interval between periods of inundation. This disparity suggests that invertebrate production in newly rewatered reaches and adjacent floodplains of the San Joaquin River may be directly related to the length of time since they were last wetted. Constructed floodplains, for example, may take considerably longer to become productive than bypass channels that receive flood flows during periodic storm events. The invertebrate community in the upper Sacramento River recovered to a composition similar to undisturbed sections of the river within 1.5 years after sterilization by a chemical spill (Boullion 2006 as cited in Cantara Trustee Council 2007). The source of invertebrates from immediately upstream areas likely contributed to the rapid recolonization of the upper Sacramento River, and a similar situation can be expected when Restoration Flows are released into the formerly dewatered reaches of the San Joaquin River in the Restoration Area.

The physical habitat structure of the rewatered habitat also plays a role in the rate, composition, and maintenance of invertebrate communities. Hilborn (1975) demonstrated that habitat heterogeneity is a fundamental control on ecosystem community structure. A simple sand-bedded channel with no riparian habitat (i.e., homogeneous habitat) will typically have lower invertebrate diversity than a comparable channel that is more complex and includes substrate size variability and developed riparian vegetation. Fundamentally, channel heterogeneity equates to more niches for more types of invertebrates. For example, Benke (2001) found that invertebrate diversity and biomass in Georgia rivers was higher in a system with a well developed floodplain and abundant instream woody material (IWM) in the river, than in an otherwise similar system with lower habitat diversity. In the Restoration Area, channels and floodplains with existing habitat complexity (e.g., riparian vegetation, IWM) are likely to support higher invertebrate production and diversity than homogeneous channels or newly constructed floodplains.

Indirect Effects of Pesticides and Other Contaminants

It is likely that contaminants usually do not kill juvenile salmonids directly, but instead substantially reduce their food resources or increase their susceptibility to disease or pathogens. However, the observed concentrations of organophosphate pesticides in water samples collected in the San Joaquin River at Vernalis and most other locations in the Delta in January through April in 2001 and 2002 shortly after rainfall events, when contaminant levels are highest (Werner et al. 2003), were seldom toxic to two cladocerans (*Ceriodaphnia dubia*, and *Simocephalus vetelus*), a chironomid larvae (*Chironomus tentans*), and an amphipod (*Gammarus daiberi*). Results of surveys conducted between 1992 and 2000 suggest that the amounts of organophosphate pesticides applied as dormant sprays in the San Joaquin River Basin have steadily decreased over the past decade, although they still exceed criterion maximum concentration levels established by DFG (Orlando et al. 2003). Since 1993, there has been a shift in insecticides in the Central Valley from organophates to permethrin and finally to new compounds of pyrethroids, which are nearly 20 times more toxic to aquatic invertebrates and fish than permethrin (Amweg et al. 2005). Fresno, Madera, and Stanislaus are three of four counties with the greatest pyrethroid use in the San Joaquin River watershed. Pyrethroids are the likely cause of frequent sediment toxicity in the westside subbasin of the San Joaquin River Basin. The sediment has been categorized as highly toxic based on *H. azteca* mortality. *Hyalella azteca* is an epibenthic freshwater amphipod that shows sensitivity to toxic compounds adsorbed to the sediment, including herbicides and pyrethroid pesticides. A *H. azteca* 10-d survival and growth toxicity test is used to assess toxicity from pyrethroids and other compounds adsorbed to the sediment. Two examples of commonly used pyrethroids that are found in sediments are bifenthrin (Type I pyrethroid) and esfenvalerate (Type II pyrethroid).

Bed sediments of the San Joaquin River had trace amounts of bifenthrin during the irrigation season (Domagalski et al. 2009). Bifenthrin was one of the most commonly detected pyrethroids in bed sediments. Bifenthrin is one of the pyrethroids of greatest toxicological concern in urban runoff (Holmes et al. 2008) because of its residential use (Weston et al. 2005). In the San Joaquin River, one sample on the downstream edge of Stockton was toxic to *Hyalella*, probably because of bifenthrin (Weston and Lydy 2009).

East-side tributaries and the San Joaquin River had very little mortality from sediment toxicity. However, small west side creeks have most frequent occurrence and highest toxicity of bed sediments.

Unfortunately, there are not enough field monitoring data on the spatial and temporal occurrences of pyrethroids for making risk assessments to date (Oros and Werner 2005).

Sedimentation and Gravel Extraction

Sedimentation, which is the deposition of fine sand (less than or equal to 0.2 mm), and gravel extraction, which created ditches and ponds in the riverbed and floodplain, have probably reduced the availability of food resources for juvenile Chinook salmon and steelhead in the Restoration Area. Waters (1995) suggested that a change from gravel and cobble riffles to deposits of silt and sand results not only in a decrease in abundance of invertebrates that are important prey, but also results in a change in invertebrate species from those inhabiting the interstitial spaces of large particles to small, burrowing forms less available to fish. However, captured mine pits in the San Joaquin River Basin typically store large volumes of organic matter and contain dense growths of aquatic vegetation. There is an abundant —hatch” of adult aquatic insects from these ponds, and it is possible that these ponds provide more food than is produced in the main channels.

Nutrients from Adult Salmon Carcasses

After spawning, adult Chinook salmon carcasses remain in the stream corridor to decompose, and are an important food and nutrient source within a watershed (Cederholm et al. 1999). Decomposing salmon carcasses are recognized as a source of marine-derived nutrients that play an important role in the ecology of Pacific Northwest streams (Gresh et al. 2000). On the Olympic Peninsula in Washington, 22 different animal species were observed feeding on salmon carcasses (Cederholm et al. 1999). Carcass nutrients can affect the productivity of algal and macroinvertebrate communities that are food sources for juvenile salmonids. Decomposing salmon carcasses have also been shown to be vital to the growth of juvenile salmonids (Bilby et al. 1998; Bilby et al. 1996, as cited in Gresh et al. 2000).

The relatively low abundance of Chinook salmon and steelhead has significantly reduced this important nutrient source in the Central Valley, and throughout the Pacific Northwest. Gresh et al. (2000) estimated that the annual biomass of salmon entering Pacific Northwest streams (California, Oregon, Washington, Idaho) was historically on the order of 352 million pounds, and has been reduced to only approximately 26 million pounds, a reduction of more than 93 percent. Channelization and removal of IWM can also decrease the retention of salmon carcasses and reduce nutrient input.

Riparian Vegetation

Historically, canopy species within the riparian corridor in the upper reaches of the Restoration Area (Reaches 1 and 2A) consisted of a patchy band of cottonwoods, willows, and valley oaks on floodplain and terrace surfaces between the confining bluffs. In the downstream reaches (downstream from Mendota), there were large flood basins (low-lying areas adjacent to the river channel) dominated by tule marsh on both sides of the river, often many miles wide. Riparian canopy species (cottonwood, willow, valley oak) were limited to relatively narrow bands (typically less than 1,000 feet wide based on 1914 maps) of mineral soil berms deposited along channels that dissected the vast tule marsh.

Conversion of native vegetation types to agriculture, aggregate mining, and urban development has strongly impacted the San Joaquin River‘s wetlands and riparian habitat. As of 1998, approximately 25,380 and 6,030 acres of riparian and wetland habitats have been converted to agricultural and urban uses, respectively (McBain and Trush 2002). Approximately 4,610 and 1,920 acres of riparian forest and riparian scrub, respectively, were present in 1998 (McBain and Trush 2002).

The San Joaquin riparian corridor, like most California landscapes, is host to many nonnative invasive plant species. In 2000, the California Department of Water Resources (DWR) mapped vegetation along the San Joaquin River from Friant Dam to the confluence with the Merced River (DWR 2002). DWR identified 127 nonnative plant species – 50 percent of all plant species identified. The primary nonnative invasive species identified by DWR include tree-of-heaven, giant reed, pampas grass, eucalyptus, edible fig, white mulberry, Lombardy poplar, castor bean, Himalayan blackberry, scarlet wisteria, and tamarisk (DWR 2002). The DWR effort also recorded parrot‘s feather, a highly invasive aquatic plant. Nonnative invasive plant species cover 99 acres along the river corridor in nearly monospecific stands, and occur as a component of most, if not all, native vegetation types (McBain and Trush 2002). These plant species are particularly abundant in Reach 1, where high levels of disturbance may have aided their spread, as suggested by their distribution in and around aggregate mining pits (McBain and Trush 2002).

Exotic plant species can alter the structure and dynamics of natural ecosystems. Nonnative plant species can impact native wildlife by displacing native vegetation that is used for nesting or as a food source. Once established, nonnative plant species can alter nutrient cycling, energy fixing, food web interactions, and fire and other disturbance regimes, to the extent that the native landscape is changed. Habitat fragmentation contributes to the spread of nonnative species by increasing edge habitat, which provides greater opportunities for invasion by exotic species (Cox 1999). Ecosystem alterations resulting from nonnative plant species invasions can be exacerbated by activities such as overgrazing and vegetation clearing that create favorable conditions for further nonnative plant establishment (Cox 1999, Randall and Hoshovsky 2000). Alteration of historical flooding regimes by flow regulation further promotes invasions by nonnative species by eliminating processes necessary for recruiting and maintaining native plant species (Cox 1999).

Reservoir Productivity

The San Joaquin River Basin upstream from Millerton Lake consists of granitic soils with low mineral nutrient content (Reclamation 2006). Partly as a result, Millerton Lake is low in total dissolved solids (TDS) and has low levels of chemical nutrients (Dale Mitchell, 2006, pers. comm.). Little information is available regarding the plankton communities of Millerton Lake, but there is evidence that plankton production varies considerably on a seasonal basis. Cladocerans in the genus *Leptodora* (water fleas) have been observed to be abundant in Millerton Lake during summer months, with population crashes commonly occurring in September (Dale Mitchell 2006, pers. comm.). Threadfin shad in Millerton Lake are known to feed extensively on *Leptodora*, indicating that this organism may be seasonally available as a food source for fishes in the San Joaquin River downstream from Friant Dam.

Competition with Native and Introduced Species

Some nonnative fish species have habitat requirements that overlap with those of native species. These species may be more aggressive and territorial than native species, resulting in the exclusion of native species from their optimal habitats. Many of the nonnative species, such as green sunfish, also tolerate extremely high water temperatures and appear better able to persist in water with low DO, high turbidity, and contaminants than native fishes.

The arrival of the Asiatic clams (*Corbicula fluminea* and *Corbula amurensis*) in the San Francisco Estuary disrupted the normal benthic community structure and depressed phytoplankton levels in the estuary due to the highly efficient filter feeding of these clams (Cohen and Moyle 2004). The decline in the levels of phytoplankton reduces the population levels of zooplankton that feed on them, and hence reduces the forage base available to salmonids transiting the Delta and San Francisco Estuary. This lack of forage base can adversely impact the health and physiological condition of these salmonids as they migrate through the Delta to the Pacific Ocean.

Introductions of exotic zooplankton species have supplanted other zooplankton species that provided important food resources for fish in the upper San Francisco Estuary (Hennessy and Hieb 2007). In 1993, *Limnoithona tetraspina*, an introduced cyclopoid copepod, mostly replaced the historically common and larger *L. sinensis*. The introduced copepod (*Pseudodiaptomus forbesi*) along with the Asiatic clam contributed to the decline of the calanoid copepod (*Eurytemora affinis*) beginning in the late 1980s. *E. affinis* was an important food resource for juvenile fish. The introduced calanoid copepod (*Sinocalanus doerrii*) was first recorded in spring 1979. In contrast, the native cladocerans (*Bosmina*, *Daphnia*, and *Diaphanosoma*) and the native rotifer (*Synchaeta bicornis*) have gradually declined since the early 1970s. It is likely that relatively small exotic species, such as *L. tetraspina*, are not as important in the juvenile salmonid forage base as were the displaced native species.

4.2.2 Disease

USFWS conducted a survey of the health and physiological condition of juvenile fall-run Chinook salmon in the San Joaquin River and its primary tributaries, the Stanislaus, Tuolumne, and Merced rivers, during spring 2000 and 2001 (Nichols and Foott 2002). *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease (BKD), was detected in naturally produced juveniles caught in rotary screw traps from the Stanislaus and Tuolumne rivers and juveniles caught with a Kodiak trawl at Mossdale in the San Joaquin River. No gross clinical signs of BKD were seen in any of the fish examined. However, these low-level infections might remain active after the fish enters the ocean where the clinical symptoms might develop.

Proliferative kidney disease (PKD) was detected in both natural and hatchery juveniles from the Merced and mainstem San Joaquin rivers in 2000 and 2001 (Nichols and Foott 2002) and in natural juveniles from the Merced River in 2002 (Nichols 2002). The myxozoan parasite *Tetracapsula bryosalmonae*, which causes PKD, was detected in the kidney samples of only 2 percent of the juvenile Merced River fish in April 2000, but in 90 percent of the April 2001 samples, 100 percent of the May 2001 samples, and 51 percent of the April 2002 samples. Heavy infections were observed in 22 percent of the samples in 2002 (Nichols 2002). These data suggest that the incidence of pathogen infection is low in above-normal water years such as 2000 compared to dry water years such as 2001 and 2002. PKD has been described at the Merced River Fish Hatchery since the 1980s and in California since at least 1966. It compromises the fish‘s performance in swimming, salt water entry, and disease resistance (Nichols and Foott 2002). Nichols and Foott (2002) suggested that PKD could be a significant contributor to mortality in natural fish.

Columnaris disease, caused by the bacterium *Flexibacter columnaris*, was observed in juvenile Chinook salmon caught in rotary screw traps in the Stanislaus River in spring 2007. The disease can rapidly increase in the population as water temperatures reach a mean daily temperature of 68 to 69.8°F (20 to 21°C). Along with the protozoan *Ichthyophthirius multifillis* (also referred to as Ich), columnaris was a leading cause of adult salmon mortality in the lower Klamath River in 2002.

There were no signs of infection from pathogenic species of bacteria, including *Aeromonas salmonicida, Yersinia ruckeri,* and *Edwardsiella tarda*, in the San Joaquin River Basin during spring 2001 (Nichols and Foott 2002). Although *Myxobolus cerebralis*, the causative agent of whirling disease, was not detected in a pooled sample of 194 fish, the parasite has been detected in rainbow trout from the Stanislaus River. Tests were not conducted for *Flavobacterium columnare*.

The pathogen *Ceratomyxa* is present in the Central Valley and studies indicate that it causes a high mortality rate of Chinook smolts migrating through the lower Willamette River, Oregon (Steve Cramer 2001, pers. comm.). This disease relies on tubifix worms for an intermediate host and the worms flourish in organic sediments. It is likely that the worms multiply and the disease spreads in years when organic sediments are not flushed by high flows. There are indications that mortality of smolts due to this disease increases in drought years and decreases in wet years. *Ceratomyxa* disease is a particular concern for the San Joaquin River because there is a tubifex worm farm located in Reach 1A, at RM 261 (Jones and Stokes 2002a). It is also possible that organic sediments accumulate and produce tubifex worms in captured mine pits.

4.2.3 Predation

Fish species in the Restoration Area that will probably prey on juvenile Chinook salmon include largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), Sacramento pikeminnow (*Ptychocheilus grandis*), green sunfish (*Lepomis cyanellus*), warmouth (*L. gulosus*), black crappie (*Pomoxis nigromaculatus*), and striped bass (McBain and Trush 2002). DFG (2007a) electrofishing surveys of the Restoration Area in 2004 and 2005 indicated that largemouth and spotted bass (*M. punctulatus*) were prevalent as far upstream as Reach 1B and were very common in the lower reaches of the river. Largemouth bass are adapted to low flow and high water temperature habitats and typically inhabit captured mine pits in the San Joaquin River Basin. Smallmouth bass are adapted to riverine habitats but are also relatively inactive when water temperatures are low. Large salmonids, such as rainbow trout at least 140-mm FL, would also be expected to prey on juvenile Chinook salmon. Although planted catchable-sized rainbow trout might prey on juvenile Chinook salmon, it is DFG policy not to plant hatchery trout in rivers that contain anadromous fish populations, such as Chinook salmon.

Juvenile salmonids are also susceptible to avian predators. Species including California gulls, ring-billed gulls, Caspian terns, double-crested cormorants, and American white pelicans have been documented to prey on outmigrating steelhead and salmon as they pass through dams on the Columbia and Snake rivers (Bayer 2003). Fish-eating birds that occur in the California Central Valley include great blue herons (*Ardea herodias*), gulls (*Larus spp*.), osprey (*Pandion haliaetus*), common mergansers (*Mergus merganser*), American white pelicans (*Pelecanus erythrorhynchos*), double-crested cormorants (*Phalacrocorax spp*.), Caspian terns (*Sterna caspia*), belted kingfishers (*Ceryle alcyon*), black-crowned night herons (*Nycticorax nycticorax*), Forster‘s terns (*Sterna forsteri*), hooded mergansers (*Lophodytes cucullatus*), and bald eagles (*Haliaeetus leucocephalus*) (Stephenson and Fast 2005). These birds have high metabolic rates and require large quantities of food relative to their body size.

Predation in Central Valley Rivers

High predation rates are known to occur below small dams, such as RBDD and Sack Dam in the Restoration Area. As juvenile salmon pass over small dams, the fish are subject to conditions that may disorient them, making them highly susceptible to predation by other fish or birds. In addition, deep pool habitats tend to form immediately downstream from the dams where Sacramento pikeminnow (*Ptychocheilus grandis*), striped bass, and other predators congregate. Tucker et al. (1998) showed high rates of predation by Sacramento pikeminnow and striped bass on juvenile salmon below the RBDD.

EA Engineering, Science and Technology (TID and MID 1992), conducted river-wide electrofishing surveys in the Tuolumne River in spring 1989 and 1990, and found that few largemouth and smallmouth bass contained naturally produced juvenile Chinook salmon in their stomachs, whereas bass had numerous hatchery-reared juvenile Chinook salmon in their stomachs shortly after the fish were released for a survival study (Table 4-1). It is likely that there were numerous naturally produced juvenile Chinook salmon during both years because there was a moderate number of spawners present during both years: 5,779 and 1,275 present in fall 1988 and 1989, respectively (http://dnn.calfish.org/IndependentDatasets/CDFGFisheriesBranch/tabid/157/Default.aspx). The spring 1990 studies should have been particularly effective for evaluating predation because the electrofishing was conducted at night, shortly after the bass would have been feeding and their stomachs would still have contained undigested juvenile Chinook salmon. In addition, the study was conducted during a drought, when predation rates would be expected to be highest due to low flows and high water temperatures. These results suggest that bass prey on few naturally produced juveniles because they primarily migrate at night when predation rates are lowest, whereas hatchery fish typically migrate during the day (Roper and Scarnecchia 1996) and they are thought to be naïve at avoiding predators.

Table 4-1.
Predation Studies in Lower Tuolumne River in 1989 and 1990

Sampling Dates	La Grange Flows (cfs)	Percent Largemouth Bass with Juvenile Salmon in Stomachs	Percent Smallmouth Bass with Juvenile Salmon in Stomachs	Origin of Juvenile Salmon
4/19 to 5/17, 1989	40 to 121	3.6 (2 out of 56)	8.6 (5 out of 58)	Naturally Produced
1/29 to 3/27, 1990	142 to 174	2.1 (2 out of 97)	3.1 (1 out of 32)	Naturally Produced
4/25 to 4/28, 1990	187 to 207	2.6 (2 out of 76)	6.3 (1 out of 16)	Naturally Produced
5/2 to 5/4, 1990	299 to 572	26 (40 out of 152)	33.3 (6 out of 18)	CWT Hatchery

Source: TID and MID 1992.
Key:
cfs = cubic feet per second
CWT = coded wire tag

Striped bass, which primarily migrate into the San Joaquin River tributaries during the late-winter and spring (S.P. Cramer and Associates 2004, 2005; Cramer Fish Sciences 2006, 2007), were the primary predators of juvenile fall-run Chinook salmon fitted with radio tags in a Stanislaus River study (Demko et al. 1998). Although more than 90 percent of the radio-tagged fish appear to have been eaten by predators, there is uncertainty as to whether gastrically implanting the radio tags, which had 12-inch-long external whip antennas, impaired the ability of the juvenile salmon to avoid predators.

Adult Sacramento pikeminnow, which form large schools in ditch-like channels 3 to 8 feet deep, are very abundant in the San Joaquin River Basin and prey on Chinook salmon fry. Although none of the electrofishing studies conducted in the Tuolumne and Stanislaus rivers identified pikeminnow as predators of juvenile Chinook salmon, it is relatively difficult to capture schooling Sacramento pikeminnow with electrofishing gear, and they have complex stomachs that may be difficult to sample using flushing techniques.

Predation in the Delta

Striped bass, Sacramento pikeminnow, and largemouth bass are predators of juvenile Chinook salmon in some Delta habitats. Pickard et al. (1982) reported that juvenile salmon predation was high for both Sacramento pikeminnow and striped bass in the Sacramento River Delta between 1976 and 1978. Gill nets were set in Horseshoe Bend and near Hood to collect predators between February 1976 and February 1978. The results suggest that 150- to 1,050-mm FL striped bass and 300- to 700-mm FL Sacramento pikeminnow primarily fed on fry and relatively few smolts. Feeding rates for pikeminnow and striped bass were highest in winter (December through February), when 77.7 percent had fish in their stomachs, and low during spring (March through May), when only 23.3 percent had fish in their stomachs. However, stomach evacuation rates would be expected to be higher during the spring; therefore, an in-depth analysis is needed to determine the relative predation rates for fry and smolts. Relatively few steelhead, white catfish (*Ictalurus catus*), channel catfish (*I. punctatus*), and black crappie (*Pomoxis nigromaculatus*) were caught in the gill nets at Horseshoe Bend.

In contrast, Nobriga et al. (2003) used seines and experimental gill nets to sample age-0 and age-1 striped bass and largemouth bass in 3- to 13-foot-deep water in the Yolo Bypass, lower Sacramento River, and in the Central Delta from March through June 2001. They reported that only 1 juvenile Chinook salmon was found in the stomach of 1 of 81 striped bass and another juvenile Chinook salmon was found in the stomach of 1 of 63 largemouth bass. These predators were primarily feeding on yellowfin goby (*Acanthogobius flavimanus*), gammarid amphipods, *Corophium*, and/or aquatic insects.

Densities of black bass and striped bass are about 3 times higher in the central Delta downstream from Rough and Ready Island near Stockton and in the Mokelumne River (eastern Delta) than in the northern or southern areas of the Delta based on a DFG resident fish study conducted from 1980 to 1983 (Table 4-2), (Urquhart KAF 1987). DFG introduced Florida largemouth bass into the Delta in the early 1980s and again in 1989, and catch rates of black bass have increased since 1993 (Lee 2000). Although predation of juvenile Chinook salmon in the Delta has not been quantified, predation would contribute to the low survival rates of juvenile Chinook salmon migrating between Dos Reis and Jersey Point and to Sacramento River juveniles migrating into the Mokelumne River through the Delta Cross Channel.

Table 4-2.
Densities and Mean Fork Length of Largemouth Bass, Smallmouth Bass, and Striped Bass per Kilometer Collected in DFG Electrofishing Surveys in Sacramento-San Joaquin Delta, 1980 to 1983

Location	Largemouth Bass 208 mm FL	Smallmouth Bass 225 mm FL	Striped Bass 140 mm FL
Central Delta	12.81	0.02	0.03
Eastern Delta	12.92	0.20	0.19
Southern Delta	4.42	0.36	0.03
Northern Delta	3.83	0.78	0.03
Western Delta	5.97	0.08	0.00

Note:
The sampling sites in each region of the Delta are shown in Figure 1 of Schaffter (2000).
Key:
DFG = California Department of Fish and Game
FL = fork length
mm = millimeter

4.2.4 Water Quality

Water quality in the valley floor of the San Joaquin River Basin has been impaired as a result of contamination from a variety of sources, including (1) aquatic and terrestrial herbicide application, (2) urban and agricultural pesticide application, (3) trace elements from industrial and agricultural activities as well as those naturally present in soils, and

(4) effluent from wastewater treatment plants and livestock operations, particularly dairy farms. Point sources of pollution originate from single identifiable sources, whereas nonpoint sources that originate from many different sources. Examples of nonpoint sources are agricultural runoff (e.g., excess fertilizers, herbicides, and pesticides) and urban stormwater containing oil, grease, heavy metals, polycyclic aromatic hydrocarbons, and other organics (Central Valley Water Board 1998). Impervious surfaces (e.g., concrete) tend to reduce water infiltration and increase stormwater runoff (NMFS 1996).

In general, water contamination or degradation may cause chronic or sublethal effects that compromise the physical health of aquatic organisms and reduce their survival over an extended period of time beyond initial exposure. For example, a study conducted in Puget Sound, Washington (Arkoosh et al. 1998), indicates that emigrating juvenile Chinook salmon exposed to contaminants, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls suffered increased susceptibility to the common marine pathogen (*Vibrio anguillarium*). Similarly, a laboratory study suggests that sublethal concentrations of pollutants can be acting synergistically with endemic pathogens of juvenile Chinook salmon, thus compromising survivorship through immunologic or physiologic disruption (Clifford et al. 2005). Although less common, high concentrations of particular contaminants (e.g., ammonia, hydrogen sulfide, herbicides, pesticides) may lead to acute toxicity and death after only short exposure times.

Recent studies suggest that chronic or sublethal effects of contaminants may be subtle and difficult to detect. For example, early experimental studies indicated that hatchery-reared juvenile Chinook salmon exposed to undiluted agricultural subsurface drainwater from the west side of the San Joaquin River had greater than 75 percent mortality, whereas there were no chronic detrimental effects on the growth and survival of the study fish exposed to agricultural return flows that were diluted by greater than or equal to 50 percent (Saiki et al. 1992). However, recent studies suggest that juvenile fall-run Chinook salmon died in the laboratory after eating selenium-contaminated invertebrates and prey fish over a 90-day period that were collected from the San Joaquin River Basin (Beckon 2007). These two sets of studies suggest that bioassays of fathead minnows in water samples from the San Joaquin, Merced, Tuolumne, and Stanislaus rivers that showed little evidence of toxicity (Brown 1996) may not have detected chronic or sublethal effects that may affect Chinook salmon.

Herbicides

Chemicals containing ingredients such as diquat dibromide, free and complexed copper (e.g., copper ethylenediamine), fluridone, glyphosate, dimethylamine salt of 2, 4-dichlorophenoxyacetic acid, and alkylphenolethoxylates are applied to control aquatic weeds such as *Egeria densa* and water hyacinth (*Eichhornia crassipes*) in the Delta (DFG 2004). The primary impacts of diquat dibromide and fluridone are sublethal to juvenile Chinook salmon causing of narcosis rheotropism, chemical interaction, and immunotoxicity (NMFS 2006a). Exposure of juvenile Chinook salmon to these herbicides can increase their vulnerability to predation from both piscine and avian predators as well as reduce valuable invertebrate prey items (NMFS 2006a). In addition, the application of herbicides may result in low DO concentrations as the plants decompose (NMFS 2006a, 2006b).

Pesticides/Insecticides/Fungicides

Recent studies have indicated a serious potential risk of pesticides/insecticides/fungicides to exposed early life stages of Chinook salmon and aquatic invertebrates in the Central Valley (Viant et al. 2006). A large number of pesticides/insecticides/fungicides have been detected by water quality sampling programs in the San Joaquin River Basin, including aldrin, carbaryl, chlorpyrifos, diazinon, dieldrin, diuron, heptachlor, lindane, malathion, metribuzin, and trifluralin (Domagalski et al. 2000). Most problems occur in the lower Restoration Area (Reaches 3 through 5) where water quality is influenced by water imported from the Delta and by agricultural drainage, particularly from Mud and Salt sloughs. Reaches 1 and 2 have generally good water quality (Brown 1997). Domagalski‘s study (et al. 2000) and other multiyear studies (Brown 1997, Panshin et al. 1998) assessed a wide array of contaminants. More than half of the surface water samples from certain agricultural drainages in the Central Valley contain seven or more pesticides/insecticides/fungicides (Panshin et al. 1998). These pesticide mixtures include organophosphates and carbamates that are likely to have additive effects on the neurobehavior of salmon exposed in contaminated watersheds (Scholz et al. 2006). The growing number of chemical pesticides/insecticides/fungicides found in the San Joaquin Valley is too large to encompass in this review. Furthermore, accurately quantifying risks of individual pesticides/insecticides/fungicides or synergistic effects of multiple pesticides/insecticides/fungicides is not easily validated; most studies rely on comparing contaminant levels (from biota or the environment) to literature values, regional or national statistics, or suitable reference sites.

USGS NAWQA Toxicity Monitoring. The San Joaquin-Tulare study unit was among the first basins chosen for the U.S. Geological Survey (USGS) National Water Quality Assessment Program (NAWQA), and has recently focused considerable attention on pesticide contamination in the San Joaquin River Basin (Dubrovsky et al. 1998, Panshin et al. 1998, Kratzer and Shelton 1998, Brown and May 2000). Generally, toxicity within the San Joaquin River has been attributed to pesticides/insecticides/fungicides from agricultural nonpoint sources, substantiated by the lack of detection of pesticide compounds in reference sites on the upper Kings River and Tuolumne River, situated above agricultural influences (Dubrovsky et al. 1998). In the NAWQA studies, available drinking water standards were not exceeded at San Joaquin River monitoring sites, but the concentrations of several pesticides/insecticides/fungicides exceeded the criteria for the protection of aquatic life. As mentioned previously, regional or national contamination levels are used to interpret San Joaquin River study results. Gilliom and Clifton (1990, from Brown 1998) reported that the San Joaquin River had some of the highest concentrations of organochlorine residues in bed sediments among the major rivers of the United States. Although the organochlorine pesticide DDT (dichloro-diphenyl-trichloroethane) was banned in the United States in 1973, DDT concentrations have continued to be detected in biota of the San Joaquin Valley streams at lower levels (Goodbred et al. 1997, Dubrovsky et al. 1998) as contaminated soils are transported to streams and sediment is resuspended from riverbeds.

Concentrations of organophosphate pesticides (i.e., diazinon and chlorpyrifos) in runoff are high, and highly variable during winter storms (Kratzer and Shelton 1998). In winter, dormant-spray pesticides, including diazinon and chlorpyrifos are applied to fruit orchards and alfalfa fields in the San Joaquin River Basin and Delta islands (Kuilvila 1995, 2000). These pesticides are delivered to local watercourses and the Delta by overland runoff. Diazinon is the common name of an organophosphorus (OP) pesticide used to control pest insects in soil, on ornamental plants, and on fruit and vegetable field crops. Chlorpyrifos is also an OP pesticide and is used to kill insect pests by disrupting their nervous system. OP pesticides were originally developed for their water solubility and ease of application. After they have been applied, they may be present in the soil, surface waters, and on the surface of the plants that are sprayed, and may be washed into surface waters by rain.

Reaches 1 and 2 of the San Joaquin River have not been identified as problem areas by the NAWQA studies, but pesticides have been detected in groundwater samples from domestic water supply wells. However, concentrations of pesticides in groundwater supplies generally have not increased in the last decade (Dubrovsky et al. 1998). The extremely low levels of pesticides and herbicides, and ephemeral nature of their presence in surface waters, prompted the creation of the California Department of Pesticide Regulation (DPR) within the California Environmental Protection Agency (CalEPA), which tracks pesticide use. Data are available at the following Web site: http://www.cdpr.ca.gov/dprdatabase.htm.

Basin Plan Objectives and Central Valley Water Board Monitoring. For most pesticides, numerical water quality objectives have not been adopted, but a number of narrative water quality objectives (e.g., no adverse effects) for pesticides and toxicity are listed in the Basin Plan (Central Valley Water Board 1998). The EPA criteria and other guidelines are also extremely limited, since numerical targets based on the anti-degradation policy would not allow pesticide concentrations to exceed natural —background” levels (i.e., nondetectable levels or “zero”). For the San Joaquin River system, including the five reaches of this study area, the California State Water Quality Control Board (SWRCB) has set a goal of —zero toxicity” in surface water. This goal is intended to protect the beneficial uses of recreation, warm freshwater habitat, cold freshwater habitat, and municipal and domestic supply from potential pesticide impacts.

The most recent 303(d) list of impaired waterbodies presented by the Central Valley Region Water Quality Control Board (Central Valley Water Board) identifies Reaches 3, 4, and 5 of the San Joaquin River study area, Mud Slough, and Salt Slough as impaired due to pesticides and —unknown toxicity.” In addition to the Central Valley Water Board, USGS, and DPR are conducting cooperative synoptic and/or in-season sampling for pesticides, herbicides, and insecticides. The following stations are part of the ongoing studies: San Joaquin River at Vernalis (USGS 11303500), Maze (USGS 11290500), Patterson (USGS 11274570), Crows Landing (USGS 11274550), and Stevinson (USGS 11260815), Bear Creek at Bert Crane Road. (Central Valley Water Board MER007), Salt Slough at Lander/Hwy 165 (USGS 11261100), Mud Slough (USGS11262900), and Los Banos Creek at Hwy 140 (Central Valley Water Board MER554). Results of these sampling efforts will help characterize the distribution of pesticides and other toxins within these impaired waterbodies. Annual reports discussing the results for DPR-funded studies can be found at http://www.cdpr.ca.gov/docs/empm/pubs/memos.htm.

Because of their importance as a marker of pesticide-use practices, DDT and two OP pesticides, diazinon and chlorpyrifos are focused on in this document. These compounds, and simazine and metolachlor, were some of the most frequently detected compounds in the NAWQA program studies (Dubrovsky et al. 1998). In addition to the well-known effects of DDT on egg shell thinning and deformities in birds, OP pesticides can affect survival or cause chronic physiological effects on exposed fish via acetylcholinesterase (AChE) enzyme inhibition and induction of heat shock proteins in response to stress. Juvenile Chinook salmon may be more vulnerable to predation and grow less as a result of only brief exposures to AChE-inhibiting pesticides (Eder et al. 2007, Scholz et al. 2000). Recently, there has been a general movement towards the use of pyrethroids instead of OP pesticides in agriculture. High doses of pyrethroid compounds, such as esfenvalerate can be acutely toxic to juvenile Chinook salmon (Wheelock et al. 2005). The ecological effects of increased use of pyrethroids on aquatic ecosystems and Chinook salmon populations are in need of further research (Phillips 2006). Despite the fact that pyrethroids are now one of the most important insecticides and increasingly applied in the Central Valley, primarily for agriculture and urban purposes, only a limited number of studies and monitoring efforts are focusing on occurrence and toxicity (Oros and Werner 2005). There are not enough field monitoring data to date on the spatial and temporal occurrences of pyrethroids for making risk assessments (Oros and Werner 2005).

Trace Elements

Selenium and mercury are two environmental contaminants of primary concern in aquatic environments, and the San Joaquin River is not an exception. Selenium and mercury are trace elements that can be harmful to aquatic life because they undergo biomagnification after being converted to organic forms in reducing (i.e., low oxygen) conditions by methylating bacteria. As a result of this conversion to an organo-metallic compound, methylated selenium and mercury are preferentially absorbed into fatty tissues and can biomagnify through the food chain despite low ambient concentrations. Central Valley Water Board water quality objectives for selenium are currently being exceeded for Mud Slough and downstream reaches. While the reported background concentrations for selenium for the San Joaquin River above Salt and Mud sloughs are about 0.5 micrograms per liter (µg/L), selected sites along the river have selenium concentrations from 1 to 5 µg/L (Central Valley Water Board 2001). The input of selenium from the Grasslands area into the San Joaquin River represents a major risk for larval fish, including Chinook salmon (Beckon 2007).

Effluent from Wastewater Treatment Plants and Livestock Operations

Free ammonia (NH_3), other nitrogen species (nitrates, nitrites, organic nitrogen), pH, chlorine, and DO are a concern in the Delta, particularly near the outflow from sewage treatment plants and dairy farms. One of the most significant water-quality problems in the Delta is the low DO problem in the Stockton Deepwater Ship Channel. The first 7 miles of the Stockton Deepwater Ship Channel west of the Port of Stockton experiences DO concentrations below the Central Valley Water Board DO water quality standards (SJRDOTWG 2007). The low DO problem is due to poor water circulation, flow, the deepness of the channel, and the oxygen demand exerted by wastewater discharge from the Stockton Regional Wastewater Control facility and the decomposition of algal biomass produced upstream. In response to nutrients discharged by irrigated agriculture and dairy operations in the San Joaquin River Basin, high concentrations of planktonic algae grow within 8 to 10 feet of the water‘s surface upstream from the ship channel and then settle below the sunlight zone and die when the water flows into the 35-foot-deep ship channel (Lee and Jones-Lee 2003). Minimum DO concentrations measured in the San Joaquin River ship channel at the DWR Rough and Ready Island station during April and May typically range between about 3 mg/L during low flows (e.g., 1987) and 7 mg/L during flood conditions (e.g., 1998). DO levels below 3.3 mg/L are considered lethal for salmon whereas levels below 5.0 mg/L may reduce growth rates of juvenile salmon (Spence et al. 1996). Nitrification of even low levels of ammonia as well as decomposition of algal detritus and residual wastewater use large amounts of DO. Other factors that affect DO concentrations in the ship channel include water temperature, atmospheric aeration, and sediment oxygen demand (Jones and Stokes 2002b).

Observed Salmon Mortalities During the 2007 VAMP Studies. It is possible that impaired water quality in the San Joaquin River near Stockton was responsible for the mortality of about 20 percent of tagged juvenile fall-run Chinook salmon during the May 2007 Vernalis Adaptive Management Plan (VAMP) studies. A total of 152 out of about 780 juvenile Chinook salmon that had surgically inserted acoustic tags and were released in the mainstem San Joaquin River stopped their migrations and presumably died adjacent to a railroad bridge and the Stockton Regional Wastewater Control Facility outfall (Natural Resource Scientists 2007). Initially, 116 dead fish were observed on May 17 and 18 (Natural Resource Scientists 2007), whereas another 36 dead fish were located after May 20, 2007. The cause of the mortality remains uncertain because few of the dead fish were recovered, no bioassay studies were conducted in the river near the wastewater facility, and there were no water quality monitoring stations where the dead fish were found. Because of the high concentration of fish tags at this location, either unusually high predator activity or some toxicity event was hypothesized to have resulted in the localized fish mortality.

Potential water quality constituents that may be associated with fish toxicity or mortality of the VAMP study fish in May 2007 include NH_3, hydrogen sulfide (H_2S), and low levels of OP pesticides (e.g., chlorpyrifos and diazinon). Monitoring of the wastewater control facility‘s effluent indicated that pH, DO, turbidity, chlorine, and ammonia were within compliance conditions of the facility‘s permits shortly after the fish had been released (Patricia Leary 2007, pers. com). Monitoring in the river approximately 0.5 mile upstream and downstream from the site also suggest that pH (7.75 to 8.25) and DO (greater than 9 mg/L) levels would not account for the mortality (Mueller-Solger 2007). However, although unionized ammonia levels in the river were less than 0.02 mg/L, well below the EPA (1999) critical levels for salmon (e.g., 0.21 mg/L NH_3 at 68°F, and a pH of 8), final effluent grab samples collected by Central Valley Water Board staff at the Stockton Regional Wastewater Control Facility contained total ammonia and total Kjeldahl nitrogen (TKN) at levels of 4.4 mg/L and 6.2 mg/L, respectively. Since average daily pH at the Port of Stockton approaches levels (pH 8 or above) that produce acute and chronic ammonia toxicity, and algal photosynthesis in the lower San Joaquin likely produces diel pH swings due to scavenging of carbon dioxide and alkalinity, it is possible that ammonia toxicity to fish occurs at some time of day for several months from spring through fall of each year.

4.2.5 Entrainment

In 2001, DFG inventoried 95 riparian diversions in the Restoration Area between RM 209 and 267 that were mostly unscreened pumps (McBain and Trush 2002). The estimated maximum diversion capacity ranged between less than 1 cubic feet per second (cfs) to 63 cfs. Three of these diversions are weir structures just downstream from Friant Dam. The Big Willow Unit Diversion (RM 261.3) is a cobble-type weir that diverts a small amount of water to the Fish Hatchery. The Rank Island Unit is a cobble weir located at RM 260, and diverts approximately 5 cfs to property on the north side of the river. The Milburn Unit Diversion is a small concrete-rubble weir located at RM 247.2. A small pump is located just upstream. In addition, Herren and Kawasaki (2001) found 298 and 2,209 diversions in the San Joaquin River Basin and Delta respectively. More than 95 percent of these diversions were unscreened, and the impacts of these diversions on juvenile Chinook salmon are unknown. No studies have been conducted to determine the entrainment rates at the pumps and weirs in the Restoration Area or downstream in the Delta.

Below the Restoration Area

The irrigation season in the San Joaquin River between Stockton and the Merced River between 1946 and 2002 has been principally between March and October, with some water diverted in February and November (Hallock and VanWoert 1959, Quinn and Tulloch 2002). DFG estimated that an average of 127,000 acre-feet of water was diverted annually from all diversions in this reach from 1946 to 1955 (Hallock and VanWoert 1959). Quinn and Tulloch (2002) estimated that from 1999 to 2001, annual pumping rates increased to an average of about 154,500 acre-feet at the four largest diversions, which include the Banta-Carbona Irrigation District, West Stanislaus Irrigation District, Patterson Water Company, and El Solyo Water Company.

During 1955, nets were fished in the Banta-Carbona Irrigation District pumps (RM 67.5), El Solyo pumps (RM 82.0), and Patterson Water Company pumps (RM 104.4) (Hallock and Van Woert 1959). The highest entrainment rates were measured at the Banta-Carbona site in 1955 at about 12 fish per hour. In summer 2002, screens were installed at Banta-Carbona that appear to be effective at protecting juvenile salmon. In comparison, the Patterson Water Company pumps entrained about 1.6 juvenile Chinook salmon per hour and the El Solyo pumps entrained about 5.2 Chinook salmon per hour in 1955. There are no screens at the West Stanislaus Irrigation District, Patterson Water Company, or El Solyo Water Company pumps, although screens are proposed for the Patterson pumps.

Entrainment of juvenile Chinook salmon at the Federal (Central Valley Project (CVP)) and State (State Water Project (SWP)) pumping facilities in the Delta is not directly measured but instead estimated as a function of the expanded number of fish salvaged, fish size, and water velocity through the louvers (Foss 2003). For a 2,000-cfs export flow, the efficiency of the louvers for fish larger than 100 mm in length is estimated to be

70 percent and 68 percent at the CVP facilities and SWP facilities, respectively. Louver efficiencies are about 6 percent higher for Chinook salmon up to 100 mm in length compared to larger fish. The number of fish salvaged at the louvers is estimated with samples taken at least every 2 hours while water is pumped (Foss 2003). When tagged juvenile fall-run Chinook salmon were released in the San Joaquin River near Mossdale in spring 1992 and 1993, means of 3.3 percent and 0.3 percent were salvaged at the CVP and SWP facilities, without and with a barrier at the Head of the Old River, respectively (Table 4-3).

Most juvenile mortality at the Delta pumping facilities is probably due to predation in Clifton Court Forebay and the canals leading to the pumps by nonnative predators such as striped bass, largemouth bass, and sunfishes (i.e., Centrarchidae). It is assumed that prelouver predation losses are 15 percent from the trash racks to the louvers at the CVP facilities and 75 percent in Clifton Court Forebay which leads to the SWP facilities (Foss 2003). Some of the acoustically tagged juvenile fall-run Chinook salmon released for the spring 2007 VAMP studies were preyed on by large fish congregated near the trash racks at the CVP pumping facilities (Vogel 2008).

Table 4-3.
Number of Tagged Fall-Run Chinook Salmon Smolts from the Feather River Hatchery Released in San Joaquin River at Mossdale in 1992 and 1993, and Salvage Rates

Release Date	Vernalis Flow (cfs)	CVP and SWP Export Rates (cfs)	HORB Installed	Number Released	Expanded Salvage		Percent Salvaged	
					CVP	SWP	CVP	SWP
04-May-93	4,730	1,494	No	51,937	931	102	1.79%	0.20%
12-May-93	3,770	1,585	No	52,616	1,332	113	2.53%	0.21%
07-Apr-92	1,620	5,682	No	107,103	5,380	71	5.02%	0.07%
13-Apr-92	1,530	1,185	No	103,712	3,385	106	3.26%	0.10%
24-Apr-92	1,070	1,009	Yes	104,739	28	28	0.03%	0.03%
04-May-92	1,480	2,777	Yes	99,717	28	8	0.03%	0.01%
12-May-92	1,020	1,757	Yes	105,385	0	6	0.00%	0.01%

Source: USFWS 2000a.
Key:
cfs = cubic feet per second
CVP = Central Valley Project
HORB = Head of the Old River Barrier
SWP = State Water Project

4.2.6 Degraded In-River Physical Habitat

In Pacific Northwest and California streams, habitat simplification has led to a decrease in the diversity of anadromous salmonid species habitat (NMFS 1996). Habitat simplification may result from blocked gravel recruitment by upstream dams as well as various land-use activities, including gravel extraction, bank revetment, timber harvest, grazing, urbanization, and agriculture.

Gravel Recruitment Blocked by Dams and Levees

Friant Dam eliminated sediment supply from the upper watershed, and combined with the modified flow regime and land use downstream from Friant Dam, varying degrees of sediment budget imbalance have occurred in the river downstream. The current paradigm of dam impacts to sediment supply downstream from the dams is that periodic high flow releases from the dam transport sediment stored in the stream bed, and because the sediment supply from the upper watershed is blocked, channel degradation occurs downstream from the dam as alluvial features (bars and riffles) slowly diminish (Collier et al. 1996). Instream gravel mining has exacerbated this sediment deficit in the Restoration Area (McBain and Trush 2002). Local imbalances in sediment supply and transport have caused primarily incision and channel widening with some local aggradation (sedimentation) in the Restoration Area (Cain 1997). Loss of alluvial features in the Restoration Area has contributed to the reduction in frequency of floodplain inundation, which has probably caused a substantial reduction in potential food resources and refuge from predators for juvenile salmonids in the Restoration Area. In addition, channel incision reduces the availability of alternating bars and riffles that juvenile Chinook salmon use for feeding and predator avoidance during low flow periods.

Lack of Large Woody Debris

Large quantities of downed trees are a functionally important component of many streams (NMFS 1996). IWM influences channel morphology by affecting longitudinal profile, pool formation, channel pattern and position, and channel geometry. Downstream transport rates of sediment and organic matter are controlled in part by storage of this material behind IWM. IWM affects the formation and distribution of habitat units, provides cover and complexity, and acts as a substrate for biological activity (NMFS 1996). Wood enters streams inhabited by salmonids either directly from adjacent riparian zones or from riparian zones in adjacent nonfish-bearing tributaries. Removal of riparian vegetation and IWM from the streambank results in the loss of a primary source of overhead and instream cover for juvenile salmonids. The removal of riparian vegetation and IWM and the replacement of natural bank substrates with rock revetment can adversely affect important ecosystem functions. Living space and food for terrestrial and aquatic invertebrates is lost, eliminating an important food source for juvenile salmonids. Loss of riparian vegetation and soft substrates reduces inputs of organic material to the stream ecosystem in the form of leaves, detritus, and woody debris, which can affect biological production at all trophic levels. The magnitude of these effects depends on the degree to which riparian vegetation and natural substrates are preserved or recovered during the life of the project.

Dikes, Levees, and Bank Revetment

The construction of levees and dikes to convert land for agricultural production tends to channelize riverine habitats and reduces channel migration and avulsion (McBain and Trush 2002). Reduced channel migration has eliminated off-channel habitats, reduced complex side channels, and reduced instream habitat complexity that all serve to provide suitable conditions for juvenile salmonids over a wide range of flow. Agricultural conversion has also directly reduced the amount of floodplains, and levees and dikes have further isolated historic floodplains from the channel. It is likely that the loss of floodplain habitats has substantially reduced food resources and refuge from predators for juvenile salmonids.

Angular rock (riprap) is used to armor the streambanks from erosive forces in the Restoration Area and throughout the Central Valley. Simple slopes protected with rock revetment generally create nearshore hydraulic conditions characterized by greater depths and faster, more homogeneous water velocities than occur along natural banks (USFWS 2000b, Garland et al. 2002). Higher water velocities typically inhibit deposition and retention of sediment and woody debris. These changes generally reduce the range of habitat conditions typically found along natural shorelines, especially by eliminating the shallow, slow-velocity river margins used by juvenile fish as refuge and escape from fast currents, deep water, and predators (USFWS 2000b).

The use of rock armoring also limits recruitment of IWM and greatly reduces, if not eliminates, the retention of IWM once it enters the river channel. Riprapping creates a relatively clean, smooth surface that diminishes the ability of IWM to become securely snagged and anchored by sediment. IWM tends to become only temporarily snagged along riprap, and generally moves downstream with subsequent high flows. Habitat value and ecological functioning aspects are thus greatly reduced, because wood needs to remain in place to generate maximum values to fish and wildlife (USFWS 2000b). Recruitment of IWM is limited to any eventual, long-term tree mortality and any abrasion and breakage that may occur during high flows (USFWS 2000b). Juvenile salmonids are likely being impacted by reductions, fragmentation, and general lack of connectedness of remaining nearshore refuge areas.

A separate but connected bypass system, consisting of the Chowchilla Bypass Channel, Eastside Bypass Channel, and Mariposa Bypass Channel, was constructed to divert and carry flood flows from the San Joaquin River and eastside tributaries upstream from the Merced River. These bypasses lack floodplain access, habitat structure, nearshore habitat and riparian habitat required by Chinook salmon.

Urbanization

CALFED (2000) estimated that wetted perimeter reductions in the Delta have decreased from between 25 and 45 percent since 1906. Historically, the San Francisco Estuary included more than 242,000 acres of tidally influenced bay-land habitats, and tidal marsh and tidal flats accounted for 98 percent of bay-land habitats. Today, only 70,000 acres of tidally influenced habitat remain (CALFED 2000). While historical uses of riparian areas (e.g., wood cutting, clearing for agricultural uses) have substantially decreased, urbanization still poses a serious threat to remaining riparian areas. Riversides are desirable places to locate homes, businesses, and industry.

4.2.7 High Water Temperatures

Release temperatures from Friant Dam currently range from 48°F to 58°F (8.9°C to 14.4°C) and water temperatures are expected to be suitable for juvenile rearing except in the downstream reaches (Reaches 2B to 5) as air temperatures increase.

Unsuitably high water temperatures and exaggerated fluctuations in water temperature result from a combination of factors, including seasonally high air temperatures (May and June), low flow releases, groundwater pumping that eliminated the inflow of cool groundwater throughout the Restoration Area, removal of large woody riparian forests that provided shade, warm agricultural runoff, and warm flood flows from the Kings River through the James Bypass. It is also possible that high flow releases during summer and fall could exhaust the cold water pool in Millerton Lake and thereby cause release temperatures to substantially increase above 58°F (14.4°C).

Many of these impacts will directly affect the juvenile life stages of Chinook salmon in the river. Juveniles start to experience stress from increased water temperature in the 64.4 to 70°F (18 to 21.1°C) (Rich 2007, Pagliughi 2008). Although floodplain rearing temperatures can exceed these temperatures and benefit fish growth in the presence of adequate food supply (Jeffres et al. 2008). Prolonged exposure to temperatures above 75°F (23.9°C) can lead to nearly 100 percent mortality (Hanson 1997, Rich 1987, Zedonis and Newcomb 1997, as cited in Pagliughi 2008).

Delta Conditions

Currently, there are no flow or water temperature standards to maintain suitable habitat for juvenile Chinook salmon in the lower San Joaquin River. Water temperatures in the San Joaquin River near Vernalis (DWR gage data) were usually below 65°F (18.3°C) from mid-April to mid-May when Vernalis flows were at least 3,500 cfs. Springtime water temperatures at Vernalis exceeded 65°F (18.3°C) during drought years (e.g., 1977 and 1987 to 1992) and when high flows entered the San Joaquin River from the James Bypass upstream from Newman during spring 1986. By the end of May, water temperatures typically ranged between 65°F and 70°F (18°C and 21°C) and regardless of flow.

4.2.8 Harvest of Yearling-Sized Juveniles

Following reintroduction of spring-run Chinook salmon into the San Joaquin River, yearling Chinook salmon may be present in portions of the Restoration Area throughout the year. Yearling spring-run Chinook salmon (those adopting a stream-type life history strategy) typically range in length from about 80 to 150 mm (3 to 6 inches), depending on growth rate and freshwater residence time (Moyle 2002). Sport anglers may catch yearling Chinook salmon while fishing for trout or other game fish, likely resulting in injury or mortality due to hooking and handling. State fishing regulations specify bag limits for trout and Chinook salmon in the San Joaquin River, but size restrictions are not designated (DFG 2007b).

4.3 Ocean Phase

The survival of smolts entering the ocean during June and July is probably the most critical phase for salmon in the ocean (Pearcy 1992, Mantua et al. 1997, Quinn 2005). Marking studies suggest that about 59 to 77 percent of juvenile pink salmon (*O. gorbuscha*) died in their first 40 days at sea off the coast of British Columbia, whereas 78 to 95 percent of those that survived their first 40 days died over the next 410 days at sea (Parker 1968). Another marking study with chum salmon off the coast of Washington indicated that juvenile mortality averaged 31 to 46 percent per day during the first few days (Bax 1983).

The survival of smolts entering the ocean is highly correlated with ocean productivity as affected by freshwater outflow from the estuary. This, in turn, affects the availability of food resources at the interface between freshwater and saltwater, as well as coastal upwelling, ocean currents and El Niño events (Casillas 2007).

4.3.1 Inadequate Juvenile Food Availability

Long-term records indicate that there are 15- to 25-year cycles of warm and cool periods that strongly correlate with marine ecosystem productivity (Mantua et al. 1997; Hollowed et al. 2001). Cool productive cycles prevailed from 1947 through 1976, and a new cycle began in 1998, whereas warm unproductive cycles dominated from 1925 through 1946, and from 1977 through 1997 (Mantua et al. 1997; Mantua and Hare 2002). The coastal warming that occurred in the mid-1970s is believed to have caused increased stratification in the California Current; a sharper thermocline with less upwelling of nutrient-rich water; a reduction in the duration of upwelling; and a reduction in nutrients and/or zooplankton abundance carried by the California Current (Francis et al. 1998). In addition, the abundance of coastal euphausiids (*Thysanoessa spinifera*) declined whereas oceanic euphausiids (*T. pacifica*) increased (Francis et al. 1998). Such changes are thought to affect salmon early in their marine life history (Hare and Francis 1995), and coastal invertebrate species are important prey for ocean-type juveniles, such as Central Valley fall-run Chinook salmon.

The interface between the plume of freshwater outflow from the Columbia River and saltwater in the ocean is a highly productive area that is important to the survival of juvenile Chinook salmon and other salmonid species migrating into the ocean (Casillas 2007). Large freshwater plumes that extend well offshore 7 to 10 days after juvenile salmonids enter the ocean are highly correlated with higher numbers of returning adults 2 years later (Casillas 2007). The density of food organisms, particularly crustacean larvae, is unusually high at the freshwater-saltwater interface. It is likely that freshwater outflow from the San Francisco Estuary between May and July is also important to the survival of juvenile San Joaquin River Chinook salmon. The May through July period is probably important because that is when juvenile Chinook salmon entered the Gulf of the Farallones during spring 1997 (MacFarlane and Norton 2002). In the Gulf of the Farallones, the size of the plume would be controlled by inflow to the Delta from the Sacramento and San Joaquin river basins as well as Delta exports, which can be as high as 35 percent of Delta inflow from February through June, and 65 percent of Delta inflow from July through January (SWRCB 1995, California Regional Water Quality Control Board 2007).

Indicators of Ocean Productivity

Coastal waters off the Pacific Northwest are influenced by atmospheric conditions in the North Pacific Ocean, but also in equatorial waters, especially during El Niño events. Strong El Niño events result in the transport of warm equatorial waters northward along the coasts of Central America, Mexico, and California, and into the coastal waters off Oregon and Washington. These events affect weather in the Pacific Northwest, often result in stronger winter storms and transport of warm, offshore waters into the coastal zone. The transport of warm waters toward the coast, either from the south or from offshore, also creates unusual mixes of zooplankton and fish species.

The Pacific Decadal Oscillation (PDO) is a climate index based on patterns of variation in sea surface temperature of the North Pacific from 1900 to the present (Mantua et al. 1997). While derived from sea surface temperature data, the PDO index is well correlated with many records of North Pacific and Pacific Northwest climate and ecology, including sea level pressure, winter land-surface temperature and precipitation, and stream flow. The index is also correlated with salmon landings from Alaska, Washington, Oregon, and California.

Since 1955, the presence/absence of conditions caused by the El Niño Southern Oscillation (ENSO) has been gauged using the Multivariate ENSO Index (MEI). El Niño conditions were observed infrequently before 1977 (during the cool phase of the PDO).

Both the PDO and MEI can be viewed as "leading indicators" of ocean productivity because after a persistent change in sign of either index, ocean conditions in the California Current soon begin to change. Most recently, in September 2005, the MEI appears to have signaled a return to warmer ocean conditions.

4.3.2 Marine Predation

Both bird and fish predators congregate at the freshwater-saltwater interface of the freshwater plume of the Columbia River where juvenile salmon feed (Casillas 2007). In spring 2003, there were many species of bird predators. Marine fish that intensively prey on juvenile salmon include Pacific hake (*Merluccius productus*), rockfish (*Sebastes spp.*), and to a lesser degree, jack mackerel (*Trachurus symmetricus*), Pacific mackerel (*Scombrus japonicus*), and spiny dogfish (*Squalus acanthias*). The abundance of bird and fish predators has been highly correlated with juvenile salmon abundance off the coast of Washington. However, the impact of predation on the number of returning adult salmon has not been quantified.

The primary marine mammals preying on salmonids are pinnipeds, including harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and Steller‘s sea lions (*Eumetopia jubatus*) (Spence et al. 1996). Pacific striped dolphin (*Lagenorhynchus obliquidens*) and killer whale (*Orcinus orca*) also prey on adult salmonids in the nearshore marine environment. Seal and sea lion predation is primarily in saltwater and estuarine environments, although they are known to travel well into freshwater after migrating fish. All of these predators are opportunists, searching out locations where juveniles and adults are most vulnerable.

4.3.3 Adult Commercial and Sport Harvest

Extensive ocean recreational and commercial troll fisheries for Chinook salmon exist along the Central California coast, and an inland recreational fishery exists in the Central Valley for Chinook salmon and steelhead. Ocean harvest of Central Valley Chinook salmon is estimated using an abundance index, called the Central Valley Index (CVI). The CVI is the ratio of Chinook salmon harvested south of Point Arena (where 85 percent of Central Valley Chinook salmon are caught) to the sum of the estimated escapements and harvest of Central Valley fish.

Ocean fisheries have affected the age structure of Central Valley spring-run Chinook salmon through targeting large fish for many years and reducing the numbers of 4- and 5-year-old fish (DFG 1998). Ocean harvest rates of Central Valley spring-run Chinook salmon are thought to be a function of the CVI (Good et al. 2005). Harvest rates of Central Valley spring-run Chinook salmon ranged from 55 percent to nearly 80 percent between 1970 and 1995, when harvest rates were adjusted to protect Sacramento River winter-run Chinook salmon. The drop in the CVI in 2001 as a result of high fall-run Chinook salmon escapement to 27 percent also reduced harvest of Central Valley spring-run Chinook salmon.

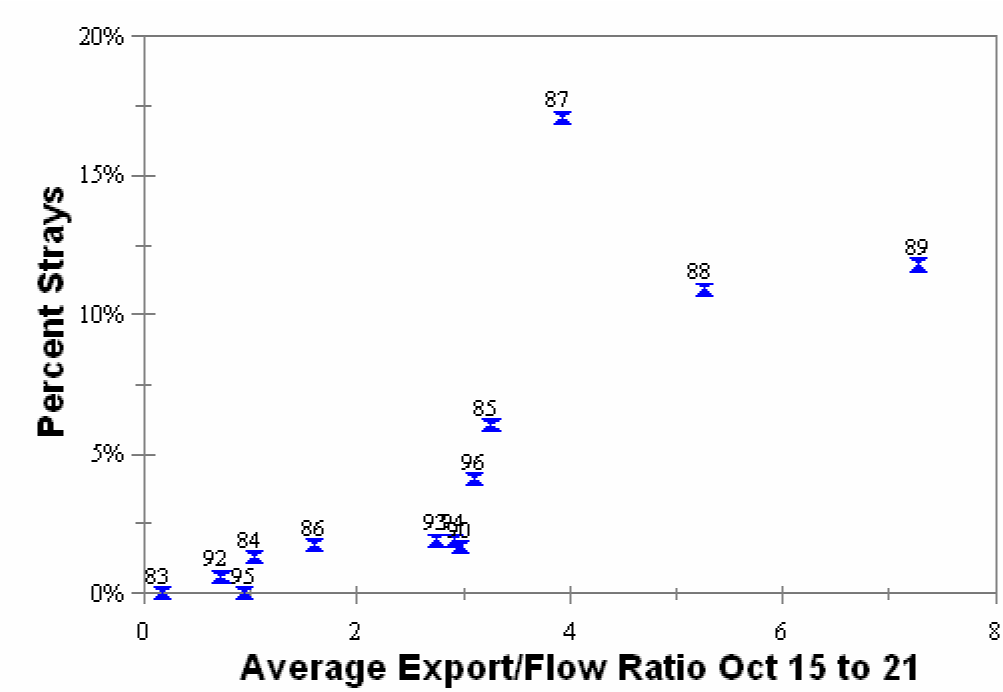
In-river recreational fisheries historically have taken Central Valley spring-run Chinook salmon throughout the species‘ range. During the summer, holding adult Central Valley spring-run Chinook salmon are targeted by anglers when they congregate in large pools. Poaching also occurs at fish ladders, and other areas where adults congregate; however, the significance of poaching on the adult population is unknown. Specific regulations for the protection of Central Valley spring-run Chinook salmon in Mill, Deer, Butte, and Big Chico creeks were added to existing DFG regulations in 1994. The current regulations, including those developed for Sacramento River winter-run Chinook salmon, provide some level of protection for spring-run Chinook salmon (DFG 1998).

4.4 Adult Migration

Adult Chinook salmon will have to navigate approximately 270 miles from the ocean to spawning habitat downstream from Friant Dam. The number of Chinook salmon that successfully complete their migration will partly depend on environmental conditions that are needed for the fish to home to their natal stream as well as other factors, such as predation and harvest, that result in mortality.

4.4.1 Inadequate Flows and High Delta Export Rates

An important factor for successful upstream migration is sufficient flow throughout the migratory corridor that provide olfactory cues allowing the adult salmon to home to their natal stream. This has been a concern for adult fall-run Chinook salmon in the San Joaquin River Basin since 1996 when Delta export rates at the CVP and SWP were increased to near maximum (about 9,600 cfs) to ―make up” for reduced pumping rates during the spring outmigration period. When exports are high relative to San Joaquin River flows, it is likely that little, if any San Joaquin River water reaches the San Francisco Bay where it may be needed to help guide the Chinook salmon back to their natal stream. An analysis of recovered adult Chinook salmon with CWT that had been reared at the Merced River Fish Facility and released in one of the San Joaquin tributaries suggests straying occurred when the ratio of exports to flows was high (Mesick 2001b). The analysis indicates that during mid-October from 1987 through 1989, when export rates exceeded 400 percent of Vernalis flows, straying rates ranged between 11 percent and 17 percent (Figure 4-3). In contrast, straying rates were estimated to be less than 3 percent when Delta export rates were less than about 300 percent of San Joaquin River flow at Vernalis during mid-October.



Source: Mesick 2001b.

Notes:

1. Juveniles were released in the San Joaquin River Basin and subsequently strayed to the Sacramento River and eastside tributary basins to spawn.
2. Average Export/Flow Ration is based on the average ratio of the export rate at the CVP and SWP pumping facilities in the Delta compared to the flow rate in the San Joaquin River at Vernalis between 15 and 21 October, from 1983 to 1996.

Figure 4-3.
Estimated Percent of Adult Merced River Hatchery Coded Wire Tagged Chinook Salmon Strays Relative to Export to Flow Ratio

4.4.2 High Water Temperatures

In general, Chinook salmon appear capable of migrating upstream under a wide range of temperatures. Bell (1986) reported that salmon migrate upstream in water temperatures that range from 37°F (2.8°C) to 68°F (20°C). Bell (1986) reports that temperatures ranging between 37°F (2.8°C) and 55°F (12.8°C) are suitable for upstream migration of spring-run Chinook salmon, and between 50°F (10°C) and 66°F (18.9°C) for fall-run Chinook salmon. Based on numerous studies, Rich (2007), cites 59°F (15°C) as the upper limit to the optimal temperature range for adult Chinook migration. Thermal stress in migrating adults is detectable from 62.6 to 68°F (17 to 20°C) (Marine 1992) and significant mortality is observed at temperatures above this range (Marine 1992).

4.4.3 Physical Barriers and Flow Diversion

Historically, adult spring-run Chinook salmon migrated as far upstream as Graveyard Meadows (Lee 1998). The amount of holding and spawning habitat available to spring-run Chinook salmon was reduced around 1920, when Kerckhoff Dam —blocked the spring-run Chinook salmon from their spawning areas upstream and seasonally reduced flows in about 14 miles of stream, below the dam, where there were pools in which the fish would have held over the summer" (DFG 1921, as cited in Yoshiyama et al. 1996). The completion of Friant Dam in 1941 blocked access to approximately 16 additional miles of habitat that was historically used by spring-run Chinook salmon for spawning, representing an estimated 36 percent loss of the historic spawning habitat (Hatton 1940, as cited in Yoshiyama et al. 1996).

Passage below Friant Dam during the 1940s was inhibited by low flows in the channel. In 1944 and 1947, DFG (1955) observed from 5,000 to 6,000 spring-run Chinook salmon migrating up the San Joaquin River as far as Mendota Dam in a flow that was estimated to be 100 cfs in the reach between Sack Dam and the confluence with the Merced River. DFG observed that —many of these fish have rubbed themselves raw going over the shallow sandbars" between Sack Dam and the confluence with the Merced River (a distance of approximately 50 miles). Such abrasions can increase the risk of mortality from disease for spring-run Chinook salmon, since they must hold in pools throughout the summer before spawning. Passage for the San Joaquin River adult spring-run Chinook salmon has been completely blocked in the Restoration Area since the 1950s, when the river was dewatered below Sack Dam except during uncontrolled flow releases in wet years.

The Settlement prescribes that passage will be restored at all structures that may impede the passage of adult Chinook salmon through the Restoration Area. Improvements will be made at the following structures during Phase 1:

- Mendota Dam – A bypass channel will be created around Mendota Pool (RM 205)
- Reach 4B headgate and Sand Slough control structures (RM 168.5)
- Arroyo Canal Water Diversion – Screens will be installed (RM 182)
- Sack Dam, a diversion dam for the Arroyo Canal (RM 182)
- Eastside Bypass structures (RM 138 and RM 168)
- Mariposa Bypass structures (RM 147.2)
- Salt and Mud sloughs – Seasonal barriers will be installed to prevent adult Chinook salmon from entering these false migration pathways

Improvements will be made at Chowchilla Bifurcation Structure (RM 216) during Phase 2. McBain and Trush (2002) identified at least one earthen diversion dam just downstream from Gravelly Ford (RM 227) that may be potential impediments to both upstream and downstream fish movement.

4.4.4 Delta Water Quality

Hallock et al. (1970) showed that radio-tagged adult fall-run Chinook salmon delayed their migration in the Delta at Stockton whenever DO concentrations were less than 5 mg/L and/or water temperatures exceeded about 65°F (18.3°C) in October. Delaying the migration of adult fall-run Chinook salmon in the Stockton Deepwater Ship Channel may reduce gamete viability if the fish are exposed to high temperatures for prolonged periods. DFG reports that the quality and survival of eggs was poor from females exposed to water temperatures that exceeded 56°F (13.3°C) (DFG 1992).

DO concentrations near Stockton in October were greater than 5 mg/L from 1983, when DWR began monitoring, to 1990, but were lower than 5 mg/L for most of October in 1991 and 1992. The Head of the Old River Barrier was installed in fall 1992, but it did not correct the problem until late October (Figure 4-4). In 1993, DO levels were low until about October 10, and it is likely that pulse flows that raised Vernalis flows to about 4,000 cfs on October 7 were responsible for increasing DO levels at Stockton (Figure 4-4). Similarly in 1994, DO levels were low until October 15, when pulse flows raised Vernalis flows to about 2,000 cfs (Figure 4-4). In 1995, DO levels were at least 6 mg/L in October when Vernalis flows ranged from about 3,000 cfs to 6,000 cfs through mid-October. DO levels were low or fluctuated greatly in 1996 until October 13, when pulse flow releases increased Vernalis flows from 2,000 to about 3,000 cfs (Figure 4-4).

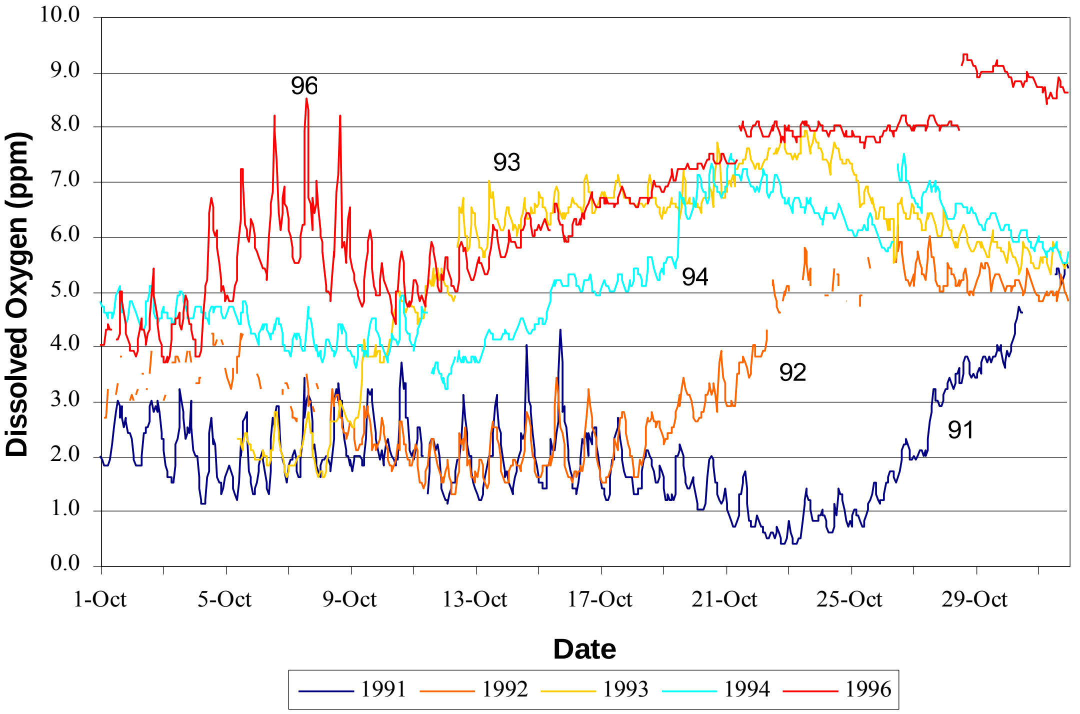


Figure 4-4.
Hourly Dissolved Oxygen Measurements at Burns Cut Off Road Monitoring Station During October in 1991 Through 1994 and 1996

4.4.5 In-River Harvest

During the 1940s, DFG (1946) reported that low flows resulted in high rates of harvest and incidental mortality from spearing in the lower river. In 1944, approximately 200 people were observed spearing salmon at each sand bar in the lower river. Some people used pitch forks, which wounded many fish that probably died before spawning (DFG 1946). Although spearing is no longer legal, the illegal poaching of adult Chinook salmon will still be a concern.

Current bag limits specified by State fishing regulations allow legal catch throughout the year of one salmon in the San Joaquin River from Friant Dam downstream to the Highway 140 Bridge (DFG 2007b). Size restrictions, however, are not designated for salmon in any portion of the San Joaquin River. Downstream from the Highway 140 Bridge, one salmon may be harvested from January through October. During November and December, a zero bag limit for salmon is enforced downstream from the Highway 140 Bridge that requires any salmon caught during these months to be unharmed and not removed from the water.

4.5 Adult Holding

When adult spring-run Chinook salmon begin their migration to their natal streams, they are sexually immature, unable to spawn. After they arrive in their natal streams in the spring, they hold in deep pools through the summer, conserving energy until the fall when their gonads ripen and they spawn. Fall-run Chinook salmon generally do not hold in pools for long periods of time (more than 1 week), but they may briefly use large resting pools during upstream migration.

4.5.1 Historical Habitat in the San Joaquin River

Adult spring-run Chinook salmon held in pools above Friant Dam before its construction (DFG 1921, as cited in Yoshiyama et al. 1996), probably as far upstream as Mammoth Pool Reservoir (Yoshiyama et al. 1996). Hatton described —long, deep pools" in the canyon above Friant (1940, as cited in Yoshiyama et al. 1996). The amount of holding and spawning habitat available to spring-run Chinook salmon was reduced around 1920, when Kerckhoff Dam —blocked the spring-run salmon from their spawning areas upstream and seasonally dried up about 14 miles (22.5 kilometers) of stream, below the dam, where there were pools in which the fish would have held over the summer" (DFG 1921, as cited in Yoshiyama et al. 1996). The completion of Friant Dam in 1941 further reduced the holding and spawning habitat available to spring-run Chinook salmon by completely blocking access to upstream areas.

4.5.2 Habitat Below Friant Dam

In July 1942, Clark (1943) observed an estimated 5,000 adult spring-run Chinook salmon holding in two large pools directly downstream from Friant Dam. He reported that the fish appeared to be in good condition, and that they held in large, quiet schools. Flow from the dam was approximately 1,500 cfs, and water temperatures reached a maximum of 72°F (22.2°C) in July. Several hundred yards downstream, there is another pool that has a maximum depth of 25 feet (8 meters) with an average depth of 11 feet (3 meters), with an approximate area of average depth of 93,000 square feet (8,600 square meters) (Stillwater Sciences 2003). Chinook generally do not feed while they hold; therefore, they can hold at very high densities. It is possible that these pools can hold up to about 20,000 adult spring-run Chinook salmon.

Although some fish may have held in pools downstream from Lanes Bridge, Clark (1943) concluded that the abundant spawning he observed in September and October in riffles between Friant Dam and Lanes Bridge were from fish holding in the pools below the dam that had moved back downstream to spawn.

4.5.3 Harvest

Current bag limits specified by State fishing regulations allow legal catch throughout the year of one Chinook salmon in the San Joaquin River from Friant Dam downstream to the Highway 140 Bridge (DFG 2007b).

Illegal harvest of holding spring-run Chinook salmon remains a concern because fish are vulnerable for several months in a confined location at high densities. The banks of the pool below Friant Dam are fenced off, thus minimizing access for poachers. However, the North Fork Road Bridge downstream from the dam has a boat launch that provides access to the river where poachers could gain access to the pool.

4.5.4 High Water Temperatures

Table 3-1 lists optimal adult holding temperatures of less than or equal to 59°F (15°C) for long-term population sustainability. Moyle reports water temperatures for adult Chinook salmon holding are optimal when less than 60.8°F (16°C). Moyle et al. (1995) reported that spring-run Chinook salmon in the Sacramento River typically hold in pools that have temperatures below 69.8°F (21°C) to 77°F (25°C), however, in Butte Creek in 2003, 11,000 adults died before spawning, while more than 6,000 survived to spawn. Mortalities were attributed to high temperatures, large numbers of fish and outbreaks of two pathogens, Columnaris and Ich. Average daily temperatures exceeded 59oF (15°C) at all sites from late-June until the first week of September, exceeded 63.5°F (17.5°C) by July 12, and exceeded 68oF (20°C) for 7 days during the holding period at the uppermost holding pool (Quartz Bowl) in 2003 (Ward et al. 2004). In Butte Creek, prespawn adult mortalities were minimal when average daily temperatures were less than 66.9°F (19.4°C) with only brief periods of high temperatures up to about 70°F (21°C) in July between 2001 and 2004 (Ward et al. 2006). Based on these and other studies, critical temperatures that cause thermal stress for holding adults in Table 3-1 are in the range of 62.6 to 68°F (17 to 20°C) with significant mortality occurring above that range.

4.5.5 Disease

Diseases such as BKD, C*eratomyxosis shasta* (C-shasta), columnaris, furunculosis, infectious hematopoietic necrosis, redmouth and black spot disease, whirling disease, and erythrocytic inclusion body syndrome are known, among others, to affect Chinook salmon (NMFS 1996, 1998). Many pathogens are ubiquitous along the northwestern Pacific coast of the United States in salmon populations. However, the pathogens are normally present at low levels and do not usually affect the host to the point of causing disease (Arkoosh et al. 1998). Only when other stressors are present are there increased incidences of disease outbreaks. These stressors can include elevated water temperature, low DO, crowding, high levels of ammonia, and presence of pollutants (Wedemeyer 1974). The susceptibility of anadromous salmonids to these pathogens is also influenced by hydrological regime, behavior, and physiological changes associated with spawning activity.

Two extreme cases of disease-related fish kills occurred in the Klamath River and Butte Creek in 2003. In September 2002, 34,000 adult salmon, mostly Chinook, died in the lower 25 miles of the Klamath River, California due to a combination of low flows, high temperatures, and high infestation rates of Ich and/or columnaris. Significant prespawning mortality of spring-run Chinook salmon also occurred in Butte Creek, California, during 2003 as a result of high temperatures and subsequent infection of columnaris and Ich (Ward et al. 2006).

4.5.6 Predation

Mammals may be an agent of mortality to salmonids in the Central Valley. Predators such as river otters (*Lutra Canadensis*), raccoons (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and western spotted skunk (*Spilogale gracilis*) are common. Other mammals that take salmonids include badger (*Taxidea taxus*), bobcat (*Linx rufis*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), long-tailed weasel (*Mustela frenata*), mink (*Mustela vison*), mountain lion (*Felis concolor*), red fox (*Vulpes vulpes*), and ringtail (*Bassariscus astutus*). These animals, especially river otters, are capable of removing large numbers of salmon and trout (Dolloff 1993). Mammals have the potential to consume large numbers of holding adults, but generally scavenge post-spawned salmon.

4.6 Spawning

Clark (1943) estimated that about 267,000 square feet (64 percent) of spawning habitat remained after Friant Dam had been constructed in 1941. Chinook salmon were observed spawning in large numbers on all the riffles in the 10-mile reach between Friant Dam and Lanes Bridge in 1942. Since the 1940s, spawning habitat has been highly degraded by dams that block gravel recruitment, in-river gold and gravel mining, and water diversions that reduce flows and increase water temperatures. It is assumed that the Restoration Flow Schedule will provide suitable water depths and velocities for spawning based on a Physical Habitat Simulation study conducted by USFWS in 1993.

4.6.1 Insufficient Spawning-Sized Gravels

The abundance of spawning-sized gravels below Friant Dam has gradually decreased as a result of upstream dams blocking sediment recruitment and gravel mining from the river terrace and low-flow channel. The estimated average unimpaired coarse sediment supply for the mainstem San Joaquin River is approximately 48,600 cubic yards/year (Cain 1997). There is relatively little gravel recruitment from the tributaries below Friant Dam: Cottonwood Creek (RM 267.4) contributes about 55 cubic yards/year and Little Dry Creek (RM 261) contributes an average of about 335 cubic yards/year (Cain 1997).

An absence of gravel recruitment reduces the amount of useable spawning habitat in three ways. First, without recruitment, uncontrolled high flow releases scour the gravel from the spawning beds so that they gradually become smaller in length and the depth of the gravel becomes shallower. Cain (1997) compared the 1939 and 1996 measurements of the channel thalweg elevation at seven cross sections in Reach 1A. At four cross sections, the thalweg elevation decreased by 4.5 to 7.0 feet whereas it increased by 0.8 to 3.2 feet at three cross sections. Second, smaller gravels tend to be mobilized at the highest rates, which causes the bed surface to armor with large rocks that can be too large for the salmon to move for redd construction. Both the reduction in spawning bed size and the armoring of the bed‘s surface has the effect of crowding spawners into the remaining usable spawning areas. Crowding is thought to increase the rate of redd superimposition, when spawners construct their redds on top of preexisting redds, thereby killing or burying some of the eggs in the preexisting redds. The third problem caused by reduced gravel recruitment is that uncontrolled scouring flows also erode sediment from the floodplains.

A reduction in upstream gravel supply can disrupt the balance between sediment supply and transport capacity, disturbing the longitudinal continuity of the river system and altering channel pattern (Kondolf and Swanson 1993, Kondolf 1997). The excess energy of sediment-starved water is typically expended on the bed, causing incision and likely channel narrowing. Sediment-starved channels can also respond through lateral migration into banks and floodplains, potentially causing greater rates of bank failure as the channel pattern adjusts to a new sediment supply and transport equilibrium (Simon 1995). Channel widening is a problem in some reaches of the Stanislaus River (Schneider 1999) and it appears to be a problem in Reach 1 of the Restoration Area (FMWG 2007). Bank erosion degrades the spawning habitat by reducing water depths and velocities and degrades the egg incubation habitat by increasing the rate that fine sediments are deposited on the spawning beds.

Instream aggregate extraction may have further reduced the amount of spawning-sized gravel in Reach 1A, where the majority of the Chinook salmon are expected to spawn. In Reach 1A, Cain (1997) estimated that 1,562,000 cubic yards were removed from the active channel of the San Joaquin River between 1939 and 1989 (3,124 cubic yards/year), and 3,103,000 cubic yards were removed from the floodplain and terraces. Nine large captured mine pits occur from about 8.7 miles (RM 258.8) to about 34.3 miles (RM 233.2) below Friant Dam (Table 3-16 in McBain and Trush 2002); therefore, it is likely that many spawning beds were highly degraded by gravel mining.

During July 2007, the FMWG observed one spawning bed with suitably sized gravels near the dam and three highly silted spawning beds during foot and canoe surveys of the first 5 miles of the low-flow channel below Friant Dam (RM 262.5 to RM 267.5) where a majority of the spring-run Chinook salmon would be expected to spawn. They also observed 22 potential spawning beds in the next 4.4-mile-long reach (RM 257.75 to RM 262.15) that had moderate levels of silt and suitably sized gravels for spawning. The D_{50} of the surface substrate at three of these riffles ranged between 40 and 47 mm based on pebble counts (Table 3-7 in McBain and Trush 2002).

4.6.2 High Water Temperatures

Preferred spawning temperatures for spring-run and fall-run Chinook salmon are between 42°F (5.6°C) and 57°F (13.9°C) (Bell 1986). Temperatures above the preferred spawning range have been observed to increase the occurrence of abnormal fry and mortality, and lengthen the duration of the hatching period (Spence et al. 1996). The FMWG recommends 57°F as a target for maintaining optimal spawning temperatures for Chinook salmon.

4.6.3 Hybridization Between Spring-Run and Fall-Run Salmon

Historically, spring-run Chinook salmon spawned in the upper watersheds whereas fall-run Chinook salmon were confined to the lower watersheds when fall flows dropped and barriers prevented their migration to the areas used by the spring-run Chinook salmon. Currently, with access to historical higher elevation spring-run Chinook salmon spawning habitat blocked by Friant Dam, both runs would share the available spawning habitat downstream from Friant Dam, posing the risk of hybridization. Forced coexistence of these two runs caused by substantial damming and loss of habitat in other river systems has led to concern for their genetic integrity (Cope and Slater 1957, Banks et al. 2000). However, despite spatial and temporal overlap of Chinook salmon spawning runs in the Central Valley, no evidence for natural hybridization among runs has been documented (Banks et al. 2000).

Genetic effects of run hybridization on Chinook salmon populations remain unclear. It is likely, however, that hybridization between spring- and fall-run Chinook salmon in the San Joaquin River would influence the life-history strategy adopted by genetically mixed progeny. Given the potential for water temperatures in large portions of the Restoration Area to exceed suitable limits during key periods of upstream migration (late summer and fall) and rearing (spring and early summer), altered run timing is of particular concern. To prevent spawning overlap by the two runs, it may be necessary to construct artificial barriers to separate spring- and fall-run spawners.

4.6.4 Instream Flows

The relationship between instream flow and spawning habitat availability was modeled by USFWS (1994b). Although the study assessed spawning habitat availability for fall-run Chinook salmon, the relationships can be transferable to spring-run Chinook salmon. USFWS (1994b) found stream flows of 150 cfs to provide close to optimal spawning conditions in Reach 1A. Settlement flows for incubation range from 120 cfs to 350 cfs, depending on water year type (Settlement, Exhibit B). Settlement flows appear adequate for incubation and emergence; however, this information should be taken cautiously, as it is extrapolated from fall-run Chinook salmon work conducted in 1993.

4.6.5 Harvest

Currently, fishing regulations in the San Joaquin River permit the harvest of one Chinook salmon year-round from Friant Dam downstream to the Highway 140 Bridge; therefore, a majority of the spawning adults should be protected.

Poaching of adult fall-run Chinook salmon from their spawning beds is a common occurrence in the Stanislaus, Tuolumne, and Merced rivers based on reports from DFG wardens; however, the number of adult fish taken has not been estimated. Most poachers snag fish with large treble hooks, but others use gill nets to catch fish. It is likely that spring- and fall-run Chinook salmon will be illegally harvested from the Restoration Area, but the likely extent of the problem in the Restoration Area is unknown.

4.7 Hatchery Impacts

The goal of the SJRRP is to restore naturally reproducing and self-sustaining populations of Chinook salmon and native fish species. However, it is increasingly evident that some form of hatchery intervention will be required by the SJRRP to help achieve this goal. Allowing only natural recolonization is problematic for spring-run Chinook, given the lack of geographically proximal spring-run populations, and the low census and protected status of spring-run Chinook salmon in California prohibits excessive take of this species, which will severely limit the availability of donor fish. Also, relocating adult and juvenile fish to the Restoration Area is complicated by stress-related mortality and other technical challenges, and some number of study fish will be needed for telemetry, habitat, and other types of controlled research studies.

Hatcheries can generally be classified as supplementation hatcheries or conservation hatcheries, with the latter differing in its emphasis on not only producing desired numbers of fish for hatchery release, but also reducing genetic and ecological impacts of releases on wild fish (Flagg and Nash, 1999). As many Pacific Coast salmon populations continue to decline, the use of supplementation hatcheries has been relied on to recover populations; however, there is controversy concerning the role of hatcheries in the recovery and supplementation of wild salmon stocks (Brannon et al. 2004). Recent literature suggests that supplementation hatchery programs have had negative impacts on wild fish due to genetic, domestication, physiological, behavioral, disease, and population level effects. Recent efforts to reform hatchery management and minimize impacts to native salmonid populations are ongoing and have placed increasing emphasis on the role of conservation hatcheries. Objectives of developing a conservation hatchery include:

- Create breeding protocols and standard operation procedures for hatchery operations to allow for maximum effective population sizes, minimum impact on wild (or naturalized) spring-run Chinook and nontarget populations
- Employ physical and genetic marking techniques to evaluate and adapt hatchery contribution to the census size of returning upper San Joaquin River Chinook salmon populations
- Evaluate effective population size and genetic diversity for the hatchery population

The goal of hatchery implementation for the SJRRP is to restore naturally reproducing, viable spring- and fall-run Chinook salmon populations, and so its success is marked by the ability to ultimately phase out hatchery production. This will reduce the negative influences that continued hatchery supplementation can have on the reestablished spring- and fall-run Chinook salmon populations. Use of spring- or fall-run Chinook salmon hatchery production will be determined by an adaptive management approach given the likely uncertainty of initial restoration phases. Genetic accommodation of the natural population, quantitative natural population targets (e.g. N_e, census size, genetic diversity), and other community and ecosystem indicators of reintroduction success will be derived and periodically evaluated to phase out hatchery production. Hatchery production phase-out will be further detailed in ESU-specific Hatchery and Genetic Management Plans, as per NMFS guidelines. Additionally, uncertainties such as local habitat change, climate change, and others, will be given consideration in phase-out determinations.

Traditional supplementation hatchery models have a low likelihood of achieving the Restoration Goals of the SJRRP without detrimental genetic impacts to the reintroduced population. However, the FMWG supports the use of a Conservation Hatchery for the initial reintroduction effort of salmonids into the Restoration Area as one strategy to be used in combination with other reintroduction strategies to best meet the population objectives developed by the FMWG. Therefore, the SJRRP is advancing plans for the development of a salmon conservation and research hatchery to provide facilities available to meet SJRRP timelines.

4.8 Climate Change

The world is about 1.3°F (0.7°C) warmer today than a century ago. The latest computer models predict that, without drastic cutbacks in emissions of carbon dioxide and other gases released by the burning of fossil fuels, the average global surface temperature may rise by two or more degrees in the 21st century (IPCC 2001). Much of that increase will likely occur in the oceans, and evidence suggests that the most dramatic changes in ocean temperature are now occurring in the Pacific (Noakes 1998). The northwestern U.S. has warmed by between 1.3°F to 1.6°F (0.7°C and 0.9°C) during the 20th century (Battin et al. 2007).

Sea levels are expected to rise by 1.5 to 3.3 feet (0.5 to 1.0 meters) along the northeastern Pacific coasts in the next century, mainly due to warmer ocean temperatures, which lead to thermal expansion much the same way that hot air expands. This may trigger increased sedimentation, erosion, coastal flooding, and permanent inundation of low-lying natural ecosystems (e.g., salt marsh, riverine, mud flats) affecting salmonid primary constituent elements. Increased winter precipitation, decreased snowpack, permafrost degradation, and glacier retreat due to warmer temperatures will cause landslides in unstable mountainous regions, and destroy fish and wildlife habitat, including salmon-spawning streams. Glacier reduction could affect the flow and temperature of rivers and streams that depend on glacier water, with negative impacts on fish populations and the habitat that supports them.

Summer droughts along the south coast and in the interior of the northwest Pacific coastlines will mean decreased stream flow in those areas, decreasing salmonid survival and reducing water supplies in the dry summer season when irrigation and domestic water use are greatest. Global warming may also change the chemical composition of the water that fish inhabit by potentially reducing the oxygen in the water, while pollution, acidity, and salinity levels increase. This will allow more invasive species to overtake native fish species and impact predator-prey relationships (Peterson and Kitchell 2001).

It is expected that Sierra snowpacks will decrease with global warming, and that the majority of runoff in California will shift to winter rainfall instead of melting snowpack in the mountains. This will alter river runoff patterns and transform the tributaries that feed the Central Valley from a spring/summer-snowmelt-dominated system to a winter-rain-dominated system. In addition, the cold snowmelt that furnishes the late spring and early summer runoff will be replaced by warmer precipitation runoff. This may truncate the period of time that suitable cold water conditions persist below existing reservoirs and dams because of the warmer inflow temperatures to the reservoir from rain runoff. Without the necessary cold water pool developed from melting snowpack filling reservoirs in spring and early summer, late summer and fall temperatures below reservoirs could potentially rise above thermal tolerances for juvenile and adult salmonids.

New efforts on salmonid habitat restoration will need to accommodate the imminent impact of climate change. Recent simulation studies indicate that climate change is bound to have a large negative impact on freshwater salmonid habitat. For instance, Battin et al. (2007) predict the combined effect of climate change and habitat restoration will be a change in salmonid population abundance with a spatial shift toward lower elevations preferred by ―ocean-type‘ salmon runs such as fall-run Chinook salmon. An Adaptive Management Approach will provide the flexibility to track significant changes in the life history of restored Chinook salmon challenged by the most human-induced rapid environmental change in the San Joaquin River watershed.

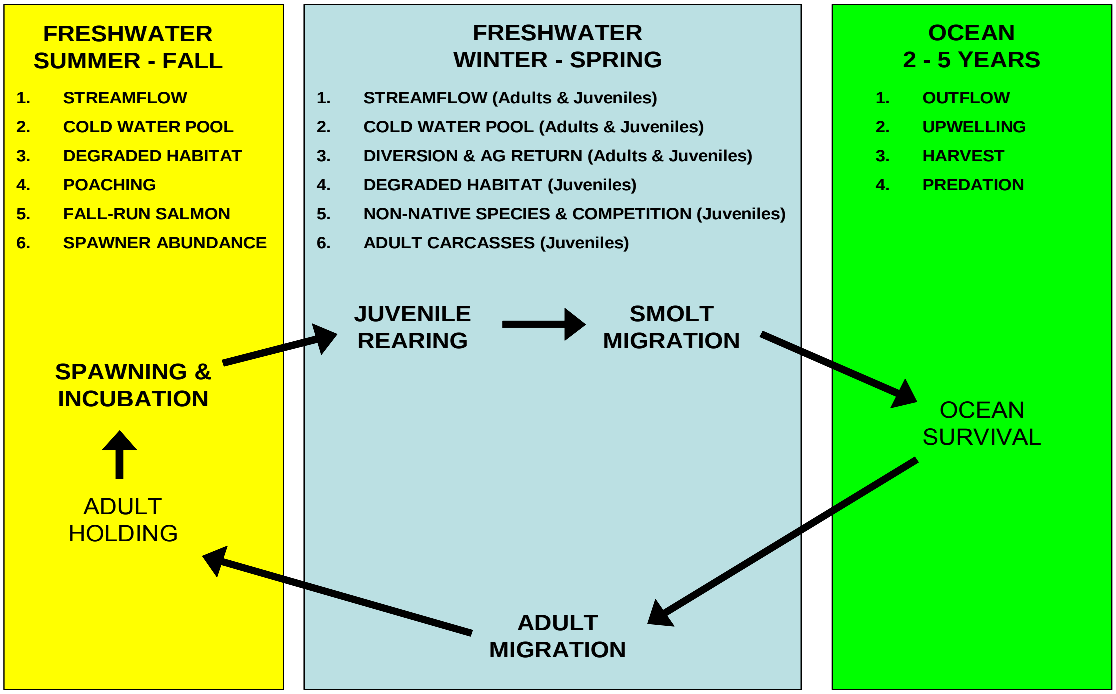
Chapter 5 Conceptual Models

The following conceptual models represent the FMWG understanding of how the limiting factors may affect each life history stage of spring- and fall-run Chinook salmon in the San Joaquin River Basin. For the SJRRP, limiting factors are defined as the physical, biological, or chemical conditions and associated ecological processes and interactions that influence the abundance and productivity of San Joaquin River Chinook salmon. The FMWG recognizes that it is possible that not all limiting factors have been identified, and that the identified limiting factors may not be fully understood. Recognizing these uncertainties, the conceptual models will be developed into a series of testable hypotheses and appropriate studies described in the SJRRP Adaptive Management Approach (as described in the FMP) to help evaluate the effectiveness of all restoration and management actions implemented to achieve the Restoration Goal.

The conceptual models assume that all actions prescribed in the Settlement, such as screening the bypass channels and improving passage conditions, will be implemented. The Adaptive Management Approach will include monitoring to determine the effectiveness all actions, including those described in the Settlement.

5.1 Spring-Run Chinook Salmon

The abundance of adult spring-run Chinook salmon that return to spawn in the Restoration Area will probably be affected by numerous factors, only some of which will be under the control of the SJRRP whereas other factors will be outside the control of the SJRRP (Figure 5-1).



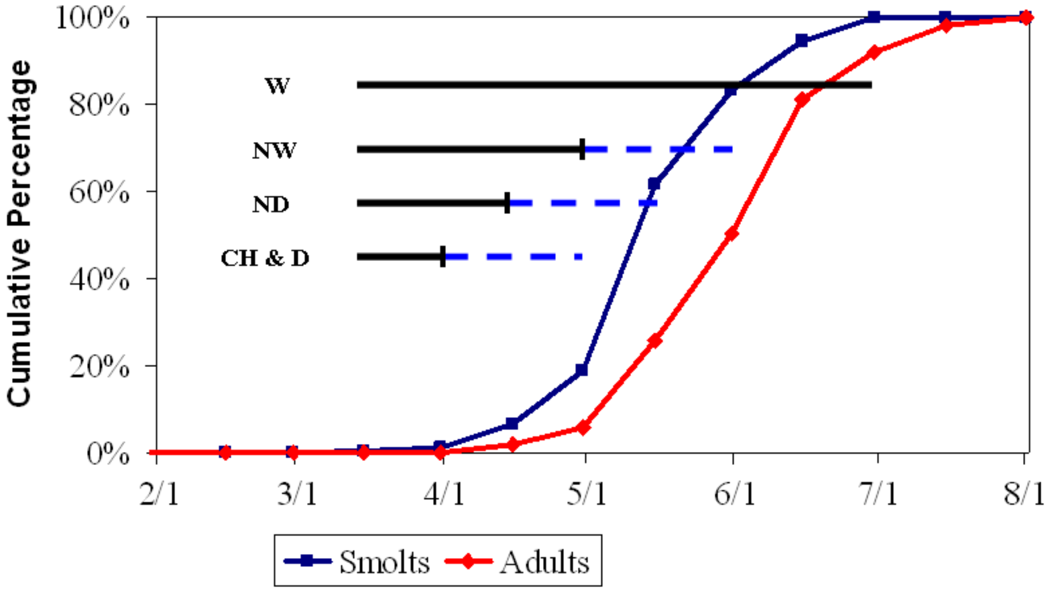
Note: The life stages in bold type are assumed to be the most critical for achieving the Restoration Goal.

Figure 5-1.
Overall Conceptual Model for San Joaquin River Spring-Run Chinook Salmon

Potential limiting factors that the SJRRP will have some control over include the following:

- **Inadequate Streamflows** –The Restoration Flow Schedule has truncated spring pulse flows that may protect no more than 83 percent of the migrating smolt-sized juveniles (greater than or equal to 70-mm FL) and no more than 50 percent of the migrating adults during all but wet years. This is based on the assumption that Restoration Flow Schedule can be shifted up to 4 weeks, and that reintroduced San Joaquin fish behave similarly to those that rear in the upper reaches of Butte Creek in the Sacramento River Basin (Figure 5-2).

In the Merced, Tuolumne, and Stanislaus rivers, Chinook salmon production seems highest during wet years, characterized by high flows from February through June. It is unknown whether it will be possible to shift the Restoration Flow Schedule into May to protect migrating adults and juvenile Chinook salmon; provide at least periodic floodplain inundation during the March through May rearing period; maintain suitable water temperatures for juvenile and adult Chinook salmon (target less than or equal to 68°F (20°C)); and not exhaust the cold water pool in Millerton Lake. Extending the high-flow period into May and June would probably increase smolt production and survival by improving or ameliorating a combination of factors, which include food availability, predation, disease, water temperatures, contaminants, water quality, harvest, and entrainment. However, it is also possible that many fry will migrate to the downstream reaches of the Restoration Area where they will rapidly grow to a smolt size in restored floodplain and wetland habitats before May. If true, pulse flows between February and April may produce a sufficient number of smolts to sustain the spring-run Chinook salmon populations.



Sources: Hill and Webber 1999, Ward and McReynolds 2001, Ward et al. 2002, DFG 1998.

Notes:

1. The solid black horizontal lines represent the release period for spring pulse flows as prescribed in the Settlement during Critical High (CH), Dry (D), Normal Dry (ND), Normal Wet (NW) and Wet (W) years. No spring pulse flows would be released during Critical Low years.
2. The dashed blue horizontal lines represent the maximum flexibility to shift the flow schedule as prescribed by the Settlement.

Figure 5-2.
Relationship Between Timing of Settlement Spring Pulse Flows and Mean Cumulative Percentage of Fish Passage for Butte Creek Subyearling Spring-Run Smolts and Historical Populations of Adult Spring-Run Chinook Salmon in the Sacramento Basin

- **Inadequate Cold Water Pool –** The volume of the cold water pool in Millerton Lake may be insufficient to provide the prescribed summer and fall flow releases and maintain suitable water temperatures for holding adult spring-run Chinook salmon during the summer (target less than 70°F (21°C)) and incubating salmon eggs during the fall (target less than 58°F (14°C)).

- **Degraded Habitat –** The highly degraded channel and floodplain morphology, loss of native riparian vegetation, and exotic species below Friant Dam to the confluence with the Merced River may result in high rates of mortality for juvenile spring-run Chinook salmon. In addition, the reduced gravel recruitment from lateral and upstream sources and high flow events (e.g., 1997) have gradually scoured away the spawning gravels immediately downstream from Friant Dam. In the main San Joaquin River tributaries, it has been noted that regardless of the number of spawning adults, the habitat capacity for rearing fry and juveniles limits the actual Chinook salmon production.

- **Inadequate Spawner Abundance** – Legal and illegal harvest of yearling juveniles and holding and spawning adults may substantially limit adult recruitment, particularly if escapements are low. In addition, conditions that result in low production of juvenile spring-run Chinook salmon will limit the number of adult fish that return to spawn 2 to 4 years later.

Factors outside the control of the SJRRP that have been identified include the following:

- **Streamflow Releases Outside the Restoration Area –** Stream flow releases in the Stanislaus, Tuolumne, and Merced rivers that contribute to flows in the mainstem San Joaquin River, Delta, and San Francisco Estuary are expected to affect the survival of rearing and migrating juvenile and the survival and homing ability of adults.

- **Degraded Habitat –** The highly degraded channel and floodplain morphology, loss of native riparian vegetation, and exotic species below the confluence with the Merced River, the Delta, and San Francisco Estuary are expected to substantially reduce the survival of rearing and migrating juvenile spring-run Chinook salmon.

- **Degraded Water Quality –** Pesticides and other contaminants may substantially reduce the food resources needed by juvenile spring-run Chinook salmon within and below the Restoration Area, and to a lesser degree, result in direct mortality of juveniles. In addition, poor water quality (e.g., low DO and high ammonia concentrations) in the mainstem channel may affect the survival of juvenile, and to a lesser degree, adult spring-run Chinook salmon.

- **Delta Exports –** Springtime Delta exports at the CVP and SWP pumping facilities affect entrainment of juvenile Chinook salmon. Delta exports also reduce flow in the Stockton Deepwater Ship Channel and the amount of freshwater outflow into the ocean, all of which affect the survival of juvenile Chinook salmon and the ability of adults to home to the Restoration Area.

- **Low Ocean Productivity –** Ocean productivity (food resources), as affected by upwelling, coastal currents, El Niño events, and the amount of freshwater outflow from the San Francisco Bay, will affect the survival of juvenile and adult spring-run Chinook salmon.

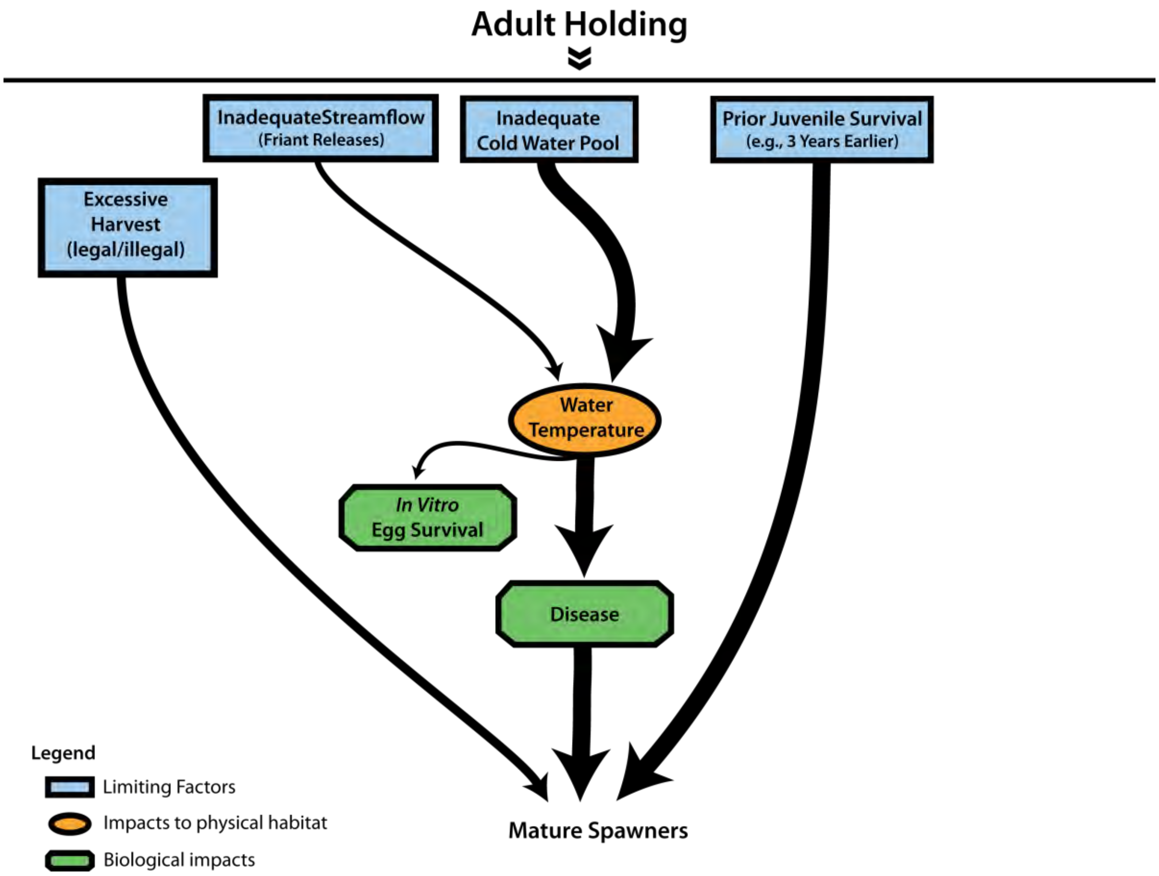
- **Climate Changes –** Climate changes are expected to affect inland water temperatures, hydrographs (i.e., floodplain inundation), and ocean productivity conditions, and therefore, affect the survival of juvenile and adult spring-run Chinook salmon.

- **Excessive Harvest and Predation in the Ocean –** Ocean harvest of adults and predation of juvenile and adults in the ocean affect the number of adults that return to spawn, which may affect the number of juveniles produced during the following spring.

The following are potential mechanisms by which the above limiting factors are expected to affect each life-history stage of spring-run Chinook salmon, including adult holding, spawning, juvenile rearing, smolt migration, ocean survival, ocean harvest, and adult migration. Potential benefits and impacts of hatcheries and climate change are also discussed in terms of overall population effects.

5.1.1 Adult Holding

There are currently several holding pools below Friant Dam that were extensively used by spring-run Chinook salmon during the 1940s. These pools may be able to sustain at least 20,000 fish. However, there are concerns that high water temperatures, and to a lesser degree, predation and harvest (legal and illegal) may affect the ability of spring-run salmon to hold in these pools (Figure 5-3). The number of spawners is also substantially affected by the survival of the fish when they were juveniles, 2 to 5 years earlier.



Note: The width of the arrows indicates the relative importance of each mechanism.

Figure 5-3.
Possible Limiting Factors, Impacts to Physical Habitats, and Biological Impacts that May Affect Holding Adult Spring-Run Chinook Salmon

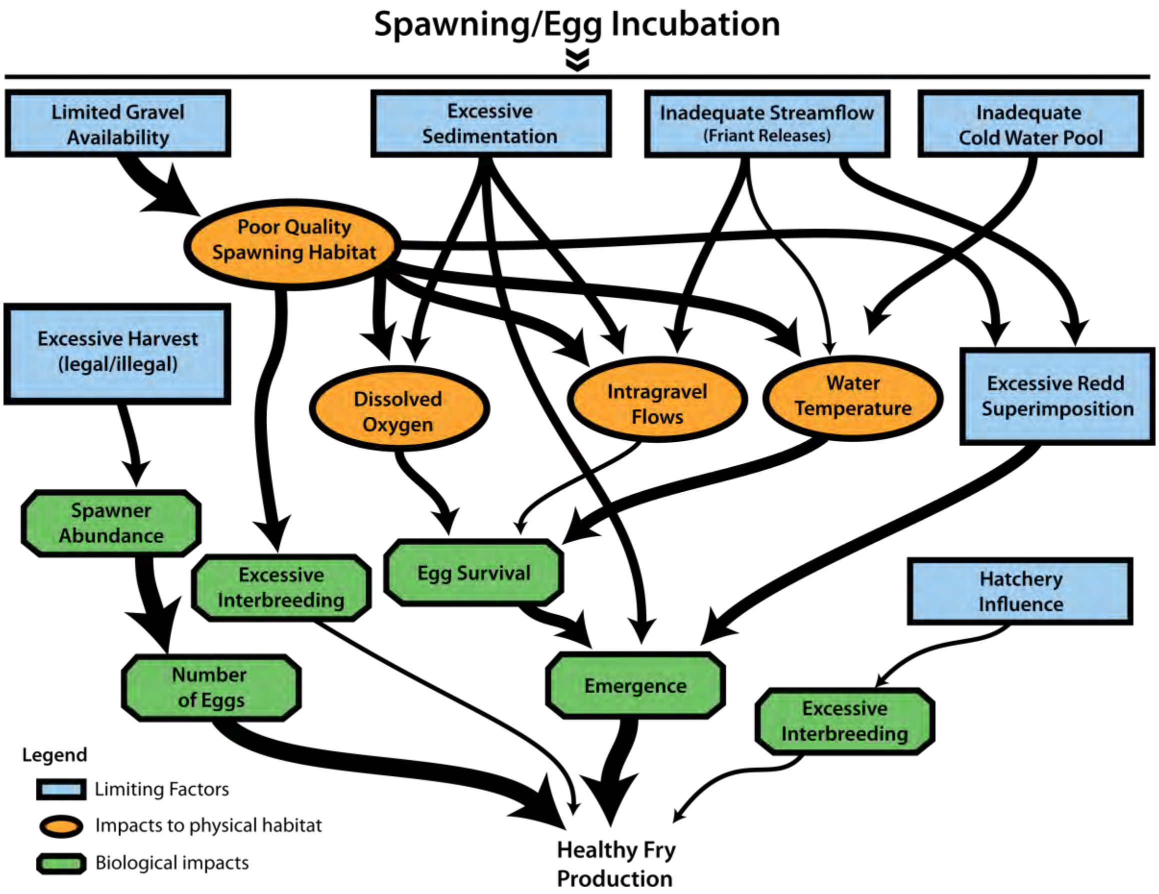
- **Excessive Water Temperatures –** If the cold water pool in Millerton Lake is exhausted as a result of increased summer and fall flows, the temperature of the release flows could exceed suitable levels for holding adults. If temperatures become unsuitably high, disease may become a likely cause of mortality.

- **Excessive Harvest** – Adults will be susceptible to legal and illegal harvest while they hold in the pools below the dam. If escapements are too low to saturate the rearing habitat with juvenile fish, the harvest of adult spawners from the holding pools could become a substantial limiting factor.

- **Excessive Predation** – Mammals have the potential to consume large numbers of spawners, but generally scavenge post-spawned fish. It is assumed that predation of holding adults will not have a population level effect. Therefore, predation will not be directly evaluated unless routine monitoring indicates that adult mortality rates during the holding period are higher than expected.

5.1.2 Spawning and Egg Incubation

Spring-run Chinook salmon will probably spawn in the reach immediately downstream from Friant Dam, where water temperatures should be suitable for spring-run spawning and egg incubation between August and January. However, there are only a few, highly silted beds in this reach because Friant Dam has blocked most of the gravel recruitment, and high flows since 1950 have scoured the gravels from these beds. It is likely that the adults would be forced to spawn in either the highly degraded habitats immediately below the dam or in the downstream habitats where egg survival and alevin emergence could be highly impaired by high water temperatures. Another substantial concern is that the increased summer and fall flows required by the Settlement may exhaust the cold water pool in Millerton Lake such that water temperatures of the release flows become unsuitable for adult spawners and egg incubation (Figure 5-4). Other concerns include sedimentation of spawning gravels, turbid storm runoff during egg incubation, redd superimposition by fall-run Chinook salmon, hybridization with fall-run Chinook salmon, and legal and illegal harvest of adults (Figure 5-4).



Note: The width of the arrows indicates the relative importance of each mechanism.

Figure 5-4.
Possible Limiting Factors, Impacts to Physical Habitats, and Biological Impacts that May Affect Spawning and Incubation Habitat for Spring-Run Chinook Salmon

- **Excessive Redd Superimposition by Fall-Run Chinook Salmon –** Fall-run Chinook salmon will probably spawn at the same locations where spring-run Chinook salmon spawn; thus, there is potential that spring-run Chinook salmon redds would be superimposed by fall-run spawners, thereby killing spring-run Chinook salmon eggs, especially when fall-run Chinook salmon escapements are high.

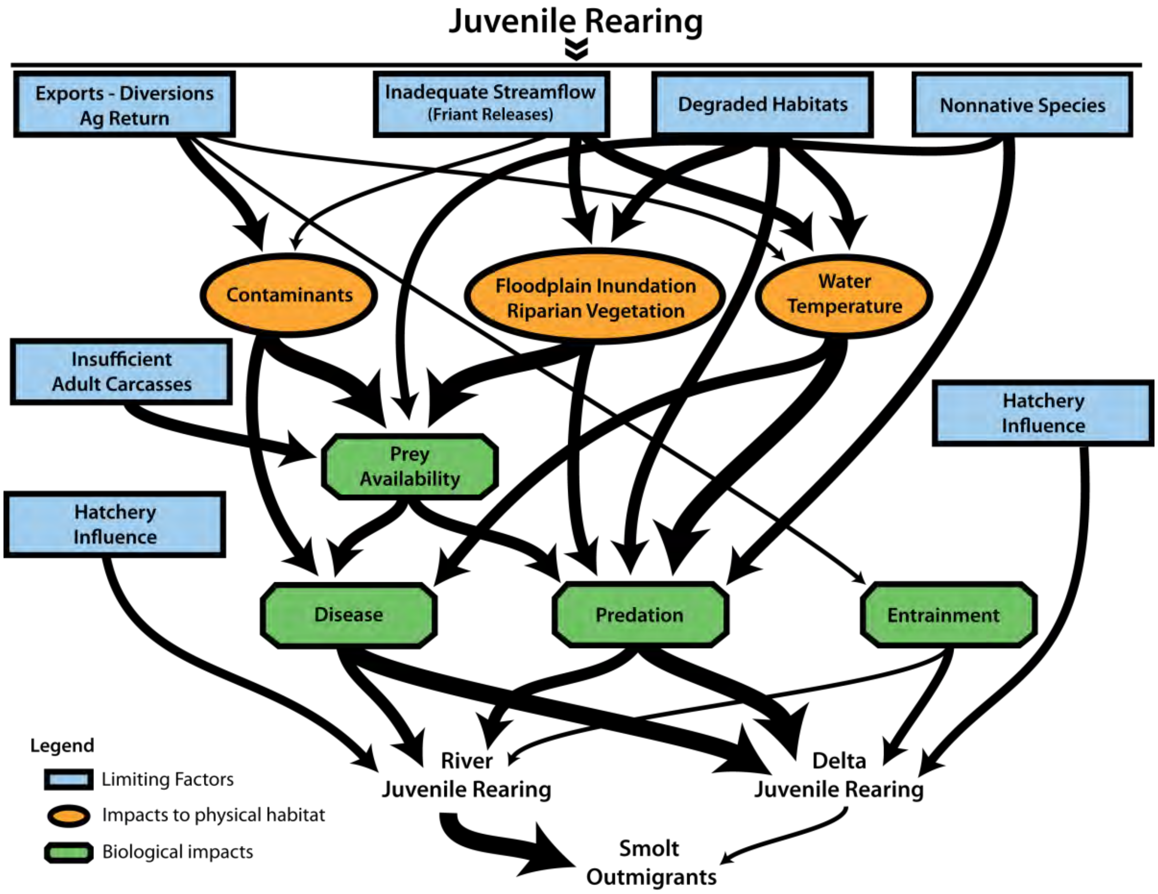
- **Excessive Hybridization with Fall-Run Chinook Salmon** – A small percentage of fall-run Chinook salmon will probably spawn at the same time and location as spring-run fish, so there is potential for hybridization. Some levels of hybridization may occur naturally between Chinook salmon runs, in which case increased genetic variation may counteract inbreeding and natural selection pressures, maintain fit hybrids while eliminating unfit hybrids, thus increasing fitness. However, when excessive hybridization occurs, reduced fitness may result from outbreeding depression. Excessive hybridization may result in fish with migratory behaviors that might not be viable in the San Joaquin River Basin. For example, hybridization between fall-run and spring-run Chinook salmon in the Feather River Hatchery has resulted in adult fish that primarily migrate during the summer (current passage rates at RBDD as shown in Figure 3-5).

- **Excessive Sedimentation** – High permeability measurements made in Reach 1A in 2002 (McBain and Trush 2002) suggest that sedimentation has not adversely affected spawning habitat quality at those locations. However, turbid storm runoff may cause egg mortality, particularly if ground-disturbing activities (e.g., construction or bank erosion) occur near Friant Dam or in one of the upper tributaries (e.g., Cottonwood Creek). It is possible that coating eggs with clay-sized particles suffocates the embryos, or at least stunts their growth.

- **Excessive Harvest** – Adults will be susceptible to legal and illegal harvest particularly while they spawn on shallow gravel beds. If escapements are too low to saturate the rearing habitat with juvenile fish, the harvest of adult spawners from the spawning beds could be a substantial limiting factor.

5.1.3 Juvenile Rearing

Juvenile Chinook salmon that rear in the upper SJRRP reaches and begin their downstream migration in May and June are expected to be substantially impacted by the truncated spring Restoration Flow Schedule prescribed in the Settlement, the highly degraded physical habitats within and downstream from the Restoration Area, and exotic species that potentially compete for food or prey on juvenile Chinook salmon (Figure 5-5). The primary mechanisms by which these factors will affect the production of Chinook salmon smolts are probably linked to reduced food resources, temperature-increased metabolic demands, and abnormally high rates of predation and disease. In the upstream reaches, it is likely that the combined effects of limited food resources and low water temperatures will result in slow growth rates for juvenile Chinook salmon that delay the onset of smoltification until late spring (May and June) when downstream conditions in the Delta are usually unsuitable for migrating smolts. In the downstream reaches, the lack of inundated floodplain and wetland habitats from late January through early May may limit their survival.



Note: The width of the arrows indicates the relative importance of each mechanism.

Figure 5-5.
Possible Limiting Factors, Impacts to Physical Habitats, and Biological Impacts that May Affect Juvenile to Smolt Survival of Spring-Run Chinook Salmon in the San Joaquin River

The following summarizes the key mechanisms by which the limiting factors may affect the survival of rearing juvenile spring-run Chinook salmon.

- **Inadequate Food Resources** can result from many potential causes:
    - Reduced magnitude and duration of winter and spring flows (presumably February through mid-June) reduces floodplain inundation that provides food organisms and organic detritus supporting the food web for juvenile spring-run Chinook salmon.
    - Pesticides and other contaminants may reduce the abundance of food organisms.
    - Elevated water temperatures may increase food requirements beyond the amount available to juvenile spring-run Chinook salmon.
    - Levees, dikes, and dredger tailings reduce floodplain habitat inundation that provides food organisms and organic detritus supporting the food web for juvenile spring-run Chinook salmon.
    - Low numbers of adult Chinook salmon carcasses will reduce food resources for juveniles. This will be a particular problem for the first few years before adults begin to return.
    - Loss of riparian vegetation on floodplain and wetland habitats reduces the input of organic detritus that drives the juvenile spring-run Chinook salmon‘s food web.
    - Nonnative invasive species include plants that may not augment the salmon's food supply. Invertebrate species, such as Asiatic freshwater clams, and fish, such as centrarchids, may compete with Chinook salmon for food.
    - Competition with other native fish species, including fall-run Chinook salmon juveniles may reduce food resources for spring-run Chinook salmon juveniles.
    - Intermittent flows in bypass channels used as rearing areas may reduce food resources. Typically when floodplains or bypass channels become inundated, there is an initial pulse in terrestrial food resources followed by a gradual increase in aquatic food resources.
    - Sedimentation and gravel extraction affects the composition of the invertebrate community, although it is unknown whether the change in species composition substantially affects the availability of food for juvenile spring-run Chinook salmon.

- **Excessive Predation** – Predation by native and introduced fish species can be abnormally high when flows are confined to the main channel and water temperatures are high.
  - Key predators are thought to include Sacramento pikeminnow, which feeds all year, striped bass, which typically begins migrating into tributary habitats in April, and introduced centrarchids, when they begin feeding in April or May as water temperatures rise. These fish tend to use dredged habitats in the Restoration Area and Delta, including captured mine pits, the Stockton Deepwater Ship Channel, and canals leading to the CVP and SWP pumping facilities. Nonnative submerged aquatic vegetation provides habitat for nonnative predators.

- **Disease –** Disease may be a substantial source of mortality when food resources are low, water quality is poor, and/or water temperatures are high**.**

- **Entrainment –** The bifurcation structures in the Restoration Area will be screened as directed by the Settlement; however, it is uncertain whether the screens will be fully effective. Large unscreened diversions, such as those of the West Stanislaus Irrigation District, Patterson Water Company, and El Solyo Water Company, may entrain a substantial number of fry and parr. There is no information on entrainment rates at the numerous small diversions throughout the basin.

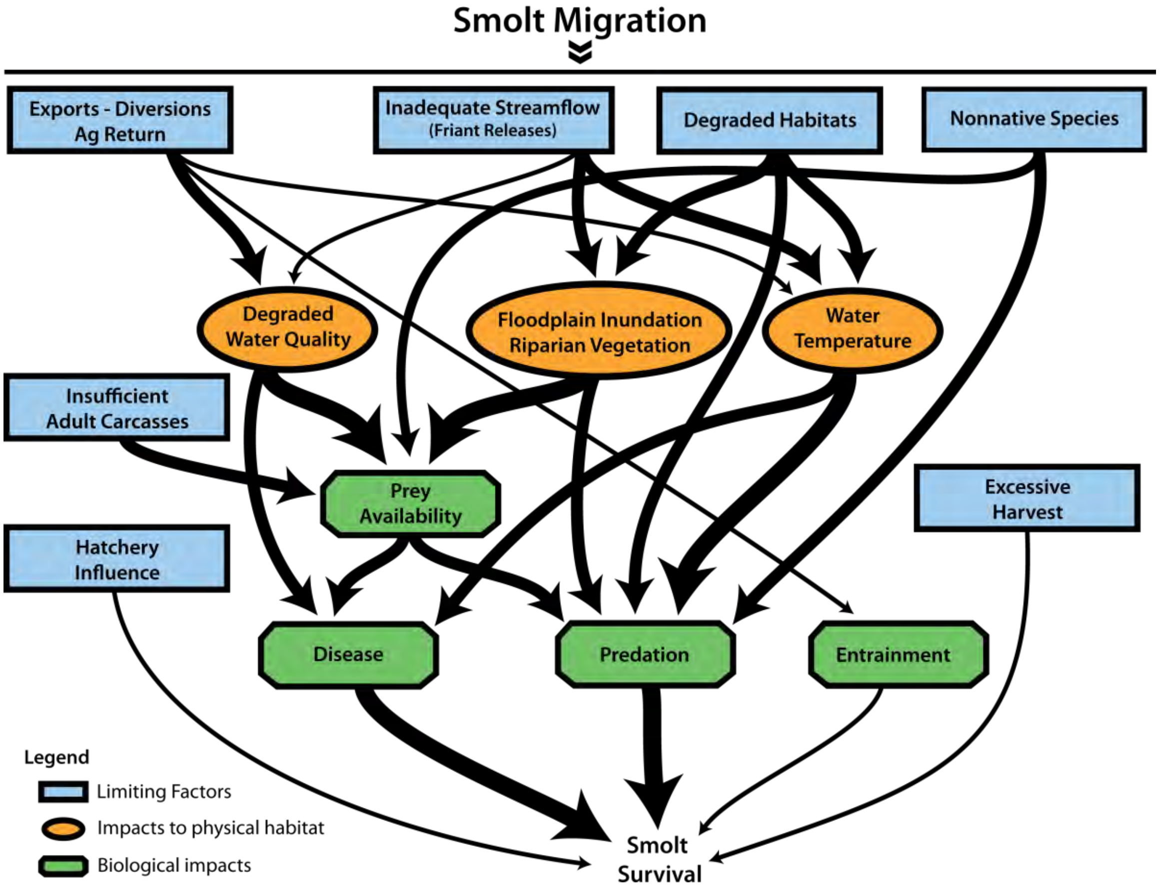
- **Degraded Habitat –** Loss of connected floodplain habitats, in-river gravel extraction, blocked sediment recruitment by upstream dams, bank stabilization, and reduced recruitment of IWM reduce the suitability of the habitats used by parr-sized juveniles (50- to 80-mm FL) for feeding stations and predator refuge.

- **Contaminants** – It is assumed that contaminants do not directly cause juvenile mortality, but rather have indirect effects by reducing food resources or accelerating disease infestation rates.

- **Excessive Water Temperatures –** Water temperatures that exceed 77°F (greater than 25°C) in late spring may cause juvenile mortality. However, it is assumed that juvenile Chinook salmon die from other factors, such as predation, disease, or starvation, as water temperatures approach lethal levels.

5.1.4 Smolt Migration

The likely causes of mortality for migrating subyearling smolts are expected to be similar to those for rearing juveniles, including the truncated spring hydrographs prescribed in the Settlement, the highly degraded physical habitats within and downstream from the Restoration Area, and exotic species that potentially compete for food or prey on juvenile Chinook salmon (Figure 5-6). However, it is likely that the negative impacts of high water temperatures, contaminants, water quality (e.g., ammonia near wastewater treatment plants, DO concentrations in the Stockton Deepwater Ship Channel), entrainment, and predation will be much worse for juveniles that slowly grow to a smolt size in the upper reaches and then outmigrate between April and mid-June compared to those that rapidly grow in warmer downstream reaches and then outmigrate between late March and early May. Another problem that may affect smolts is sport harvest.



Note: The width of the arrows indicates the relative importance of each mechanism.

Figure 5-6.
Possible Limiting Factors, Impacts to Physical Habitats, and Biological Impacts that May Affect Survival of Migrating San Joaquin River Spring-Run Chinook Salmon Smolts

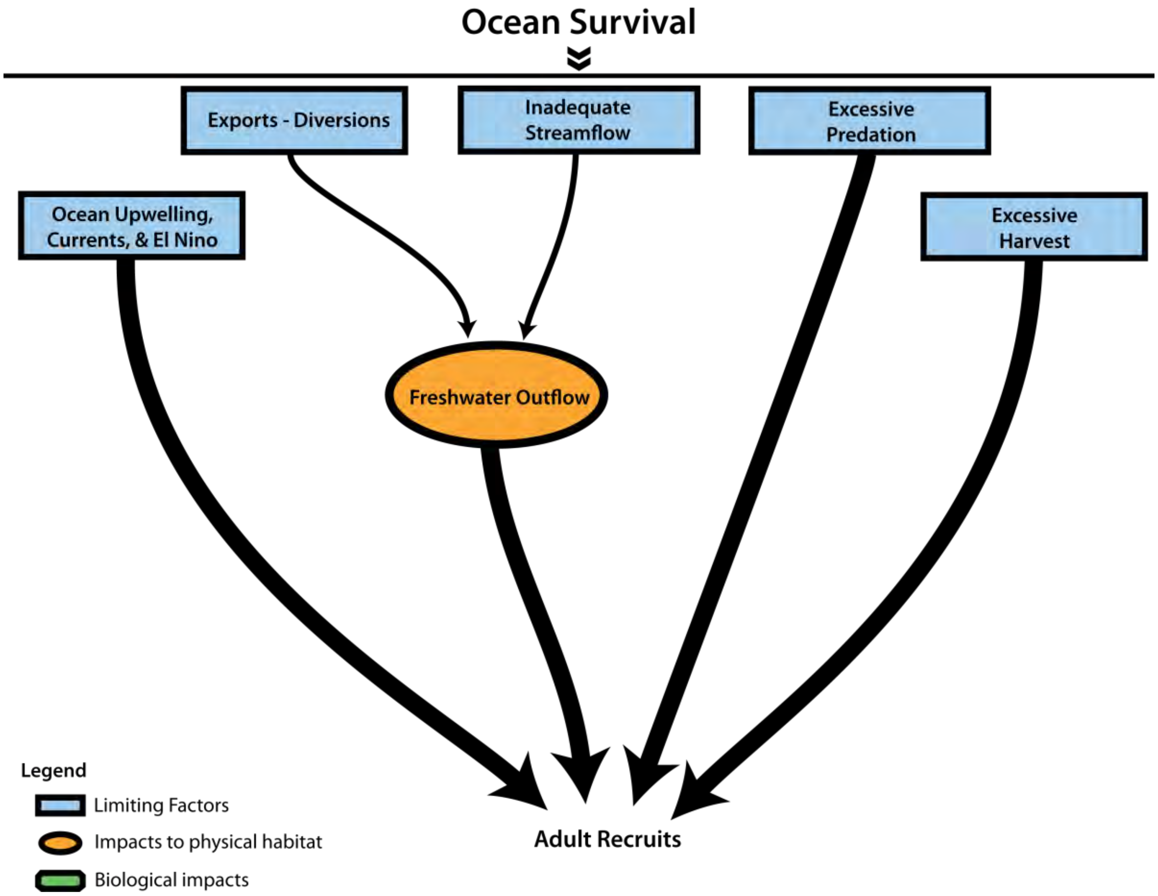
The relative importance of these stressors may partially depend on whether the smolts migrate through the natural channels or bypass channels. It is expected that predation will be a greater problem in the natural channel compared to the bypass channels, which would only receive intermittent flows during the migratory period. In contrast, the bypass channels may have higher water temperatures that would improve the growth of fry between January and April, but negatively impact spring-run Chinook salmon smolts migrating in May and June.

5.1.5 Ocean Survival

The survival of spring-run Chinook salmon smolts entering the ocean during June and July is probably the most critical phase for Chinook salmon in the ocean (Figure 5-7). Freshwater outflow from the estuary is highly correlated with smolt survival and the availability of food resources at the interface between freshwater and saltwater. Coastal upwelling, ocean currents, and El Niño events also affect ocean productivity and the survival of smolts entering the ocean. Indices of ocean productivity conditions will be incorporated into the assessment of adult Chinook salmon production in the Restoration Area.

5.1.6 Ocean Harvest

It is anticipated that ocean harvest rates will have population level effects whenever harvest rates reduce escapement to the point that there are too few spawners to saturate the habitat with juveniles (Figure 5-7). Estimates of ocean harvest rates will be incorporated into the assessment of adult Chinook salmon production in the Restoration Area.

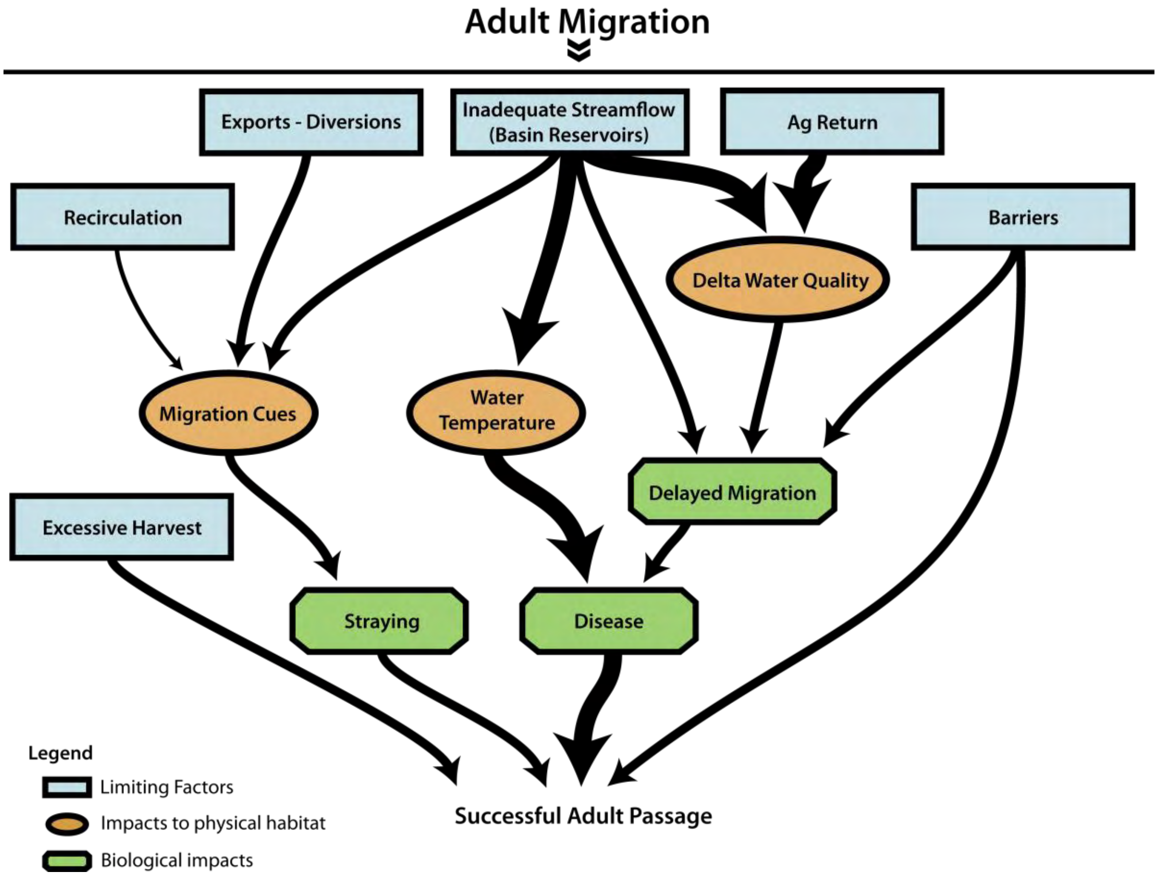


Note: The width of the arrows indicates the relative importance of each mechanism.

Figure 5-7.
Possible Limiting Factors, Impacts to Physical Habitats, and Biological Impacts that May Affect Survival of San Joaquin River Spring-Run Chinook Salmon in the Ocean

5.1.7 Adult Migration

Conditions in Reaches 3 through 5 and the Delta may affect adults in terms of passage and straying rates. The most significant concern is that when the spring-pulse flows cease, water temperatures will become unsuitable and the adults will succumb to disease or other sources of mortality (Figure 5-8). It is also important to remember that the conditions that affect juvenile survival in freshwater and ocean habitats also affect the number of adults that return to spawn.



Note: The width of the arrows indicates the relative importance of each mechanism.

Figure 5-8.
Possible Limiting Factors, Impacts to Physical Habitats, and Biological Impacts that May Affect Survival of Migrating Adult San Joaquin River Spring-Run Chinook Salmon

- **Excessive Water Temperature** – It is unlikely that without spring pulse flow releases, water temperatures will become high enough (70 to 80°F) (21 to 27°C) in late spring and early summer to cause high rates of adult mortality due to disease. It is unlikely that suboptimal water temperatures would affect gamete viability because he fish migrate when they are sexually immature.

- **Delta Water Quality** – Low DO concentrations and possibly high water temperatures may delay passage for adults in the Stockton Deepwater Ship Channel, particularly when the tributary pulse flows cease in mid- to late May and thereby worsen high temperature-related impacts.

- **Delta Exports** – High export rates relative to flows (export rates greater than or equal to 400 percent of Vernalis flows) can cause up to 20 percent of adult San Joaquin spring-run Chinook salmon to stray to the Sacramento River Basin.

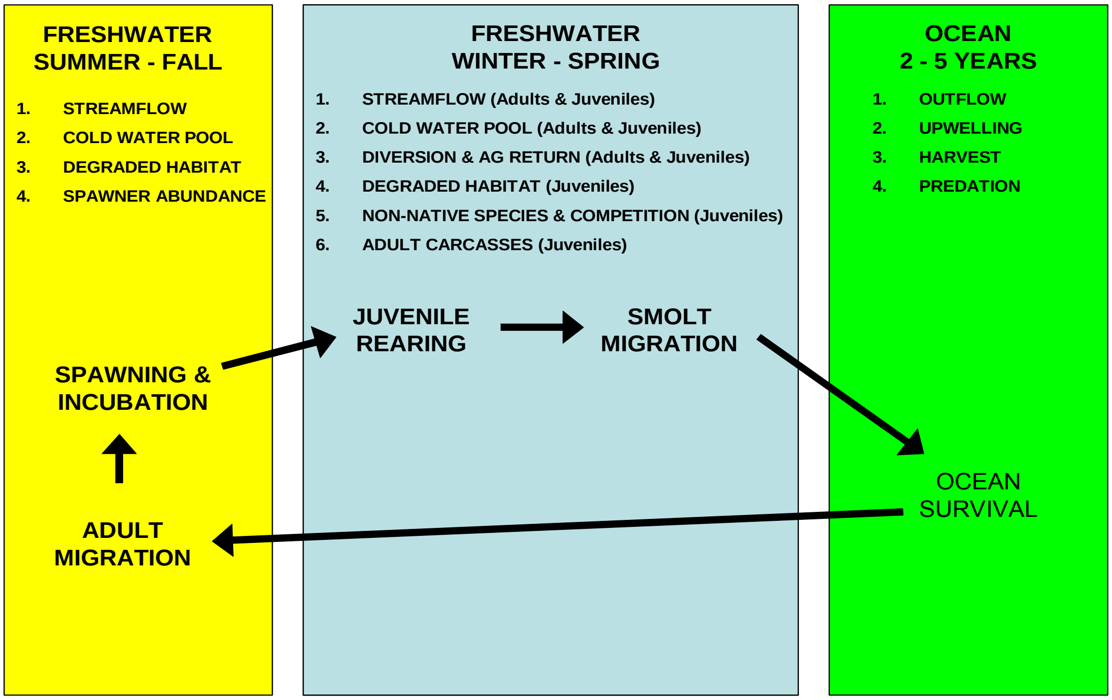
- **Excessive Harvest** – Legal and illegal harvest of adult fish in freshwater habitats may result in an inadequate number of spawners to saturate the rearing habitat with juveniles.

5.1.8 Hatcheries

Hatcheries can benefit or impact the natural Chinook salmon population depending on how they are operated. Potential beneficial uses of hatcheries include (1) incubating eggs from a source population of spring-run Chinook salmon for the purposes of reintroduction, (2) sustaining the Chinook salmon populations during drought conditions when flows are not sufficient for juvenile survival, and (3) providing fish for rotary screw trap calibration studies and smolt survival studies that identify high priority restoration projects, passage problems, and critical flow periods. Potential negative impacts to the natural population include genetic contamination (i.e., decreased fitness), sources of disease, and competition with naturally produced juveniles.

5.2 Fall-Run Chinook Salmon

The environmental factors that are likely to affect the production of fall-run Chinook salmon are nearly identical to those that affect spring-run Chinook salmon, with a few exceptions (Figure 5-9). The primary difference is that adult fall-run Chinook salmon do not require summer holding habitat, because they mostly migrate in October and November and then spawn shortly thereafter. The key management issues are whether the cold water pool in Millerton Lake will be sufficient to restore naturally reproducing populations of both Chinook salmon runs.



Note: The life stages in bold type are assumed to be the most critical for achieving the Restoration Goal.

Figure 5-9.
Overall Conceptual Model for San Joaquin River Fall-Run Chinook Salmon

5.2.1 Spawning

Adult fall-run Chinook salmon have nearly the same spawning habitat requirements as those described for spring-run fish and it is likely that they will use the same spawning beds after the spring-run have completed their spawning. It is possible that this overlap in habitat use will result in excessive redd superimposition and hybridization impacts on the spring-run population.

5.2.2 Adult Migration

Adult fall-run Chinook salmon have nearly the same migration requirements as those described for spring-run fish, except that fall-run fish typically migrate in the San Joaquin system in October and November when high flows will be needed to provide suitable water temperatures. The main concern is whether fall pulse flows of sufficient magnitude and duration to permit passage for migrating adult fall-run Chinook salmon would exhaust the cold water pool in Millerton Lake and thereby potentially increase the temperature of Friant releases above the levels needed to successfully incubate spring-run Chinook salmon eggs from August through December.

5.2.3 Juvenile Rearing

The limiting factors analyses suggest that juvenile survival in the Restoration Area will be an important determinant of adult production, and that there is potential for competition between juvenile spring-run Chinook salmon and juvenile fall-run Chinook salmon. Juveniles of both runs will probably use the same resources since their rearing periods are expected to overlap substantially. It is possible that spring-run Chinook salmon juveniles will have a competitive advantage over the fall-run Chinook salmon juveniles for the limited food resources and habitats, because they will emerge first and be slightly larger than the fall-run Chinook salmon juveniles. However, it is also possible that large numbers of juvenile fall-run Chinook salmon could substantially reduce the survival of spring-run Chinook salmon juveniles.

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Chapter 6 Data Needs

The following are key information needs, and tasks required to address the needs for spring-run and fall-run Chinook salmon in the San Joaquin River and for downstream Chinook salmon populations.

6.1 Spring-Run Chinook Salmon

To effectively manage the recovery of a naturally reproducing spring-run Chinook salmon population, the following information should be considered:

- **Source Populations –** Identify potential source populations for reintroduction. (see Draft Stock Selection Analysis)
    - Provide a thorough description of available stocks, including life history/phenotypic expression, existing conditions in which they occur, population size, genetic distinction, and history of hatchery influence on the population.
    - Develop comparisons of available stocks
    - Conduct a risk/benefit analysis of potential source populations.
    - Develop a alternatives based approach for selecting appropriate stocks for the Restoration Area.
    - Develop reintroduction strategies to maximize survival and sustainability of source stock populations.
- **Adult Fish Passage –** Evaluate the effects of the Restoration Flow releases, water temperatures, and Delta exports on adult fish passage.
    - Develop a quantitative model of the relationship of the effects of flow, water temperature, DO concentrations in the Stockton Deepwater Ship Channel, and Delta export rates on straying rates and gamete viability of adult spring-run Chinook salmon. Use existing data to estimate straying rates and gamete viability relative to flow and water temperatures. Use the CALFED-sponsored water temperature model for the San Joaquin River below the confluence of the Merced River.
    - Evaluate adult passage relative to potential barriers and structural improvements to be implemented in the Restoration Area.

  - Determine the impact of altered groundwater inflow on water temperatures and flow in the adult migration corridor.

- **Spawning Habitat Assessment** – Determine the distribution and quality of spawning habitat below Friant Dam:

  - Survey the location of spawning habitats.
  - Obtain and analyze sediment bulk samples from likely spawning beds located throughout the 10-mile-long reach immediately below Friant Dam.
  - Measure sedimentation rates and turbidity in the primary spawning reach during the spring-run spawning period.

- **Holding Habitat** – Evaluate the effects of the Restoration Flow releases and water temperatures on the suitability of holding habitat:

  - Use the SJRRP water temperature model to estimate the water temperature at one-mile intervals for the 5-mile-long reach immediately below Friant Dam in 6-hour timesteps from April 15 to August 31 for each Restoration Flow Schedule.

  - Determine temperature tolerances for holding adult spring-run Chinook salmon for each potential source population.

- **Cold Water Pool** – Evaluate the effects of the Restoration Flow releases and water diversions on the size of the cold water pool in Millerton Lake and the suitability of the release temperatures for spring-run spawning habitat:

  - Use the SJRRP‘s water temperature model to estimate the water temperature of the release flows from Friant Dam in 6-hour timesteps from April 15 to December 31 for each Restoration Flow Schedule.

  - Evaluate the benefits of installing temperature control devices on release and diversion structures to conserve the volume of the cold water pool in Millerton Lake.

- **Spawning/Incubation** – Evaluate the effects of the Restoration Flow releases and water temperatures on spawning and egg incubation habitats. Evaluate how redd superimposition from fall-run spawners may affect the production of juvenile spring-run Chinook salmon.

  - Use the SJRRP water temperature model to estimate the water temperature at one-mile intervals for the 5-mile-long reach immediately below Friant Dam in 6-hour timesteps from September 1 to December 31 for each Restoration Flow Schedule.

  - Evaluate the benefits of installing temperature control devices on release and diversion structures to conserve the volume of the cold water pool in Millerton Lake.

  - Determine temperature tolerances for adult spring-run spawners for each potential source population.

  - Develop a quantitative model of the relationship between flow, water temperature, the amount of suitable spawning habitat, redd superimposition with and without fall-run Chinook salmon, and the expected maximum number of fry that could be produced.

- **Poaching –** Estimate how poaching may impact the abundance of spring-run Chinook salmon spawners in the San Joaquin River:

  - Assess the effects of legal and illegal harvest of Chinook salmon and other fish.

- **Juvenile Survival –** Evaluate how the Restoration Flow releases and water temperatures will affect the number of spring-run juveniles that survive to a smolt size in the San Joaquin River:

  - Use the SJRRP water temperature model to estimate the water temperature at 10-mile intervals throughout Reach 1 in 6-hour timesteps from March 1 to May 31 for each Restoration Flow Schedule.
  - Estimate the impact of altered groundwater inflow on water temperatures and flow in rearing habitats.
  - Estimate the benefits of restoring channel width, channel depth, and widths of mature riparian tree forests or wetland habitats on water temperatures throughout the Restoration Area.
  - Survey the size, location, and potential for predation at the in-river gravel excavation sites in the Restoration Area.
  - Develop a quantitative model to compare the effects of flow, water temperature, and other potential stressors for juveniles rearing in the upper reaches with those rearing in the lower reaches. Stressors evaluated should include food resources, predation, disease, contamination, and entrainment.

- **Smolt Survival –** Evaluate how Restoration Flow releases and water temperatures will affect the survival of spring-run smolts migrating from the San Joaquin River:

  - Link U.S. Department of the Interior, Bureau of Reclamation‘s HEC-5Q River temperature model for the Restoration Area with the HEC 5Q CALFED temperature model for the lower San Joaquin River below the confluence of the Merced River to estimate the water temperature at 20-mile intervals throughout the migratory corridor (Friant Dam to Dos Reis) in 6-hour timesteps for smolt outmigrants (March 15 to June 15) for each Restoration Flow Schedule.

  - Determine the impact of altered groundwater inflow on water temperatures and flow in juvenile migration corridors.
  - Estimate the benefits of restoring channel width, channel depth, and widths of mature riparian tree forests or wetland habitats on water temperatures throughout the Restoration Area.
  - Survey the size, location, and potential for predation at the in-river pits and other gravel excavation sites in the Restoration Area.
  - Develop suitability criteria for juvenile spring-run Chinook salmon for each potential source population.
  - Develop a quantitative model of the effects of flow, water temperature, and smolt survival between Friant Dam and the confluence with the Merced River.

- **Food Availability –** Evaluate how the Restoration Flows, water temperatures, floodplain inundation, exotic species, contaminants, channel morphology, and fine sediments affect food availability for Chinook salmon juveniles:

  - Survey the location of functional and diked floodplain habitats, wetland habitats, exotic plant and fish species, agricultural lands that discharge irrigation runoff into the river, and fine sediment sources between Friant Dam and the confluence with the Merced River.

  - Update the hydraulic and digital terrain models used to evaluate relationships between flow and floodplain inundation.

  - Develop a quantitative food supply model that includes the effects of flow, nutrients, floodplain inundation, wetland habitat inundation, native and exotic riparian vegetation, instream production, channel morphology, and reservoir (Millerton Lake) production.

- **Limiting Factors Assessment –** Evaluate the relative importance of unscreened diversions, predators in captured mine pits and other degraded habitats, starvation, contamination, and disease to juvenile mortality in the San Joaquin River:

  - Survey the unscreened diversions, predators and their habitats, contaminated agricultural runoff, and riparian vegetation on functional floodplains.
  - Incorporate the results of these studies into the quantitative model.

- **Delta Survival –** Evaluate the effects of flow, water temperature, exports, the Head of the Old River Barrier, water quality and ocean-vessel traffic in the Stockton Deepwater Ship Channel, and conditions in the Old River channel on the survival of spring-run smolts in the Delta. Evaluate the effects of ocean conditions on the survival of San Joaquin River Chinook salmon smolts:

  - Incorporate the results of the VAMP studies into the quantitative model.
  - Incorporate the results of ongoing ocean studies.

- **Quantitative Models** – Predict the abundance of adult spring-run Chinook salmon in the San Joaquin River below Friant Dam using the quantitative models developed for the above tasks.

6.2 Fall-Run Chinook Salmon

To effectively manage the recovery of a naturally reproducing fall-run Chinook salmon population, the following information should be considered:

- **Adult Fish Passage and Gamete Viability** – Evaluate the effects of the Restoration Flow releases, water temperatures, and Delta exports on adult fish passage and gamete viability:
  - Same tasks as for spring-run Chinook salmon.
  - Assess gamete viability at the Merced River hatchery relative to flow releases, Delta exports, and water temperatures in the river and Delta.
- **Spawning Habitat** – Determine the distribution and quality of spawning habitat below Friant Dam.
  - Same tasks as for spring-run Chinook salmon.
- **Cold Water Pool** – Evaluate the effects of the Restoration Flow releases and water diversions on the size of the cold water pool in Millerton Lake and the suitability of the release temperatures for spring-run spawning habitat. Determine if it is necessary to enhance spawning habitat downstream from Friant Dam where water temperatures will be suitable under the Restoration Flows. Determine if it is necessary to block fall-run spawners from spring-run spawning areas to prevent superimposition on spring-run Chinook salmon redds.
  - Same tasks as for spring-run Chinook salmon.
- **Spawning/Incubation** – Evaluate the effects of the Restoration Flow releases and water temperatures on spawning and egg incubation habitats:
  - Same tasks as for spring-run Chinook salmon.
- **Juvenile Survival** – Evaluate how Restoration Flow releases and water temperatures will affect the number of fall-run Chinook salmon juveniles that survive to a smolt size in the San Joaquin River:
  - Same tasks as for spring-run Chinook salmon.

- **Smolt Survival –** Evaluate how the Restoration Flow releases and water temperatures will affect the survival of fall-run Chinook salmon smolts migrating from the San Joaquin River:
  - Same tasks as for spring-run Chinook salmon.
- **Food Availability –** Evaluate how the Restoration Flows, water temperatures, floodplain inundation, exotic species, contaminants, channel morphology, and fine sediments affect food availability for juvenile Chinook salmon:
  - Same tasks as for spring-run Chinook salmon.
- **Juvenile Mortality –** Evaluate the relative importance of unscreened diversions, predators in captured mine pits and other degraded habitats, starvation, contamination, and disease to juvenile mortality in the San Joaquin River:
  - Same tasks as for spring-run Chinook salmon.
- **Smolt Survival –** Evaluate the effects of flow, water temperature, exports, the Head of the Old River Barrier, water quality and ocean-vessel traffic in the Stockton Deepwater Ship Channel, and conditions in the Old River channel on the survival of spring-run Chinook salmon smolts in the Delta:
  - Same tasks as for spring-run Chinook salmon.
- **Adult Abundance –** Predict the abundance of adult fall-run Chinook salmon in the San Joaquin River below Friant Dam using the quantitative models developed for the above tasks.

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Exhibit B

Water Quality Criteria

Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program

SAN JOAQUIN RIVER
RESTORATION PROGRAM

November 2010

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Tables

Abbreviations and Acronyms

µg/L	micrograms per liter
Central Valley Water Board	Central Valley Regional Water Quality Control Board
CWA	Clean Water Act
DFG	California Department of Fish and Game
DO	dissolved oxygen
DPA	Drainage Project Area
EPA	U.S. Environmental Protection Agency
GBP	Grassland Bypass Project
MCL	maximum contaminant level
mg/L	milligrams per liter
MOA	Memorandum of Agreement
NPDES	National Pollutant Discharge Elimination System
OP	organophosphate pesticide
SJRRP	San Joaquin river Restoration Program
SWQCP	State water quality control program
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TMDL	total maximum daily load

To meet the San Joaquin River Restoration Program (SJRRP) Restoration Goals, water quality should meet minimum standards for protection of aquatic resources. Due to the lack of information on the effects of many water quality constituents on Chinook salmon and other fish, the water-quality objectives for beneficial uses defined by the Central Valley Regional Water Quality Control Board (Central Valley Water Board formerly CVRWQCB) are used to establish water-quality goals. The main beneficial uses for the enhancement of fisheries resources within the Restoration Area are: (1) cold freshwater habitat, (2) fish migration, and (3) spawning, reproduction and/or early development.

Water-quality objectives are —the limits or levels of water quality constituents or characteristics established for the reasonable protection of beneficial uses of the water or the prevention of a nuisance in a specific area” (California Water Code Section 13050(h)). Water-quality standards consist of the designated beneficial uses and water quality objectives of the State Water Resources Control Board (SWRCB) and Central Valley Water Board. For the San Joaquin River system, including the Restoration Area, SWRCB has set a goal to be free of toxic substances in surface water. In addition, beneficial uses and water quality criteria are identified in the Water Quality Control Plan (CVRWQCB 2007).

The temperature objectives are based on a California Department of Fish and Game (DFG) proposal to assess temperature impairment (DFG 2007), U.S. Environmental Protection Agency (EPA) guidelines (EPA 2003), and a report on temperature impacts on fall-run Chinook salmon and steelhead (Rich and Associates 2007).

Section 303(d) of the Clean Water Act (CWA) requires the states to develop a list of impaired water bodies and to describe a priority ranking for addressing impairments. The most recent 303(d) list of impaired water bodies presented by the Central Valley Water Board identifies Reaches 3, 4, and 5, and Mud and Salt sloughs as impaired water bodies due to pesticides and —unknown toxicity.” Total maximum daily loads (TMDLs) are developed to allocate loads from point and nonpoint pollution sources to their impaired water bodies and describe required measures, actions, and responsibilities to meet water-quality standards.

The stringency of water quality objectives specified by a TMDL can be adjusted to protect beneficial uses. Typically, a least stringent approach that can successfully protect water quality for the fisheries is preferred to manage nonpoint source contamination problems (CVRWQCB 2007), but a measure of higher stringency should be employed if it is determined that the initial management approach does not protect the fisheries. The Central Valley Water Board could apply limits more stringent than defined maximum contaminant levels (MCL) when they represent a benefit to sustainable fisheries in the Restoration Area. Implementation of the most stringent objectives will provide the maximum protection of water quality for the beneficial uses of the San Joaquin River waters for fishes.

The Central Valley Water Board and the SWRCB mandates and objectives are used by, and in conjunction with, water quality monitoring elements of the SJRRP. The following sections describe the various water quality constituents and the objectives used to evaluate water quality conditions in the Restoration Area.

Water Temperature

Water quality could be degraded as a result of high water temperatures. High water temperatures promote poor water quality conditions and compromise fish survival (DFG 1998). Unsuitable temperature conditions contribute to limiting the production of juvenile salmonids and may account for some of the variability in the number of adult Chinook salmon returning to the San Joaquin River.

Changes in the water temperature profile in the Restoration Area are expected to affect movement, reproduction, growth, and/or survival of local fish populations. Specifically, Chinook salmon exposed to seasonally elevated temperatures show alterations in adult migration patterns, holding, spawning, egg incubation, juvenile rearing, or survival of migrating juveniles. Moreover, existing temperature conditions in Reach 2A are likely to be lethal to migrating adults and outmigrating juveniles. Hence, physiological tolerance of elevated temperatures during migration maximizes the probability of successful reintroduction and establishment of a new self-sustaining Chinook salmon run in the San Joaquin River.

Salinity and Boron

Salt and boron occur naturally in soils adjacent to the San Joaquin River and can be mobilized from soils by rain and applied irrigation water. Lands on the west side of the San Joaquin River are a major source of salt loads into the river. In 1969, the former Central Valley RWQCB signed a Memorandum of Agreement (MOA) with the U.S. Department of the Interior, Bureau of Reclamation, to not exceed a mean monthly total dissolved solids (TDS) concentration of 500 milligrams per liter (mg/L) in the San Joaquin River immediately below the confluence with the Stanislaus River (CVRWQCB 2007). Salinity and boron TMDLs were completed for the San Joaquin River, and the Central Valley Water Board is committed to refining and updating these guidelines with the best scientific information available (Tables B-1 and B-2).

Trace Elements: Selenium and Mercury

The presence of selenium and mercury in the San Joaquin River Basin affects fishes, their predators, and their food base (CVRWQCB 2001). The major source of selenium is subsurface agricultural return flows (tile drainage) from an area called the Drainage Project Area (DPA) that is currently under regulations to reduce selenium loading. Based on load allocation, waste discharge requirements are assigned to the DPA’s drainage system, the Grassland Bypass Project (GBP). The purpose of the GBP is to reduce selenium discharges. Load allocations for agricultural discharges were developed to meet water quality objectives for selenium in the San Joaquin River downstream from the Restoration Area. TMDLs have been completed for selenium in Salt Slough, the Grassland Marshes, and the San Joaquin River (CVRWQCB 2005) (Table B-2) and should be implemented by the SWRCB after public review (CVRWQCB 2007).

The lower San Joaquin River is federally listed under the CWA 303(d) list as impaired for selenium. The U.S. EPA aquatic life criterion of 5 micrograms per liter (µg/L) was adopted as the San Joaquin River objective (CVRWQCB 2001). A 5-µg/L objective must be met for the San Joaquin River for Reaches 4 and 5 – from Sack Dam to the Merced River confluence – starting in October 2010 (Table B-2). The selenium water quality objective for the entire San Joaquin River downstream from the Merced River will be attained when the water quality objective is also attained at a point just downstream from the Merced River confluence (CVRWQCB 2001).

The presence of mercury in the San Joaquin River Basin and its bioaccumulation potential can reach harmful levels in fishes and their predators. Piscivorous birds sampled at different locations within the Sacramento River and San Joaquin river basins have mercury concentrations within a toxic range (CVRWQCB 2007). High mercury concentrations in fish tissue result from drainage, runoff, and erosion from old mines during mineral exploration and extraction activities. Thus, ore exploration and extraction activities are discharges of great concern in the San Joaquin River Basin (CVRWQCB 2007).

Dissolved Oxygen

The Central Valley Water Board uses a number of tools to regulate discharges of waste that could impact dissolved oxygen (DO) concentration in receiving waters, including but not limited to, waivers of waste discharge requirements or National Pollutant Discharge Elimination System (NPDES) permits. Alternatively, prohibitions should help manage the low DO problem in the lower San Joaquin River. DO levels below 5.0 mg/L create an oxygen barrier, also known as —oxygen block,” which impedes upstream migration of adult Chinook salmon (SWRCB 2000). Levels as low as 1.5mg/L DO have been recorded in the lower San Joaquin River, and levels as low as 0 mg/L have been recorded in the Stockton Deep Water Ship Channel (SWRCB 2000). Table B-3 identifies the DO water quality objectives as defined by the Central Valley Water Board (2007).

Pesticides and Herbicides

Pesticide contamination of surface waters can affect fish and aquatic wildlife. For most pesticides, numerical water quality objectives have not been adopted, but a number of narrative water quality objectives (e.g., no adverse effects) for pesticides and toxicity are listed in Table B-4 through Table B-6 (CVRWQCB 2007). A goal to be free of toxic substances in surface water is established for the San Joaquin River system. This goal is intended to protect the beneficial uses of recreation, warm freshwater habitat, cold freshwater habitat, and municipal and domestic supply from potential pesticide impacts. Maximum allowable levels for two organophosphate pesticides (OP) found in the San Joaquin River, diazinon and chlorpyrifos, have been defined by the Central Valley Water Board in the form of water quality objectives (Table B-5), waste load, and load allocations (CVRWQCB 2007). High and variable concentrations of diazinon and chlorpyrifos are found in winter runoff (Kratzer and Shelton 1998). During winter, dormant-spray pesticides, such as diazinon and chlorpyrifos, are applied to fruit orchards and alfalfa fields in the San Joaquin River Basin and Delta islands (Kuivila 1995, 2000). In combination, OPs from contaminated watersheds can have additive effects on the neurobehavior of salmon (Scholz et al. 2006). In addition, bottom sediment toxicity from pyrethroids and some herbicides can impact sediment dwelling organisms (i.e., lower tropic level). Therefore, reductions to the maximum allowable levels could be mandated to account for potential additive or synergistic toxicity impacts on reintroduced salmonids.

Groundwater Quality

Groundwater quality in the San Joaquin River Basin is considered to be poor. Groundwater has little or no assimilative capacity for wastes. Preventive measures, such as overdraft prevention, are required to avoid groundwater contamination. Prevention is significantly more cost effective than designing cleanup plans when groundwater quality issues arise. For example, groundwater contamination from the use of nitrogen fertilizer on irrigation crops leads to nitrate-polluted base flows reaching the San Joaquin River creates a critical condition for both fish and municipal water users.

State water quality control programs (SWQCP) establish standards for groundwater in addition to surface waters (Table B-5) (CVRWQCB 2007). Therefore, SWQCPs approved by SWRCB are the regulatory references to meet groundwater quality requirements during management actions to restore the San Joaquin fisheries.

Regular groundwater quality monitoring is recommended at selected wells, including areas of the lower reaches of the San Joaquin River adjacent to agricultural lands (CH2M Hill 2007). A groundwater quality monitoring program could help measure salinity loads, trace elements, and heavy metals in the Restoration Area and recommend mitigation measures to protect immigrating adults and outmigrating juvenile salmon. Mitigation or avoidance measures could be developed and implemented to minimize the impact of reach-specific restoration actions on different aspects of water quality.

Other Water Quality Constituents

Other water quality constituents of concern include nutrients, suspended sediment and turbidity, as well as ammonia exports from local wastewater treatment plants and from septic leaching and animal facilities. Narrative objectives have been established for these constituents (Tables B-6 and B-7).

Ammonia, nitrates, and bacterial contamination (e.g., fecal coliforms) within the Restoration Area are a result of wastewater and stormwater inputs. Wastewater inputs can become a water quality issue when animal facilities do not comply with waste discharge requirements. Many of these animal facilities are not regulated by waste discharge requirements (CVRWQCB 2007). To prevent similar mortalities of Chinook salmon and other fishes in the San Joaquin River, numerical water quality objectives for ammonia would be derived for the protection of beneficial uses for fishes (Table B-7).

Sedimentation due to surface runoff from agricultural, roads, driveways, construction sites, etc., can impair fisheries in receiving waters and high levels has actually changed the fish community composition in some rivers (e.g., Missouri River). Sediment loading and suspension in the river increase turbidity, which may be compounded by the distribution and circulation of toxic substances bound to suspended particles. Turbidity is a measure of light transmittance in water that could be affected by different factors besides suspended solids, including algal communities and water coloration. In general, discerning individual effects may be easier than discerning population-level effects (Newcombe and Jensen 1996). Potential adverse effects of increased turbidity on fishes downstream from Friant Dam could range from a reduction in visibility that could affect feeding efficiency to gill clogging and abrasion under high sediment concentrations. Such adverse suspended sediment conditions can affect salmonid homing and cause physiological stress (Entrix 2008). Alternately, increased turbidity caused by suspended solids can have a protective impact against predation of outmigrating juveniles.

Table B-1.
Salinity Objectives for SJRRP Water Quality and/or Beneficial Uses Based on the State Water Resources Control Board Water Quality Standards

Salinity		
Season	Electrical Conductivity, EC (mS/cm)	Total Dissolved Solids (ppm)
Irrigation (April-August)	0.7	455
NonIrrigation (September-March)	1.0	650
Chloride (Cl-)[a]		
Location (Beneficial Use)*	Water Year Type	No. of Days ea. Calendar Year <150 mg/L Cl- / (%)
San Joaquin River at Antioch Water Works Intake (Municipal and Industrial Uses)	Wet	240 (66%)
	Above Normal	190 (52%)
	Below Normal	175 (48%)
	Dry	165 (45%)
	Critical Dry	155 (42%)
Agricultural Water Quality Limits	106 mg/L	
Freshwater Aquatic Life Protection (U.S. EPA)	Continuous concentration (4-day Average) = 230,000µg/L; Maximum concentration (1-hour Average) = 860,000µg/L	
Electrical Conductivity, EC[b]		
Location (Beneficial Use)*	Water Year Type	Dates (Values, µmhos)
San Joaquin River at Jersey Point (Agricultural Use)	Wet	April 1-Aug.15 (0.45)
	Above Normal	April 1-Aug.15 (0.45)
	Below Normal	April 1-June 20 (0.45); June 20-Aug.15 (0.74)
	Dry	April 1-June 15 (0.45); June 15-Aug.15 (1.35)
	Critical Dry	April 1-Aug.15 (2.20)
San Joaquin River at San Andreas Landing (Agricultural Use)	Wet	April 1-Aug. 15 (0.45)
	Above Normal	April 1-Aug. 15 (0.45)
	Below Normal	April 1-Aug. 15 (0.45)
	Dry	April 1-June 25 (0.45); June 25-Aug. 15 (0.58)
	Critical Dry	April 1-Aug. 15 (0.87)
San Joaquin River at Antioch Water Works Intake	All	April 15-May 31 (or until spawning has ended) (1.5)
(Striped Bass Spawning) This is a beneficial use.		
San Joaquin River at Antioch Water Works Intake	Dry	April 1-May 31 (1.5-1.8)
(Striped Bass Spawning - Relaxation Provision[d])	Critical	April 1-May 31 (1.5-3.7)
San Joaquin River at Prisoners Point	All	April 1-May 31 (or until spawning has ended) (0.44)
(Striped Bass Spawning) This is a beneficial use.		
San Joaquin River at Prisoners Point	Dry and Critical	April 1-May 31(or until spawning has ended) (0.55)
(Striped Bass Spawning - Relaxation Provision[d]) Refer to footnote d below.		

Table B-1.
Salinity Objectives for SJRRP Water Quality and/or Beneficial Uses Based on the State Water Resources Control Board Water Quality Standards (contd.)

Electrical Conductivity, EC[c]		
Location (Beneficial Use)*	**Water Year Type**	**Dates (Values, µmhos)**
San Joaquin River at Airport Way Bridge, Vernalis (Agricultural Use)	All	April 1-Aug. 31 (0.7); Sep. 1-Mar. 31 (1.0)
San Joaquin River at Brandt Bridge (Agricultural Use)	All	April 1-Aug. 31 (0.7); Sep. 1-Mar. 31 (1.0)
Secondary Maximum Contaminant Level (MCL)	900 µmhos/cm (at 25°C) (CDPH)	
Agricultural Water Quality Limits	700 µmhos/cm (at 25°C)	

Sources: Central Valley Water Quality Control Board 2008, SWRCB Water Rights Decision (D-1641) 2000, Basin Plan 2007.

Notes:

The water year classification will be established using the best available estimate of the 60-20-20 San Joaquin Valley water year hydrologic classification

[a] Maximum mean daily 150 mg/L chloride for at least the number of days shown during the Calendar Year. Must be provided in intervals of not less than 2 weeks duration (Percentage of Calendar Year shown in parenthesis)

[b] Maximum 14-day running average of mean daily, in µmhos/cm

[c] Maximum 30-day running average of mean daily, in µmhos

[d] Relaxation provisions replace standards whenever water projects impose deficiencies in firm supplies.

Key:

µg/L= micrograms per liter

µmhos = micromhos. The Siemens (S), a measure of electric conductance, is also referred to as mho since it is equal to inverse ohm.

CDPH = California Department of Public Health
cm = centimeter
MCL = Maximum Contaminant Level
mg/L = milligrams per liter
mS = millisiemens
ppm = parts per million or mg/L

Table B-2.
Trace Element Objectives for the SJRRP Water Quality and/or Beneficial Uses

Constituent	Maximum Concentration	Applicable Water Bodies and/or Standards
Boron[1]	2.0 mg/L (15 March through 15 September)	San Joaquin River, mouth of the Merced River to Vernalis
	0.8 mg/L (monthly mean, 15 March through 15 September)	
	2.6 mg/L (16 September through 14 March)	
	1.0 mg/L (monthly mean, 16 September through 14 mg/L March) 1.3 mg/L (monthly mean, critical year[2])	
	100 / 10,000 µg/L	California State Notification Level and Response Level for Drinking Water (DPH)
	700 /750 µg/L	Agricultural Water Limits
	1400 µg/L	U.S. EPA Integrated Risk Information System (IRIS) Reference Dose as a Drinking Water Level
	1000 µg/L	Suggested No-Adverse-Response Level (SNARL)
Molybdenum[1]	0.015 mg/L	San Joaquin River, mouth of the Merced River to Vernalis
	0.010 mg/L (monthly mean)	
	0.050 mg/L	Salt Slough, Mud Slough (north), San Joaquin River from Sack Dam to the mouth of Merced River
	0.019 mg/L (monthly mean)	
Selenium[1]	0.012 mg/L	San Joaquin River, mouth of the Merced River to Vernalis
	0.005 mg/L (4-day average)	San Joaquin River below the Merced River; Critical, Dry and Below Normal Water Year Types (1 October 2010)
	0.005 mg/L (4-day average)	Mud Slough (north), and the San Joaquin River from Sack Dam to the mouth of the Merced River (1 October 2010)
	50 µg/L	Drinking Water Standards (California & Federal) Maximum Contaminant Levels (MCL)
	20 µg/L	Agricultural Water Quality Limits
	35 µg/L	U.S. EPA Integrated Risk Information System (IRIS) Reference Dose as a Drinking Water Level
	50 µg/L	Suggested No-Adverse-Response Level (SNARL) for toxicity other than cancer risk
	5 µg/L	U.S. EPA National Recommended Ambient Water Quality Criteria for Freshwater Aquatic Life Protection - Continuous Concentration (4-day Average)
	20 µg/L	U.S. EPA National Recommended Ambient Water Quality Criteria for Freshwater Aquatic Life Protection - Maximum Concentration (1-hour Average)
	258 µg/L	U.S. EPA National Recommended Ambient Water Quality Criteria for Freshwater Aquatic Life Protection - 24-hour Average
	170 µg/L	Non-Cancer Health Effects: Sources of Drinking Water (water + organisms)
	4200 µg/L	Other Waters (aquatic organism consumption only)

Table B-2.
Trace Element Objectives for the SJRRP Water Quality and/or Beneficial Uses (contd.)

Constituent	Maximum Concentration	Applicable Water Bodies and/or Standards
Mercury (inorganic)	2 µg/L	Drinking Water Standards (California & Federal) - Primary Maximum Contaminant Level (MCL)
	1.2 µg/L	(DPH, U.S. EPA); California Public Health Goal
	2 µg/L	Suggested No-Adverse-Response Level (SNARL) for toxicity other than cancer risk
Mercury (organic and inorganic)	0.77 µg/L	U.S. EPA National Recommended Ambient Water Quality Criteria for Freshwater Aquatic Life Protection - Continuous Concentration (4-day Average)
	1.4 µg/L	U.S. EPA National Recommended Ambient Water Quality Criteria for Freshwater Aquatic Life Protection - Maximum Concentration (1-hour Average)
Methylmercury	0.07 µg/L	U.S. EPA Integrated Risk Information System (IRIS) Reference Dose as a Drinking Water Level
	0.15 µg/L	Maximum Allowable Dose Level for Reproductive Toxicity
	0.3 mg/kg	U.S. EPA National Recommended Ambient Water Quality Criteria for Human Health and Welfare Protection - Non-Cancer Health Effects

Source: Central Valley Regional Water Quality Control Board 2008.

Notes:

[1] Boron, molybdenum, and boron objectives are total concentrations.

[2] A critical year has a water index equal or less than 5.4.

Key:

µg/L = micrograms per liter
DPH = California Department of Public Health
MCL = maximum containment level
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
OEHHA = Office of Environmental Health Hazard Assessment
U.S. EPA = United States Environmental Protection Agency

Table B-3.
Dissolved Oxygen Objectives for the SJRRP

Dissolved Oxygen Water Quality Objectives			
Season	**Region**	**Values**	**Beneficial use**
1 September- 30 November	Lower San Joaquin River (Stockton to Turner Cut)	6.0 mg/L[a]	Fall-run Chinook salmon protection
1 September- 30 November	Restoration Area	6.0 mg/L[b]	Salmonid migration, spawning and rearing
All Year	Delta region	5.0 mg/L[c]	Warm Freshwater Habitat (WARM)

Sources:

[a] *SWRCB (1991)*

[b] *Fisheries Management Work Group recommendation for dissolved oxygen concentrations within the Restoration Area.*

[c] *Central Valley Regional Water Quality Control Board Basin Plan (2007)*

Key:
mg/L = milligrams per liter

Table B-4.
Narrative Water Quality Objectives for the SJRRP

Category	Description	Applicable Water Bodies
Bacteria	• Mean concentration of fecal coliforms: 200/100 ml (n>5 samples; 30-d period) • Maximum concentration of fecal coliforms: 400/100 ml (<10% of samples; 30-d period)	Waters designated for contact recreation
Biostimulatory Substances	• Will not promote aquatic growths in concentrations that cause nuisance or adversely affect beneficial uses	Inland surface waters, including the SJRB
Color	• Water will be free of discoloration that causes nuisance or adversely affects beneficial uses	Inland surface waters, including the SJRB
Floating Material	• Water will not contain floating material in amounts that cause nuisance or adversely affect beneficial uses	Inland surface waters, including the SJRB
Methylmercury	• Less than 0.09 (trophic level 3) and 0.19 (trophic level 4) mg methyl mercury/kg wet weight of fish tissue • Average concentration less than 0.12 (trophic level 3) and 0.23 (trophic level 4) mg methylmercury/kg wet weight, muscle tissue • Average concentration less than 0.05 (trophic level 2 and 3 fish) mg methylmercury/kg wet weight, whole fish	Clear Lake* Cache, North Fork Cache, and Bear Creeks*
Oil and Grease	• Waters will not contain oils, greases, waxes, or other materials in concentrations that adversely affect beneficial uses	Inland surface waters, including the SJRB

Table B-4.
Narrative Water Quality Objectives for the SJRRP (contd.)

Category	Description	Applicable Water Bodies
pH	• 6.5-8.5; Changes in normal pH levels will not exceed 0.5 in fresh waters with designated COLD or WARM beneficial uses • Drinking Water Standards (California & Federal) Secondary Maximum Contaminant Levels (MCL) = 6.5 / 8.5 units (U.S. EPA) • Agricultural Water Quality Limits = 6.5 / 8.4 units • U.S. EPA National Recommended Ambient Water Quality Criteria: Taste & Odor or Welfare = 5 / 9 units • Recommended Criteria for Freshwater and Aquatic Life Protection (Instantaneous Maximum) = 6.5 / 9 units	Inland surface waters, including the SJRB
Pesticides (in general)	• No individual pesticide or combination of pesticides will be present in concentrations that adversely affect beneficial uses • Discharges will not result in pesticide concentrations in bottom sediments or aquatic life that adversely affect beneficial uses • Total chlorinated hydrocarbon pesticides will not be present at detectable concentrations (approved by EPA) in the water column • Concentrations will not exceed those allowable by applicable antidegradation policies • Concentrations will not exceed the lowest levels technically and economically achievable • Concentrations in MUN waters will not exceed MCLs set forth in the California Code of Regulations, Title 22, Division 4, Chapter 15 • Concentrations of thiobencarb in MUN waters will not exceed 1.0 µg/L	Inland surface waters, including the SJRB
Radioactivity	• Radionucleotides will not be present in concentrations that are harmful to human, plant, animal or aquatic life • Radionucleotide concentrations will not lead to their accumulation in the food web to an extent that presents a hazard • Radionucleotide concentrations will not exceed MCLs specified in Section 64443 of Title 22 of the California Code of Regulations	Inland surface waters, including the SJRB

Table B-4.
Narrative Water Quality Objectives for the SJRRP (contd.)

Category	Description	Applicable Water Bodies
Sediment	• The suspended sediment load and suspended sediment discharge rate of surface waters will not be altered in such a manner as to cause nuisance or adversely affect beneficial uses	Inland surface waters, including the SJRB
Settleable Material	• Waters will not contain substances in concentrations that result in the deposition of material that causes nuisance or adversely affects beneficial uses.	Inland surface waters, including the SJRB
Suspended Material	• Waters will not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.	Inland surface waters, including the SJRB
Tastes and Odors	• "Water shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to domestic or municipal water supplies or to fish flesh or other edible products of aquatic origin, or that cause nuisance, or otherwise adversely affect beneficial uses."	Inland surface waters, including the SJRB
Temperature	• The natural receiving water temperature of intrastate waters will not be altered unless it does not adversely affect beneficial uses. • “At no time or place shall the temperature of COLD or WARM intrastate waters be increased more than 5°F above natural receiving water temperature.” • Reference: Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays of California. State Water Resources Control Board. http://www.swrcb.ca.gov/water_issues/programs/ocean/docs/wqplans/thermpln.pdf • The CA Thermal Plan defines natural receiving water temperature as “the temperature of the receiving water at locations, depths, and times which represent conditions unaffected by any elevated temperature waste discharge or irrigation return waters.” • In other words, this narrative objective states that the temperatures of the receiving waters of cold or warm freshwater habitat in California, including the San Joaquin River Restoration Area, should not increase more than 5°F above existing conditions (This criteria is not based on biological needs). • "The daily average water temperature shall not be elevated by controllable factors above 68°F from the I Street Bridge to Freeport on the Sacramento River, and at Vernalis on the San Joaquin River between April 1 through June 30 and September 1 through November 3 in all water year types." [a] Note this temperature can be too high to meet the needs of salmon.	Inland surface waters, including the SJRB San Joaquin River at Airport Way Bridge, Vernalis*
Toxicity	• All "waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses (or toxicity due to single or interacting substances) in human, plant, animal, or aquatic life…" Survival of aquatic life in surface waters subjected to a waste discharge shall not be less than that for the same water body in unaffected areas or other control water.	Inland surface waters, including the SJRB

Table B-4.
Narrative Water Quality Objectives for the SJRRP (contd.)

Category	Description	Applicable Water Bodies
Turbidity	- Waters will be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. - Increases in turbidity (measured by NTUs) attributable to controllable water quality factors will not exceed the following limits: Where natural turbidity = 0-5 NTUs; increases will not exceed 1 NTU Where natural turbidity = 5-50 NTUs; increases will not exceed 20 percent Where natural turbidity = 50-100 NTUs; increases will not exceed 10 NTUs Where natural turbidity > 100 NTUs; increases will not exceed 10 percent Drinking water standards (California & Federal) MCL: Primary MCL = 1 / 5 NTU (DPH, U.S. EPA); Secondary MCL = 5 NTU (DPH)	Inland surface waters, including the SJRB

Source: Modified from CVRWCB (2007) Basin Plan.

Notes:

[a] Taken from the State Water Board's "Water Quality Control Plan For Salinity," May 1991.

[b] Control water should be consistent with the requirements for "experimental water" as described in Standard Methods for the Examination of Water and Wastewater, latest edition

[c] Controllable water quality factors “are those actions, conditions, or circumstances resulting from human activities that may influence the quality of the waters of the State, that are subject to the authority of the State Water Board or the Regional Water Board, and that may be reasonably controlled.” (Central Valley RWQCB Basin Plan 2007)

[*] Water bodies outside the Restoration Area.

Key:
°F = degrees Fahrenheit
µg/L = micrograms per liter
COLD = cold freshwater habitat beneficial use
DPH = California Department of Public Health
kg = kilogram
MCL = maximum contaminant levels
mg = milligram
ml = milliliter
MUN = municipal and domestic supply beneficial use
NTU = Nephelometric Turbidity Units
SJRB = San Joaquin River Basin
U.S. EPA = U.S. Environmental Protection Agency
WARM = warm freshwater habitat beneficial use

Table B-5.
Narrative Objectives for Groundwater Quality in the San Joaquin River Basin

Narrative Water Quality Objectives for the San Joaquin River Basin Groundwaters	
Category	**Description**[a]
Bacteria	• In MUN groundwaters, the most probable number of coliform organisms over any 7-day period shall be less than 2.2/100 ml.
Chemical Constituents	• Groundwaters shall not contain chemical constituents in concentrations that adversely affect beneficial uses. • At a minimum, MUN groundwaters shall not exceed MCLs for chemical constituents as specified in Title 22 of the California Code of Regulations. In addition, MUN waters shall not contain lead in excess of 0.015 mg/L.
Radioactivity	• At a minimum, MUN groundwaters shall not contain concentrations of radionucleotides in excess of the MCLs specified in Section 64443 of Title 22 of the California Code of Regulations.
Tastes and Odors	• Groundwaters shall not contain taste- or odor-producing substances in concentrations that cause nuisance or adversely affect beneficial uses.
Toxicity	• Groundwaters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life associated with designated beneficial use(s). This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances.

Source: Modified from CVRWCB (2007) Basin Plan.

Note:

[a] These objectives are applicable to all groundwaters of the Sacramento and San Joaquin River Basins.

Key:

MCL = Maximum Contaminant Level
mg/L = milligrams per liter
ml = milliliter
MUN = Municipal and Domestic Supply beneficial use

Table B-6.
Diazinon and Chlorpyrifos Water Quality Objectives for the Protection of the San Joaquin River

Specific Pesticide Water Quality Objectives for the San Joaquin River		
Pesticide	**Maximum Concentration (µg/L) and Averaging Period**	**Applicable Water Bodies**
Chlorpyrifos	• 0.025 µg/L; 1-hour average (acute) • 0.015 µg/L; 4-day average (chronic) • Not to be exceeded more than once in a 3-year period • Continuous Concentration (4-day Average) = 0.014 / 0.041 µg/L • Maximum Concentration (1-hour Average) = 0.02 / 0.083 µg/L	• San Joaquin River from Mendota Dam to Vernalis (Mendota Dam to Sack Dam; Sack Dam to Mouth of Merced River)[a] • Mouth of Merced River to Vernalis* • Delta Waterways*
Diazinon	• 0.16 µg/L; 1-hour average (acute) • 0.10 µg/L; 4-day average (chronic) • Not to be exceeded more than once in a 3-year period. • Continuous Concentration (4-day Average) = 0.05 / 0.17 µg/L • Maximum Concentration (1-hour Average) = 0.08 / 0.17 µg/L	• As noted above for Chlorpyrifos

Notes:

* Water bodies outside the Restoration Area

[a] "Waste Load Allocations (WLA) for permitted dischargers, Load Allocations (LA) for nonpoint source discharges, and the Loading Capacity (LC) of the San Joaquin River from the Mendota Dam to Vernalis shall not exceed the sum (S) of one (1.0) (Basin Plan 2007)": $S = CD/WQOD + CC/WQOC \leq 1.0$, where:

CD = diazinon concentration (µg/L) of point source discharge for the WLA; nonpoint source discharge for the LA; or San Joaquin River for the LC.
CC = chlorpyrifos concentration (µg/L) of point source discharge for the WLA; nonpoint source discharge for the LA; or San Joaquin River for the LC.
NAS = National Academy of Sciences Delete. You don't need to include this abbreviation if the associated changes were not incorporated in the latest version of the table.
WQOD = acute or chronic diazinon water quality objective in µg/L.
WQOC = acute or chronic chlorpyrifos water quality objective in µg/L.
"nondetectable" concentrations in analytical studies = 0.0 µg/L

Key:
µg/L = microgram per liter
LA = Load Allocations
LC = Loading Capacity
WLA = Waste Load Allocations

Table B-7.
Recommended Numerical Objective for Ammonia for the SJRRP

Category	Suggested Numerical Water Quality Limit
Ammonia (total ammonia nitrogen)	U.S. EPA National Recommended Water Quality Criteria to Protect Freshwater Aquatic Life If the following conditions are met: • Minimum Target Temperature for fish = 55°F (13°C) • Mean daily pH in the lower San Joaquin > 8.0 Total Ammonia should not exceed: • Continuous Concentration, 30-day Average (mg N/L) < 2.43; when early life stages are present • Maximum Concentration, 1-hour average (mg N/L) < 5.62; when salmonids are present

Sources:
Central Valley Regional Water Quality Control Board 2007
Appendix A
Key:
< = less than
> = greater than
°C = degrees Celsius
°F = degrees Fahrenheit
mg N/L = milligrams of nitrogen per liter
U.S. EPA = U.S. Environmental Protection Agency

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Exhibit C

Spawning Habitat Characterization

Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program

SAN JOAQUIN RIVER
RESTORATION PROGRAM

November 2010

Information on spawning habitat characteristics of Chinook salmon and other fishes are valuable for guiding restoration activities focused on spawning habitat. This exhibit provides a summary of known spawning criteria of salmon and other fishes to help guide the restoration planning process.

The abundance of Chinook salmon spawning-sized gravels below Friant Dam has been gradually reduced as a result of the upstream dams blocking sediment recruitment and gravel mining from the river terrace and the river channel. An absence of gravel recruitment tends to reduce the amount of useable spawning habitat in three ways. First, without recruitment, uncontrolled high-flow releases scour the gravel from the spawning beds so that they gradually become smaller in length and the depth of the gravel becomes shallower. Second, the smaller gravels tend to be mobilized at the highest rates, which causes the bed surface to armor with large rocks that can be too large for the salmon to move for redd construction. Both the reduction in spawning bed size and the armoring of the bed's surface has the effect of crowding the spawners into the remaining usable spawning areas. Crowding is thought to increase the rate of redd superimposition, when spawners construct new redds on top of preexisting redds, thereby killing or burying some of the eggs in the original redds. The third problem caused by reduced gravel recruitment is that uncontrolled scouring flows also erode sediment from the floodplains. For a thorough description of spawning habitat criteria for spring- and fall-run Chinook salmon, the reader is, the reader is referred to Exhibit A.

Table C-1 summarizes salmonid spawning habitat characteristics, including substrate size, water depths, and velocities, from populations in the Pacific Northwest. Tables C-2 through C-4 present information regarding ratios of sediment size composition identified in three Central Valley studies as suitable for spawning Chinook salmon. The concentration of fine sediment (e.g., sediment with D50 less than 1 millimeter (mm)) in spawning gravels is considered an important factor in egg survival and fry emergence. Raleigh et al. (1986) recommends less than 10 percent fines and other studies indicate less than 12 to 14 percent of gravels should be finer than 1 mm to produce 50 percent incubation success for salmonids (Kondolf 2000).

Table C-5 summarizes spawning habitat characteristics for other fish species, including substrate size, water depths, and velocities, and spawning habitat and egg descriptions. Some categorical data were included in the tables based on text from associated references that lack precise definitions, because they represent the best information.

Table C-1.
Salmonid Spawning Habitat Characteristics

Species (Run)	Location	Substrate size (cm)		Water depth (m)		Water velocity (m/sec)		Reference
		Range	Mean or Optimum	Range	Mean or Optimum	Range	Mean or Optimum	
California Central Valley Streams								
Chinook (Fall)	American River	.04 to 30.5	N/A	N/A	N/A	N/A	N/A	20
Chinook (Fall)	Central Valley basin	2.5 to 10.0	2.5 to 5.0	N/A	N/A	N/A	N/A	21
Chinook (Fall)	Merced River	5.0 to 30.0	N/A	N/A	N/A	0.3 to 1.3	N/A	8
Chinook (Fall)	San Joaquin River	N/A	N/A	0.1 to 2.0	N/A	0.15 to 1.0	N/A	17
Chinook (Fall)	Stanislaus River	0.6 to 12.7	N/A	N/A	N/A	N/A	N/A	12
Chinook (Fall)	Tuolumne River	0.8 to 12.8	3.5	N/A	N/A	N/A	N/A	14
Chinook (Spring)	Central Valley basin	2.5 to 10.0	2.5 to 7.5, 5.0 to 10.0	N/A	N/A	N/A	N/A	21
Chinook (Spring)	Clear Creek	2.5 to 15.0	5.0 to 10.0	N/A	N/A	N/A	N/A	19
Chinook (Spring)	San Joaquin River	N/A	N/A	0.1 to 2.0	N/A	0.15 to 1.0	N/A	17
Steelhead	Clear Creek	.25 to 15.0	2.5 to 5.0	N/A	N/A	N/A	N/A	19
Steelhead	San Joaquin River	N/A	N/A	0.2 to 1.5	N/A	0.6 to 1.15	N/A	17
Columbia River and Tributaries								
Chinook (Fall)	Hanford Reach	N/A	N/A	1.2 to 2.6	1.4	0.4 to 1.9	N/A	4
Chinook (Fall)	Hanford Reach	5 to 30	10.0 to 20.0	0.3 to 9.0	1.8 to 7.6	0.4 to 2.0	N/A	18
Chinook (Fall)	Near Wells Dam	N/A	N/A	1.6 to 9.6	5.3 to 7.2	0.4 to 1.2	0.9	9
Chinook (Fall)	Not Specified	N/A	N/A	0.2 to 2.0	N/A	0.8 to 1.1	N/A	3
Chinook (Fall)	Upper	N/A	N/A	0.6 to 4.5	N/A	N/A	N/A	5
Chinook (Fall)	Kalama River	N/A	N/A	0.4	N/A	N/A	0.6	2
Chinook (Fall)	Snake River	2.5 to 15.0	N/A	~1 to 2.0	N/A	~0.5 to 1.2	N/A	6
Chinook (Fall)	Snake River	2.5 to 15.0	N/A	0.2 to 6.5	2.8	0.4 to 2.1	1.1	10
Chinook (Fall)	Snake River	N/A	N/A	4.6 to 7.9	N/A	0.3 to 0.7	N/A	7
Chinook (Fall)	Toutle River	N/A	N/A	0.3	N/A	N/A	0.4	2

Table C-1.
Salmonid spawning habitat characteristics (contd.)

Species (Run)	Location	Substrate size (cm)		Water depth (m)		Water velocity (m/sec)		Reference
		Range	Mean or Optimum	Range	Mean or Optimum	Range	Mean or Optimum	
Other River Systems								
Chinook (Fall)	Cambell River, BC	N/A	N/A	0.3 to 0.8	0.6	0.4 to 0.8	0.6	11
Chinook (Fall)	Nechako River, BC	N/A	N/A	N/A	N/A	0.15 to 1.0	0.5	15
Chinook (Fall)	Oregon Streams	N/A	N/A	0.4	N/A	N/A	N/A	16
Chinook (Fall)	Not specific	1.3 to 10.2	N/A	N/A	N/A	N/A	N/A	1
Salmonids	Not specific	a	N/A	N/A	N/A	N/A	N/A	13

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21 *Exhibit A*

Key: A = Maximum to be 10% of median female salmonid length cm = centimeters m = meters m/sec = meters per second N/A = data not available

Table C-2.
Sediment Ratios for Chinook Salmon Spawning Habitat Based on Vyverberg et al. (1997) Study Results

Millimeters	Inches	Percent by volume
152 to 305	6 to 12	30% or Less
76 to 152	3 to 6	10% or More
25 to 76	1 to 3	50% or less
13 to 25	0.5 to 1	20% or less
4 to 13	0.16 to 0.5	20% or less
0.4 to 4	0.015 to 0.16	20% or less

Source: McBain and Trush. 2003. Coarse Sediment Management Plan for the Lower Tuolumne River. Final Report. Pg 77.

Table C-3.
Sediment Ratios for Chinook Salmon Spawning Habitat Based on McBain and Trush (2003) Study Results

Millimeters	Inches	Standard mix	Finer mix
64 to 128	2.5 to 5	20%	20%
32 to 64	1.25 to 2.5	35%	30%
16 to 32	5/8 to 1.25	30%	30%
8 to 16	5/16 to 5/8	15%	12%
2 to 8	1/8 to 5/16	0%	8%
	D_{84} =	74	74
	D_{50} =	35	32

Source: Vyverberg K, B. Snider, and R. G. Titus. 1997. Lower American River Chinook Spawning Habitat Evaluation. DFG Environmental Sciences Division. Pgs. 2-7.

Key: D_{84} = 84th percentile D_{50} = Median

Table C-4.
Sediment Ratios for Chinook Salmon Spawning Habitat Based on Icanberry (2006) Personal Communication

Millimeters	Inches	Mix
>127	>5	5%
51 to 127	2 to 5	15%
25 to 51	1 to 2	35%
19 to 25	0.75 to 1	15%
13 to 19	0.5 to 0.75	15%
6 to 13	0.25 to 0.5	10%
<6	<0.25	5%

Sources:

1. *Icanberry, J. 2006. Letter to California Department of Fish and Game and California Department of Water Resources regarding AFRP recommended particle size distributions for spawning gravel enhancement projects.*
2. *McBain and Trush. 2003. Coarse Sediment Management Plan for the Lower Tuolumne River. Final Report. Pg 77.*
3. *Vyverberg K, B. Snider, and R. G. Titus. 1997. Lower American River Chinook Spawning Habitat Evaluation. DFG Environmental Sciences Division. Pgs. 2-7.*

Table C-5.
Spawning Habitat Characteristics of Other Fishes

Species	Substrate size (cm)			Spawning			Egg comments	Source
	Category	Range	Mean or optimum	Depths (m)	Velocity	Habitat		
Green sturgeon	clean sand to bedrock	0.025 to unk *	12.8 to 25.6 *	>3	fast	N/A	adhesive eggs are broadcast	3, 7, 18
White sturgeon	gravel to boulders	0.2 to unk *	N/A	>3	0.6-2.4 m/sec	deep gravel riffles or in deep holes with swift currents and rock bottoms major Sacramento River spawning area are gravel	adhesive, stick to substrate	11, 16, 18, 27
Sacramento sucker	N/A	N/A	N/A	≥ 0.3	N/A	slight depression in riffle gravels	adhere to gravel or debris or bounce along the bottom until they are caught in gravel or washed to a small backwater	18, 19, 26
Sacramento perch	clay and mud to large boulders	0.0001 to unk *	N/A	0.2 to 1.0	N/A	shallow areas with heavy growth of aquatic macrophytes or filamentous algae nearby	eggs deposited into 20- to 75-cm-deep nests	1, 14 ,15, 18, 20
Prickly sculpin	large rock	N/A	N/A	N/A	moderate	build nest underneath large flat rocks	eggs adhere to ceiling of the nest	12, 18
Riffle sculpin	N/A	N/A	N/A	N/A	N/A	underside of rocks in swift riffles or inside cavities in submerged logs	eggs adhere to underside of rocks or inside cavities in submerged logs	2, 17, 18
California roach	N/A	3.0 to 5.0	N/A	shallow	flowing	shallow flowing areas	adhesive, eggs settle into crevices between rocks and adhere	8, 18
Hardhead	N/A	N/A	0.2 to 6.4 *	shallow	N/A	beds of gravel in riffles, runs, or the heads of pools	N/A	13, 18
Hitch	fine to medium gravel	0.4 to 1.6 *	N/A	N/A	N/A	riffles	eggs are not adhesive but sink into gravel interstices	10, 13, 18, 21

Table C-5.
Spawning Habitat Characteristics of Other Fishes (contd.)

Species	Substrate size (cm)			Spawning			Egg comments	Source
	Category	Range	Mean or optimum	Depths (m)	Velocity	Habitat		
Sacramento blackfish	N/A	N/A	N/A	shallow	N/A	shallow areas with heavy growth of aquatic plants	eggs extruded onto plants	6, 18, 22, 27
Sacramento pikeminnow	gravel to rocks	0.25 to unk *	N/A	N/A	N/A	eggs sink to bottom and adhere to rocks and gravel	adhesive, stick to rocks	13, 18, 23, 27
Sacramento splittail	N/A	N/A	N/A	0.5 to 2.0	N/A	flooded vegetation	adhesive, stick to vegetation and debris	18
Speckled dace	N/A	N/A	N/A	N/A	N/A	gravel edges of riffles	eggs sink into interstices and adhere to rocks	9, 18
Tule perch	N/A	N/A	N/A	N/A	N/A	none, live bearers	N/A	4, 5, 18, 24
Threespine stickleback	N/A	N/A	0.006 to 0.2 *	N/A	N/A	males excavate a shallow pit in sand in beds of aquatic plants and constructs a pile of algae and aquatic plants	eggs are extruded into nest of algae and plant material	18
Kern brook lamprey	gravel to cobble	0.2 to 25.6 *	0.2 to 6.4 *	N/A	N/A	gravel riffles	N/A	18
Pacific lamprey	gravel to cobble	0.2 to 25.6 *	0.2 to 6.4 *	0.3 to 1.5	fairly swift	build nest in gravel areas	eggs sink into interstices and adhere to rocks	18
River lamprey	gravel to cobble	0.2 to 25.6 *	0.2 to 6.4 *	N/A	N/A	they dig saucer-shaped depressions in gravelly riffles	N/A	18
Western brook lamprey	gravel to cobble	0.2 to 25.6 *	0.2 to 6.4 *	~0.15	N/A	build nest in gravel riffles	N/A	18, 25
Rainbow trout	N/A	1 to 13	1.6 to 6.4 *	0.1 to 1.5	0.2-1.5 m/sec	N/A	eggs deposited into redds	18

Table C-5.
Spawning Habitat Characteristics of Other Fishes (contd.)

Sources:

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Key:
unk = Unknown
N/A = Data not available
cm = centimeters
m = meters
* = Substrate categories converted to numbers based on Wentworth grain size scale

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Exhibit D

Stock Selection Strategy: Spring-Run Chinook Salmon

Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program

SAN JOAQUIN RIVER
RESTORATION PROGRAM

November 2010

Table of Contents

Tables

Figures

List of Abbreviations and Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
cfs	centimeters per second
cm	centimeter
Columnaris	*Flavobacterium columnare*
CVPIA	Central Valley Project Improvement Act
CWT	coded wire tag
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
DO	dissolved oxygen
DWR	California Department of Water Resources
ESU	evolutionarily significant unit
FERC	Federal Energy Regulatory Commission
FL	fork length
FMP	Fisheries Management Plan
FMWG	Fisheries Management Work Group
GAPS	Genetic Analysis of Pacific Salmonids
GSI	genetic stock identification
HFC	high-flow channel
Ich	*Ichthyophthirius multiphilis*
JSA	Joint Settlement Agreement
km	kilometer
LFC	low-flow channel
LVNP	Lassen Volcanic National Park
m	meter
mm	millimeter
Ne	effective population size
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRDC	National Resources Defense Council
PBT	parentage-based tagging
PG&E	Pacific Gas & Electric Company
PMT	Program Management Team
Reclamation	U.S. Department of the Interior, Bureau of Reclamation

Restoration Area	San Joaquin River between Friant Dam and the confluence with the Merced River
RKM	river kilometer
RM	river mile
Settlement	San Joaquin River Settlement
SJRRP	San Joaquin River Restoration Program
SNP	single nucleotide polymorphism
USFWS	U.S. Fish and Wildlife Service

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1.0 Introduction

This document is part of a multi-step process to select a stock or stocks of spring-run Chinook salmon for reintroduction to the San Joaquin River and ultimately determine appropriate methods of reintroduction. The effort is part of the San Joaquin River Restoration Program (SJRRP), whose charge is to execute a legal settlement from the lawsuit, *NRDC et al. v. Kirk Rodgers et al.*; whereby in 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit challenging the renewal of long-term water service contracts between the United States and California's Central Valley Project Friant Division contractors. After more than 18 years of litigation, the Settling Parties reached a Stipulation of Settlement Agreement (Settlement). The Settling Parties, including NRDC, Friant Water Users Authority, and the U.S. Departments of the Interior and Commerce, agreed on the terms and conditions of the Settlement, which was subsequently approved on October 23, 2006. The Settlement establishes two primary goals:

- **Restoration Goal** – To restore and maintain fish populations in "good condition" in the mainstem San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.

- **Water Management Goal** – To reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

Related to the Settlement, President Obama signed the San Joaquin River Restoration Act on March 30, 2009, giving the U.S. Department of Interior full authority to implement the SJRRP. The implementing agencies, consisting of the U.S. Department of Interior, Bureau of Reclamation (Reclamation) and U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), California Department of Fish and Game (DFG), and California Department of Water Resources (DWR) organized a Program Management Team (PMT) and associated Work Groups to begin work implementing the Settlement. The Fisheries Management Work Group (FMWG), consisting of representatives of the above agencies, prepared the Fisheries Management Plan (FMP) to describe the program's approach to restoration. This Exhibit, the Stock Selection Strategy works to fulfill the stock selection objectives of the FMP with focus on the three largest stocks of spring-run Chinook salmon in the Central Valley: Feather River, Butte Creek, and the Deer and Mill Creek Complex. A general description of each stock and their river system is provided, as well as an analysis and comparison of each stock's genotypic and phenotypic characteristics and recommendations for stock selection.

1.1 Stock Selection Strategy Development Process

This document is the product of the Genetics Subgroup of the FMWG. The Genetics Subgroup focuses on genetic issues related to protecting the genetic integrity of the reintroduced stock, stock selection, reintroduction strategies, development of the Hatchery and Genetics Management Plan, and other hatchery-related issues. This subgroup is composed of State and Federal fisheries scientists and academic researchers. This document is guided by an adaptive management approach, as described in the FMP. While extensive analysis and expertise is used to predict stock performance in the restored environment, it is recognized that these predictions are potentially fallible due to the numerous variables associated with the massive scale of this project. A key aspect to this decision-making process is the use of adaptive management, as described by Williams et al. (2009), which recognizes and embraces this uncertainty.

> *"Making a sequence of good management decisions is more difficult in the presence of uncertainty, an inherent and pervasive feature of managing ecological systems (16, 17). Uncertainties arise with incomplete control of management actions, sampling errors, environmental variability, and an incomplete understanding of system dynamics, each affecting the decision making process. An adaptive approach provides a framework for making good decisions in the face of critical uncertainties, and a formal process for reducing uncertainties so that management performance can be improved over time."*

For more information about the adaptive management process use here, refer to Chapter 1 of the FMP.

2.0 Donor Stock Selection

Spring-run Chinook salmon once occupied all major river systems in California where there was access to cool reaches that would support over-summering adults. Historically, spring-run Chinook salmon were widely distributed in streams of the Sacramento-San Joaquin river basins, spawning and rearing over extensive areas in the upper and middle reaches (elevations ranging 1,400 to 5,200 feet (450 to 1,600 meters (m))) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud, and Pit rivers (Meyers et al. 1998). Spring-run Chinook salmon populations in the San Joaquin River Basin were extirpated following basin-wide dam construction between 1894 to 1968 (Yoshiyama et al. 2001, Lindley et al. 2004, Schick and Lindley 2007) and all extant spring-run Chinook salmon populations are believed to spawn in the Sacramento River Basin (Moyle 2002). In the upper San Joaquin River, spring-run Chinook salmon were extirpated by the mid-to late 1940s, following the construction of Friant Dam and diversion of water for agricultural and municipal purposes (e.g., Central Valley Project) to the San Joaquin Valley.

Only two evolutionarily significant units (ESU) of spring-run Chinook salmon remain in California: the Central Valley spring-run Chinook salmon ESU, consisting of four Central Valley spring-run Chinook salmon populations, and the Upper Klamath-Trinity Rivers Chinook salmon ESU, which includes all naturally spawning spring-run Chinook salmon in the Klamath and Trinity basins upstream from the confluence of the Klamath and the Trinity Rivers (Moyle et al. 1995). Only Chinook salmon from the Central Valley ESU will be considered for reintroduction. Lindley et al. (2004) used ecogeomorphic principles to identify at least 18 historic spring-run Chinook salmon populations in the Sacramento-San Joaquin watershed. While the genetic constituency of these historic populations is uncertain, it is possible that each population was sufficiently isolated and maintained some level of genetic distinctiveness in the face of limited gene flow.

Functionally independent populations of spring-run Chinook salmon remain in Deer, Mill, and Butte creeks and another spring-run Chinook salmon population is spawned at the Feather River Fish Hatchery (FRFH) and in the river below Oroville Dam. Spring-run Chinook salmon also occur in numerous smaller northern Central Valley tributaries, though these populations are small and subject to gene flow from the larger independent populations in the California Central Valley. Several tributaries within the San Joaquin Valley have spring-run Chinook salmon, but their numbers are very small and further monitoring and research is needed to determine if these fish are genotypically spring-run Chinook salmon, or fall-run Chinook salmon.

Spring-run Chinook salmon populations are phenotypically similar in their adult behavior patterns. They return to natal rivers sexually immature in the spring, typically ascending farther upstream than later-entering fall-run Chinook salmon, then reside in cool water refugia until spawning starts early in the fall. Life history differences among spring-run Chinook salmon populations are informative in considering their potential use in reintroduction actions and it is possible this phenology and local adaptation have led to underlying genetic differences among these groups. Research in other salmonids have described the local adaptation of egg incubation temperature optima, yolk conversion efficiencies, development rates, subyearling growth rates, and age at smoltification (Hendry et al. 1998, Obedzinski and Letcher 2004), which may cause differential survival among stocks in environments distinct from the natal streams.

Reintroduction efforts may have the best chance for success when the chosen broodstock have life history characteristics compatible with the anticipated environmental conditions of the reintroduction habitat. Ecoregions closest to the restoration site that contain Chinook salmon populations have the highest likelihood of similar local adaptation of traits and, therefore, only Chinook salmon populations found in California's Central Valley will presently be considered as broodstock.

The primary goal of broodstock selection is to identify the stock(s) with the highest likelihood of establishing a self-sustaining, naturally reproducing population in the San Joaquin River Restoration Area (San Joaquin River between Friant Dam and the confluence with the Merced River). A key component to identifying the "best" stock(s) is conducting genetic analyses of extant populations to ascertain the genetic integrity of all potential source populations. Measurement indices that are useful for analysis of potential broodstock(s) include, but are not limited to: effective population size (Ne); genetic comparisons to historic population in upper San Joaquin (if feasible); within population genetic diversity and inbreeding levels; among population genetic diversity; and hatchery influence. Optimum characteristics for the chosen donor population sources include:

- Be of local or regional origin (Central Valley)
- Have life history (behavioral and physiological) characteristics that fit conditions expected to occur on the San Joaquin River, thereby maximizing the probability of successful reintroduction
- Large effective population size
- High within population genetic diversity with low inbreeding coefficients
- Adequate representation of overall ESU genetic diversity

The candidate populations for this program may be limited to those with relatively large effective population size; the independent spring-run Chinook salmon populations on Deer/Mill and Butte creeks, and spring-run Chinook salmon population in the Feather River. All potential sources of spring-run Chinook salmon are analyzed in this document.

In addition to genetic considerations, the appropriate broodstock(s) for the project will be selected based on current (census) population size, compatibility of life history characteristics to anticipated restored Restoration Area conditions, and availability of broodstock. This information will be gathered through interactions with biologists for all potential source populations and review of existing literature and databases.

2.1 Risks and Uncertainties

- **Selected broodstock(s) will not capture the genetic variation needed to promote a long-term naturally self-sustaining population in the Restoration Area.**

  An assessment of each potential broodstock's genetic diversity (e.g., Ne, heterozygosity) is proposed to ensure that the chosen source population(s) possesses adequate variation to adapt to changing environmental conditions. Genetic analyses will be facilitated by genotyping a large number of single nucleotide polymorphism (SNP) markers. Selection of multiple broodstocks could act to reduce risk by increasing overall genetic variation.

- **An overlap in migration run-timing and lack of spatial separation between mature spring-run Chinook salmon and fall-run Chinook salmon in the Restoration Area are expected to result in the genetic introgression of the two populations.**

  To reduce the potential for hybridization, it is recommended that a physical barrier (e.g., weir) be installed after the spring-run Chinook salmon spawning migration is completed to separate upstream spring-run Chinook salmon spawning habitat from the downstream fall-run Chinook salmon spawning habitat. Due to overlap in spring-run Chinook salmon and fall-run Chinook salmon spawning migrations, reestablishment of late fall-run Chinook salmon may be preferable over early fall-run Chinook salmon spawners.

- **Removal of broodstock fishes from source population(s) may increase the risk of extirpation, and reduce the population viability and recovery potential of the source population(s)**.

  To reduce the potential for significant impacts to source population(s), criteria for collection strategies will balance development of reintroduced stocks with minimizing risks to the source population(s).

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3.0 Stock Descriptions

3.1 Feather River

The Feather River is a major tributary to the Sacramento River located at the northern end of the western slope of the Sierra Nevada, with a watershed encompassing 5,900 square miles (FERC 2007, NMFS 2009). The upper Feather River watershed above Oroville Dam, is approximately 3,600 square miles (approximately 68 percent of the Feather River Basin), and has four tributaries, the North, South, Middle and West forks. Downstream from Oroville Dam, the watershed includes the drainage of the Yuba and Bear rivers, and eventually meets the Sacramento River, contributing 25 percent to its flow (NMFS 2009).

3.1.1 Historic Conditions

The Feather River is renowned as one of the major salmon-producing streams of the Sacramento Valley (Yoshiyama et al. 2001) and once contained more than 200 miles of anadromous fish habitat, of which 64 miles remain (NMFS 2009). Before the construction of numerous hydroelectric power projects and diversions, spring-run Chinook salmon ascended high into the watershed (Clark 1929, Yoshiyama et al. 1996, Lindley et al. 2004). The fall-run Chinook salmon spawned primarily in the mainstem, while most of the spring-run Chinook salmon spawned in the Middle Fork, with smaller runs in the North, South and West Forks (Fry 1961, Yoshiyama et al. 2001). Each of the four tributaries above Oroville Dam generally provide suitable habitat for all life stages of Chinook salmon and steelhead (DWR 2005, NMFS 2009) and likely contained independent populations of spring-run Chinook salmon (Lindley et al. 2004).

Human impacts to the salmon runs of the Feather River began as early as the late 1800s. Hydraulic mining activity and dam construction, where established below Oroville and on the West, North, and South forks, occurred in the early 1900s (Clark 1929, Muir 1938, as found in Yoshiyama et al. 2001); up to 186 million cubic yards of mining debris were produced before 1909 (Gilbert 1917, Yoshiyama et al. 2001).

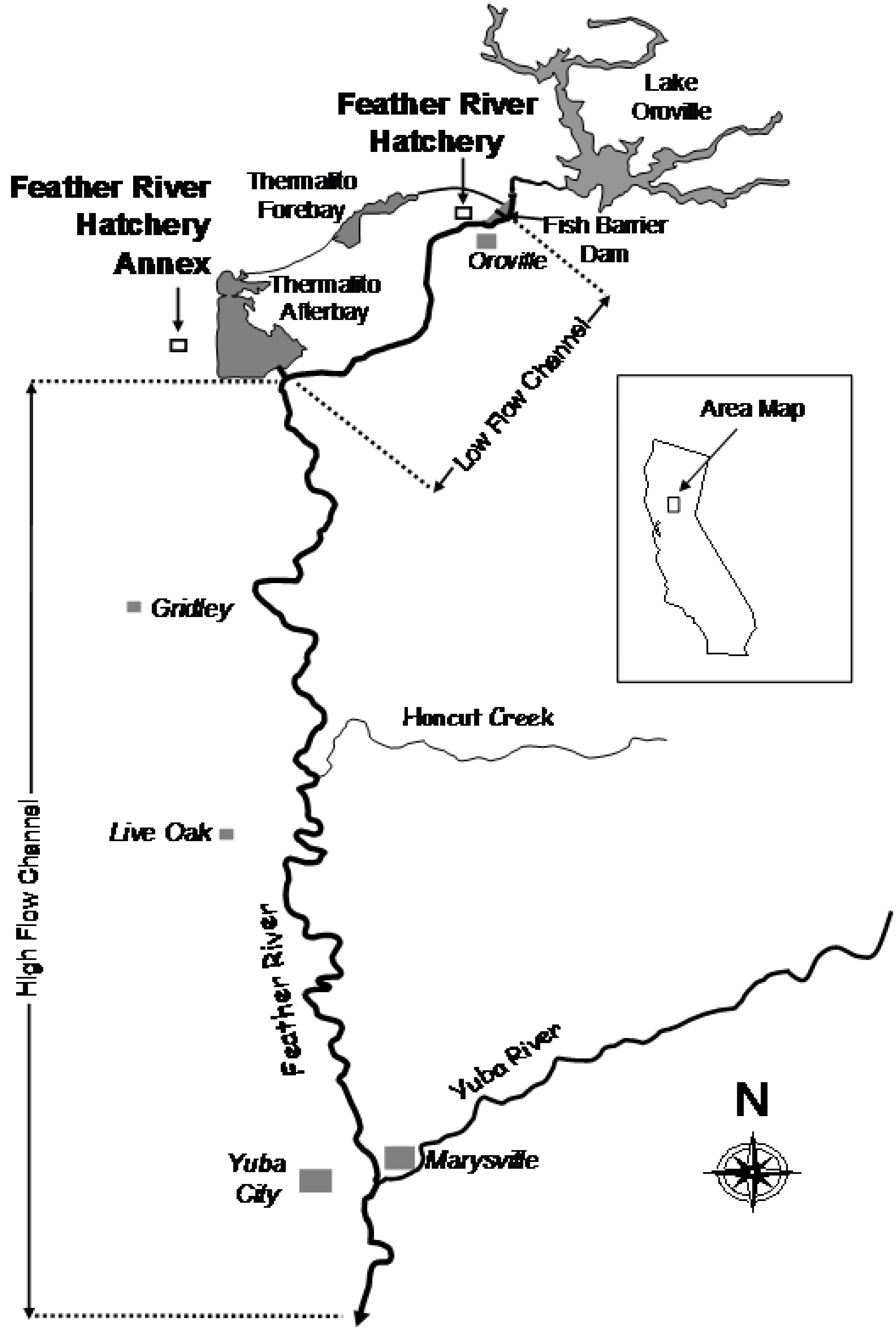
Fry (1961) reported run-size estimates for the fall-run Chinook salmon of 10,000 to 86,000 fish during the period 1940 to 1959, and about 1,000 to 4,000 spring-run Chinook salmon. Just before the completion of Oroville Dam, a small naturally spawning spring-run Chinook salmon population still existed in the Feather River (Reynolds et al. 1993, Yoshiyama et al. 2001). The number of naturally spawning spring-run Chinook salmon in the Feather River was estimated only periodically in the 1960s and 1970s, with estimates ranging from 2,908 fish in 1964 to two fish in 1978 (NMFS 2009).

3.1.2 Existing Conditions

Flow Regime

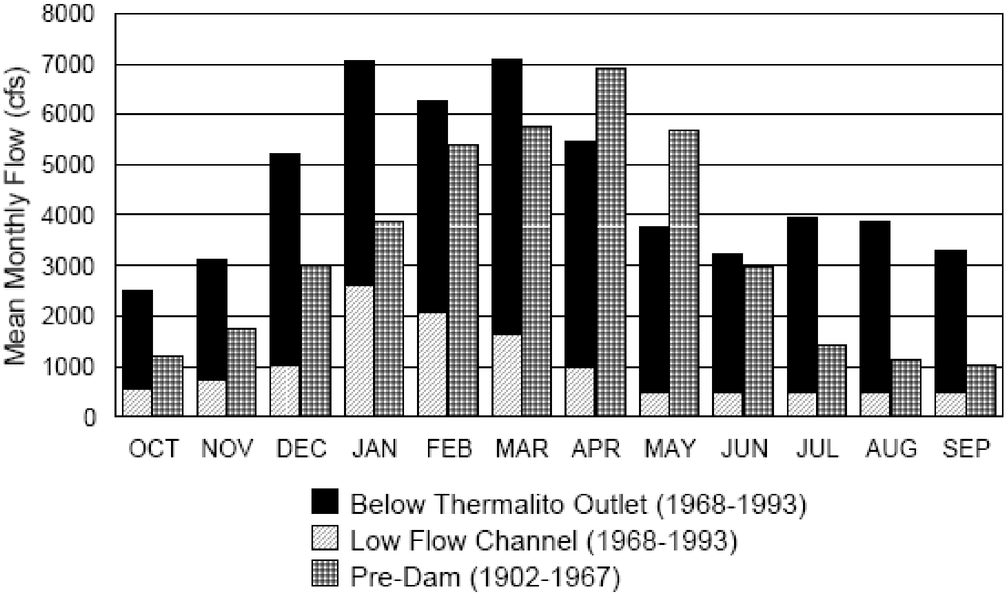
Today, flow in the Feather River is altered by hydroelectric, water storage, and diversion projects (FERC 2007). River flow below the reservoir is regulated by Oroville Dam, Thermalito Diversion Dam, and the Thermalito Afterbay Outlet. Oroville Reservoir is the lowermost reservoir on the Feather River and the upstream limit for anadromous fish (USFWS 1995, NMFS 2009).

Under normal operations, the majority of the Feather River is diverted at Thermalito Diversion Dam into Thermalito Forebay. The remainder of the flow, typically 600 cubic feet per second (cfs), flows through the historical river channel, referred to as the "low-flow channel" (LFC) (Figure 3-1). Mean monthly flows through the LFC are now significantly less than pre-dam levels (Sommer et al. 2001) (Figure 3-2). Water released by the Thermalito Forebay is used to generate power before discharge into the Thermalito Afterbay and enters the "high-flow channel" (HFC), then water flows southward through the valley until the confluence with the Sacramento River at Verona (FERC 2007).



Source: DWR

Figure 3-1.
Feather River Low-Flow and High-Flow Channel System



Source: DWR

Note:

Total flow in the post-dam period includes the portion from the low channel and the portion diverted through the Thermalito Complex.

Figure 3-2.
Mean Monthly Flows in the Feather River for the Pre-Oroville Dam (1902-1967) and Post-Oroville Dam (1968-1993) Period

Geology

The North Fork Feather River is in the southern Cascades while the other forks are in the Sierra Nevada ecoregion. The headwaters of the North Fork are fed by rainfall and by snowmelt from Mt. Lassen, and rocks are predominately of volcanic origin (Lindley et al. 2004). The bed material in the remaining three tributaries is primarily of granitic origin. As described in NMFS 2009, the most common material in the soils downstream from Oroville Dam is alluvium, with some soils derived from debris deposited during the hydraulic mining period. Channel banks and streambed in the LFC generally consist of armored cobble as a result of periodic flood flows and the absence of gravel recruitment. By far, historic hydraulic mining of gold-bearing gravel deposits has caused the largest impact on the Feather River channel, washing massive amounts of erosional debris, including cobbles, gravel, sand, silt, and clay, into the river. Floodplain soils are conducive to agriculture and many areas of riparian floodplain and fluvial terraces have been converted to irrigated crops and orchards (FERC 2007). Human activity over time has resulted in decreased vegetative cover from logging and grazing, channel clearing, levee construction, and water diversions. These activities have contributed to the increased sediment load in the Feather River watershed (FERC 2007).

Temperature and Water Quality

Water is released from Oroville Dam through a multilevel outlet to provide appropriate water temperatures for the operation of the FRFH (Table 3-1) and to protect downstream fisheries (NMFS 2009). Water temperatures downstream from the Fish Barrier Dam vary seasonally and there is a significant temperature difference between the LFC and the HFC. In both channels, temperatures begin to warm in March and peak in July and early August. In the LFC, peak temperatures range from 61 degrees Fahrenheit (°F) (16 degrees Celsius (°C)) upstream from the FRFH to 69°F (21.5°C) upstream from the Thermalito Afterbay Outlet (FERC 2007). Cooling begins in September, with water temperatures dropping to 45°F (7°C) throughout the reach by February (FERC 2007). Compared to historical levels, mean monthly water temperatures in the LFC at Oroville are 2 to 14°F (1.1 to 7.8°C) cooler during May through October and 2 to 7°F (1.1 to 3.9°C) warmer during November through April (Sommer et al. 2001). FRFH water temperatures vary little from temperatures of river water near the hatchery (FERC 2007).

Peak water temperatures in the HFC range from 71 to 77°F (22 to 25°C). River cooling begins in late August, with minimum temperatures of 44 to 45°F (6.7 to 7.2°C) reached by January or February. Releases from the Thermalito Afterbay Outlet as well as flow contributions from Honcut Creek, the Yuba River, and the Bear River influence HFC water temperatures between April and October (FERC 2007). Except during periods of high flow through the Thermalito Afterbay, which occur frequently in July and August, releases from the Thermalito Afterbay during the warm season generally raise the water temperature of the river. Honcut Creek and Bear River inflows also tend to increase Feather River temperatures downstream from their confluences during this period (FERC 2007). Flows contributed by the Yuba River tend to cool the Feather River during the warmer spring and summer months. Dissolved oxygen (DO) and pH levels in the Feather River are generally found to comply with the water quality objectives for Chinook salmon. When exceedances occur, they are considered minor (FERC 2007).

Table 3-1.
Feather River Fish Hatchery Temperature Objectives
(±4° F between April 1 and November 30)

Period	Temperature (°F)
April – May 15	51
May 16 – 31	55
June 1 - 15	56
June 16 – August 15	60
August 16 – 31	58
September	52
October – November	51
December - March	No greater than 55

Source: DWR 2001
Key:
°F = degrees Fahrenheit

3.1.3 Life History/Phenotypic Expression

Holding and Spawning

Upstream migration of Chinook salmon is blocked by Fish Barrier Dam located 0.6 mile (1 kilometer (km)) below the Oroville Dam. Adult spring-run Chinook salmon are found holding at the Thermalito Afterbay Outlet and the Fish Barrier Dam as early as April (FERC 2007, NMFS 2009) and begin spawning in September, usually 2 to 3 weeks earlier than the fall-run Chinook salmon (Kindopp pers. comm.). Adult fall-run Chinook salmon typically return to the river to spawn during September through December, with peak returns from mid-October through early December (Sommer et al. 2001).

Spring-run Chinook salmon are spawned artificially in the FRFH and also spawn naturally in the river during late September to late October (Reynolds et al. 1993, Yoshiyama et al. 2001) downstream from the Fish Barrier Dam approximately 8 miles to the Thermalito Afterbay Outlet (NMFS 2009). Fall-run Chinook salmon and steelhead are also produced by the FRFH. Approximately two-thirds of natural Chinook salmon spawning in the Feather River occurs in the LFC between the Fish Barrier Dam and the Thermalito Afterbay Outlet (NMFS 2009). Spawning occurs primarily in the riffle and glide areas, with the greatest portion crowded in the upper 3 miles of the LFC (Sommer et al. 2001). The remaining one-third of the spawning occurs between the Thermalito Afterbay Outlet and Honcut Creek (River Mile (RM) 59 to 44) (FERC 2007), where, in comparison to the LFC, there is a greater amount of available spawning areas and deeper pools (FERC 2007, NMFS 2009). This represents a marked shift in the spawning distribution of Chinook salmon since the construction of Oroville Dam and the FRFH, when less spawning activity occurred in the LFC, which has undoubtedly increased spawning densities in the LFC (Sommer et al. 2001). For both Chinook salmon and steelhead, spawning and embryo incubation is the life stage for which the smallest amount of suitable habitat is available in the upper Feather River (NMFS 2009).

Rearing

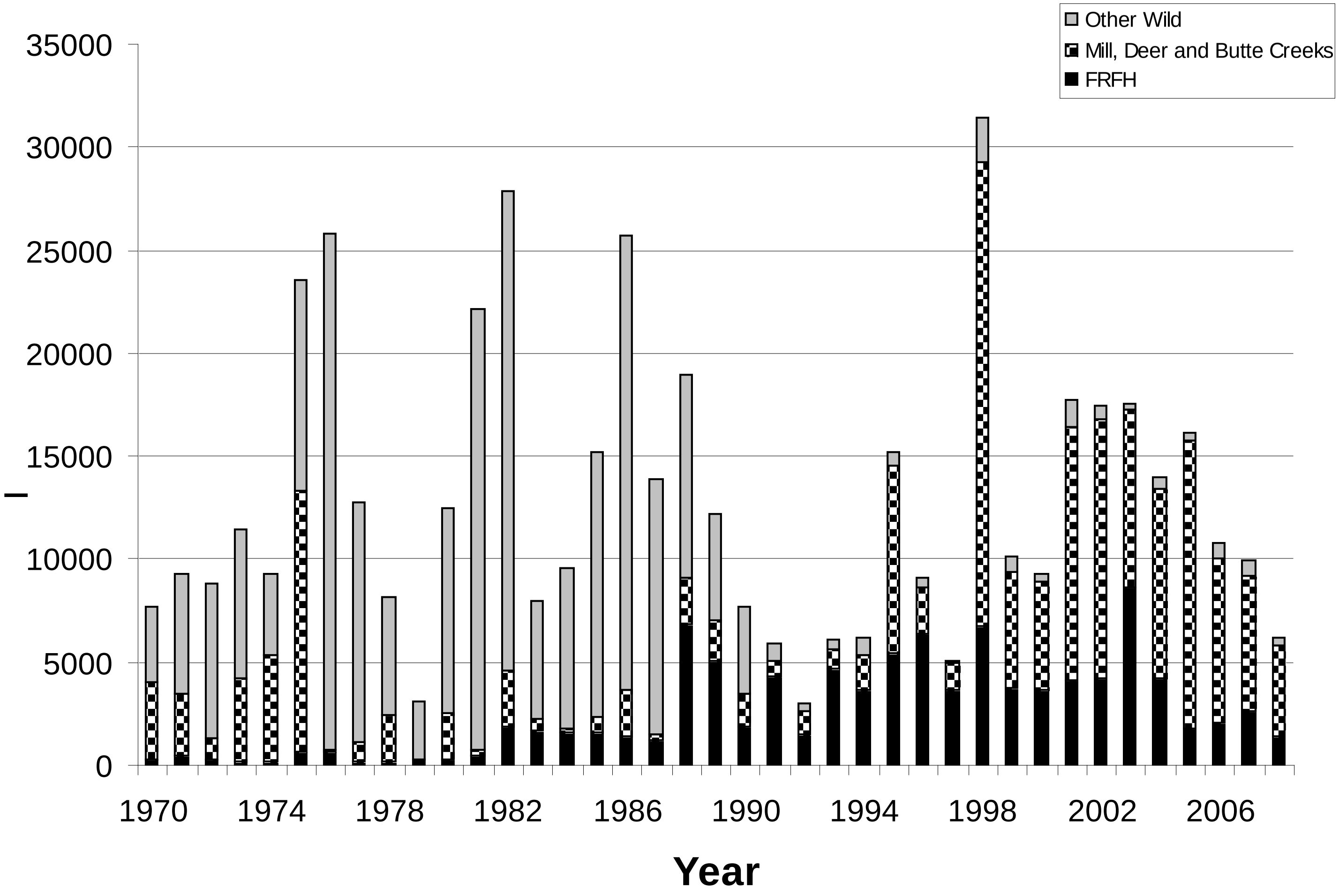
Some spring-run Chinook salmon juveniles hold over the summer in deep pools within the LFC 5 miles below Oroville Dam and the downstream Thermalito Afterbay Outlet (Reynolds et al. 1993, (Yoshiyama et al. 2001). The vast majority of spring-run Chinook salmon fish emigrate as fry (DWR unpublished data as found in Sommer et al.), suggesting that rearing habitat is limiting or that conditions later in the season are less suitable (Sommer et al. 2001). The primary location(s) where these fish rear is unknown; however in wetter years it appears that many young salmon rear for weeks to months in the Yolo Bypass floodplain immediately downstream from the Feather River before migrating to the estuary (Sommer et al. 2001).

Outmigration

Fry from both runs of Chinook salmon emerge from spawning gravels as early as November (Painter et al. 1977, DWR unpublished data as found in Sommer et al. 2001) and generally rear in the river for at least several weeks. Emigration occurs from December to June, with a typical peak during the February-through-April period (Sommer et al. 2001), with 95 percent of the juvenile Chinook typically emigrating from the Oroville Facilities project area by the end of May (FERC 2007, NMFS 2009).

3.1.4 Population Size

The Central Valley spring-run Chinook spawn run size data between 1970 and 2008 is summarized in Figure 3-3. Between this period, the highest annual hatchery spring-run Chinook salmon escapement on the Feather River was 8,662, occurring in 2003 (DFG 2009). Between 1986 and 2007, the average number of spring-run Chinook salmon returning to the FRFH was 3,992, compared to an average of 12,888 spring-run Chinook salmon returning to the entire Sacramento River Basin (NMFS 2009), and an average of 1,700 fish before the construction of Oroville Dam (Reynolds et al. 1993, Yoshiyama et al. 2001). More recently, FRFH spring-run Chinook salmon escapement from 2005 through 2008 was 1,774, 2,061, 2,674, and 1,418, respectively (DFG 2009, NMFS 2009). The increase in numbers since the completion of the dam is attributed to the consistent supply of cold water to both the hatchery and the LFC and the contribution of hatchery fish (Reynolds et al. 1993, Yoshiyama et al. 2001).



Source: DFG 2009

Figure 3-3.
Central Valley Spring-Run Chinook Salmon Spawning Run Size Composition (1970-2008)

3.1.5 Hatchery Influence and Interbasin Transfers

The FRFH was built by DWR to mitigate for the loss of upstream spawning habitat of salmon and steelhead due to the building of Oroville Dam (Reynolds et al. 1993, Yoshiyama et al. 2001). The FRFH began operation in 1967, and it is the only source of hatchery-produced spring-run Chinook salmon in the Central Valley (Reynolds et al. 1993, Yoshiyama et al. 2001). In the early stages of hatchery operations, FRFH staff attempted to maintain program separation of the two runs by designating the earliest-arriving spawners as spring-run Chinook salmon. Unfortunately, directed and unintentional incorporation of fall-run Chinook salmon broodstock into the spring-run Chinook salmon program has led to hybridization between the two hatchery stocks over time. Brown and Greene (1994) describe coded-wire-tag studies on the progeny of hatchery fish identified as “fall-run Chinook salmon” and “spring-run Chinook salmon” and found evidence of substantial introgression (Sommer et al. 2001) due to hatchery practices and the overlapping spatial proximity of spawning in the river of the two populations. It has been reported that some proportions of the offspring of each hatchery race return as adults during the wrong period, i.e., spring-run Chinook salmon are returning during months when fall-run Chinook salmon return (Sommer et al. 2001). In an attempt to improve the life-history integrity of the spring-run Chinook salmon hatchery stock, a Settlement Agreement for Licensing of the Oroville Facilities (March 2006) includes measures to improve the short- and long-term genetic management of the FRFH spring-run Chinook salmon program, and measures to physically separate and isolate spring-run Chinook salmon from fall-run Chinook salmon (NMFS 2009).

3.2 Deer and Mill Creeks

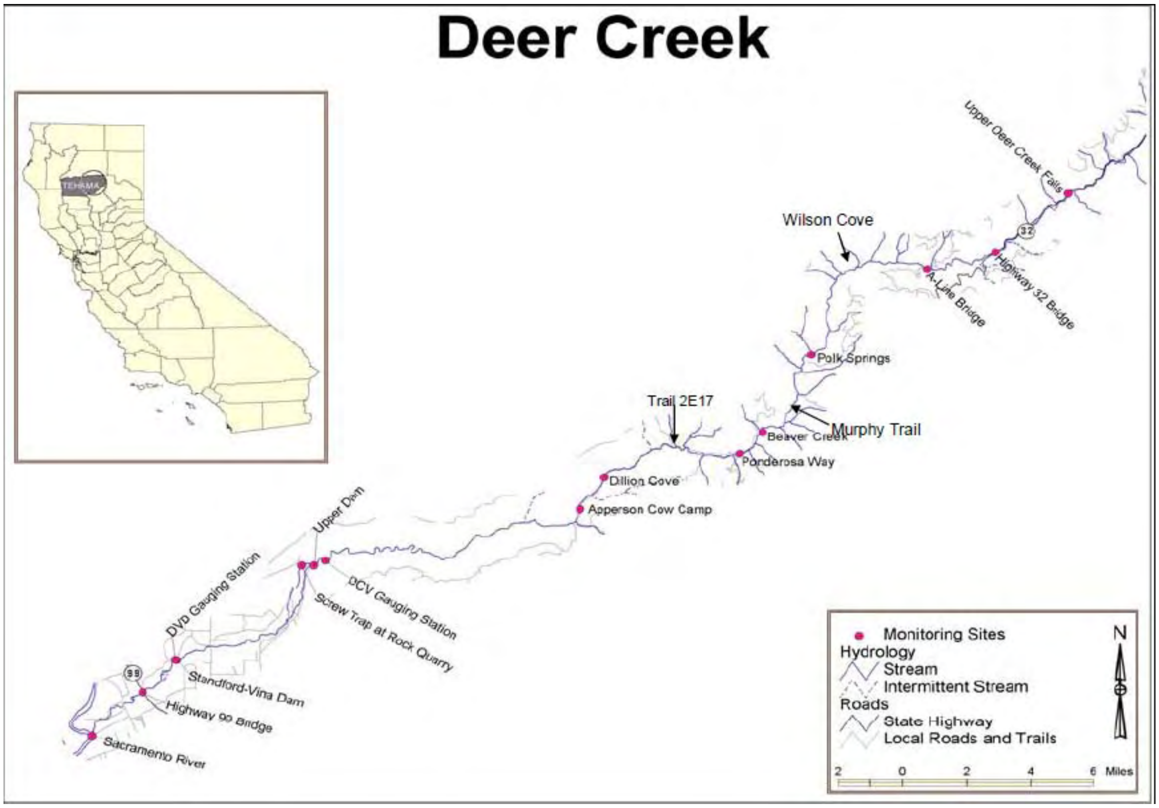
Deer and Mill creeks are eastside tributaries to the upper Sacramento River. Deer Creek enters the Sacramento River at RM 220 and Mill Creek enters at RM 230. Along with Butte Creek, they are recognized as supporting genetically distinct, self-sustaining populations of spring-run Chinook salmon, (DFG 1998, as cited in DFG 2008). Mill and Deer creeks appear genetically similar compared to the other extant spring-run Chinook salmon population in the Central Valley and likely function together demographically as a metapopulation. There is currently no hatchery program supplementing the populations on these streams. Between 1902 and 1940, the U.S. Bureau of Fisheries established a hatchery on Mill Creek near Los Molinos. During this time, fall-run Chinook salmon were spawned, with an average of 6,000,000 to 7,000,000 eggs taken annually. Juvenile salmon were reared and released in the spring. Attempts were made to spawn spring-run Chinook salmon at this site, but were prohibited by warm water temperatures during summer months. (Hanson et. al. 1940)

Additionally, during salvage operations resulting from the construction of Keswick Dam between 1941 and 1946, about 13,000 adult spring-run Chinook salmon from the upper Sacramento River were introduced into Deer Creek (Cramer and Hammack 1952). According to Harvey (1997), some of these may have been winter- and/or fall-run Chinook salmon. Small numbers of fall-run and/or late fall-run Chinook salmon may also spawn annually in Deer and Mill creeks (Harvey-Arrison 2007)

3.2.1 Existing Conditions

Deer Creek

Deer Creek is 60 miles long and its watershed drains 200 square miles (USFWS 1995). Deer Creek originates on the northern slopes of Butte Mountain at an elevation of approximately 7,320 feet. It initially flows through meadows and dense forests and then descends rapidly through a steep rock canyon into the Sacramento Valley. Deer Creek flows for 11 miles across the Sacramento Valley floor, entering the Sacramento River at approximately a 180-foot elevation (NMFS 2009) where most of the flow is diverted. In many years, diversions at three dams deplete all of the natural flow from mid-spring to fall. Each of these diversion structures have fish passage structures and screens, so Deer Creek spring-run Chinook salmon have access to 100 percent of their historic habitat (Figure 3-4) (NMFS 2009).

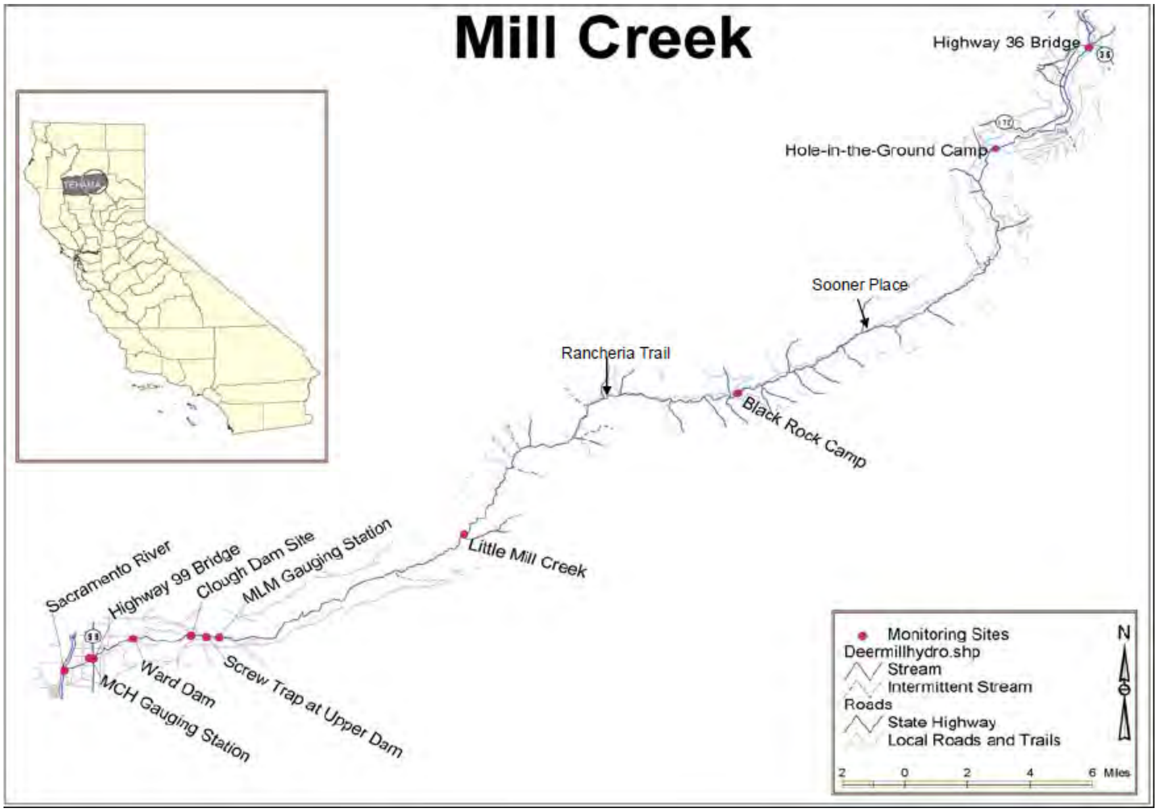


Source: Harvey-Arrison 2008

Figure 3-4.
Spring-Run Chinook Salmon Holding and Spawning Habitat in Deer Creek

Mill Creek

Mill Creek is a major tributary of the Sacramento River, flowing from the southern slopes of Mount Lassen and entering the Sacramento River at RM 230. The stream originates at an elevation of approximately 8,200 feet and descends to 200 feet at its confluence with the Sacramento River. Mill Creek originates from springs in Lassen Volcanic National Park (LVNP) and initially flows through meadows and dense forests. It descends rapidly through a steep canyon, flows eight miles across the Sacramento Valley floor, and its total length is approximately 58 miles to its confluence with the Sacramento River. Nearly all the mainstem habitat is used and/or available to spring-run Chinook salmon (Figure 3-5). The Mill Creek watershed encompasses 134 square miles. During the irrigation season, three dams on the lower 8 miles of the stream divert most of the natural flow, particularly during dry years.



Source: Harvey-Arrison 2008

Figure 3-5.
Spring-Run Chinook Salmon Holding and Spawning Habitat in Mill Creek

3.2.2 Life History/Phenotypic Expression

Deer Creek

Migration. Spring-run Chinook salmon have been documented migrating upstream on Deer Creek from March through early July. Migrations usually end during the peak of the irrigation season when flows are insufficient to pass adults and water temperatures begin to approach lethal limits low in the watershed.

Holding and Spawning. The known range for adult spring-run Chinook salmon holding extends from Upper Falls downstream to near the confluence of Rock Creek, a distance of approximately 25 miles. The upstream limit is a natural waterfall (Upper Falls). Within this area, 30 percent of the area is represented by all pools. Of 166 total pools, 98 (or 60 percent) are holding pools (more than 6 feet deep). Because maturing adult spring-run Chinook salmon enter streams during the spring months and spend the summer holding in deep pools (before fall spawning), they are present in the stream system when temperatures are at their peak (generally July and August). In Deer Creek above the canyon mouth, Needham et al. (1943) observed salmon holding in deep pools when surface water temperatures measured 73°F (23°C). Based on adult spring-run Chinook salmon mortalities reported in lower Deer Creek (below the canyon mouth) in the 1940s, Cramer and Hammack (1952) reported temperatures greater than 81°F (27°C) were lethal to migrating salmon.

The known range for adult spring-run Chinook salmon spawning extends from Upper Falls downstream to near the mouth of the canyon, a distance of approximately 30 miles. It appears that in wet years, more spawning takes place lower in the watersheds. Spawning habitat use has been known to shift between years at some sites with changes in bed composition resulting from high-flow events. Visual observations of spring-run Chinook salmon spawning in Deer Creek indicate spawning substrate is in good condition with the percent fines being low in the areas used. Deposition of fines in areas used for spawning is virtually absent year round.

Emergence and Rearing. In 2007, DFG initiated bimonthly rearing surveys to assess the relative growth of known spring-run Chinook salmon juveniles with mixed-stock juveniles captured in rotary screw traps. In 2007, surveys began in January and juveniles were first detected in February. In 2008, surveys could not begin until March due to snow conditions, and juveniles were detected on the first survey of the season. Monitoring data indicate that emergence of juvenile Chinook begins in November, peaks around February, and ends in April. These data are derived from an egg-temperature model to predict emergence based on redd placement and also from direct observation of newly emerged juveniles. (Harvey-Arrison 2007)

Outmigration. Based on annual surveys by the DFG, outmigration of yearling spring-run Chinook salmon typically occurs from October or November through March or April, depending on the year. Fry outmigration occurs from February through June, but since traps are located within the fall-run Chinook salmon spawning area, these fry migrations are a mix of fall-run and spring-run Chinook salmon progeny. In Deer and Mill creeks, many juveniles emigrate during the wet season more than a year after being spawned (Big Chico Creek Watershed Alliance 2000).

Mill Creek

Migration. While adult spring-run Chinook salmon have been observed migrating in Mill Creek as early as February, a 10-year study from 1953 to 1964 (DFG 1966) has documented the majority of upstream migration as occurring between mid-April and the end of June.

Based on observations of spring-run Chinook salmon adults holding and/or spawning, the known range of this habitat extends a distance of approximately 48 miles from near the Little Mill Creek confluence (Harvey pers. comm. as cited in Armentrout 1998 and reported in NMFS 2009) upstream to within 0.5 mile of the LVNP boundary (personal observation of adult holding). Suitable spawning habitat on the mainstem of Mill Creek extends to near Morgan Hot Springs (approximately 3 miles downstream from LVNP), although salmon have been reported spawning in "Middle Creek", a small tributary located approximately two miles downstream from the park boundary (McFarland 1997).

Holding and Spawning. There are two geographically important sections of holding habitat available on Mill Creek, Upper Mill Creek and Lower Mill Creek (Canyon). Upper Mill Creek, is defined as the upper 7.6 miles of Mill Creek between the LVNP boundary and Mill Creek campground, and Lower Mill Creek (canyon reach), is defined as the area downstream from the Mill Creek campground (Figure 3-5).

In Upper Mill Creek, the availability of spring-run Chinook salmon holding habitat appears to be limited. Based on stream survey data collected in 1990, 5 percent of the area was represented by all pools. Of all 88 pools noted in 1990, none was classified as a holding pool.

Downstream from the Mill Creek campground, in the Lower Mill Creek (Canyon) reach, available holding habitat is more abundant. In 1990 and 1994, a survey was conducted on more than 13 miles of approximately 20 miles of stream extending from the campground to 2 miles downstream from Black Rock. Within the surveyed segments, 13 percent of the area was represented by all pools. Of all 86 pools documented, 20 (or 23 percent of the total) were holding pools.

Little quantifiable data is available on the distribution of holding habitat from approximately 2 miles downstream from Big Bend to approximately 2 miles upstream from Black Rock due to the difficulty in accessing the area. In a 1988 holding survey, more than 200 adult salmon were noted within most of the 7 miles of stream that had not been previously habitat classified, indicating additional suitable holding habitat is present. Given similar channel characteristics such as substrate composition, gradient, etc., holding habitat distribution and abundance would not likely differ greatly from other areas of Mill Creek surveyed in the lower canyon reaches (McFarland 1997).

Above the canyon mouth, in the upper alluvial reach of Mill Creek, is an area of possible temperature-related impacts on adults. Adult mortalities have been reported during mid-summer in a single drought year (McFarland 1997). The area where the mortalities occurred contained natural hot springs and lacked deep holding pools. The stream channel was mostly open with little riparian shading and overhead cover, the mortalities may have been attributed to a prolonged exposure to elevated stream temperatures.

Mill Creek spring-run Chinook salmon are unique for spawning at an elevation of more than 5,000 feet, the highest elevation known for salmon spawning in North America (Armentrout et al. 1998. In Mill Creek, sediment loading is greater than in Deer Creek and fines are notable, especially in areas of deposition. High gravel embeddedness has been observed in some areas of spawning use (McFarland 1997). Conditions observed however, do not appear to limit salmon from spawning.

Size distribution of Mill Creek spring-run Chinook salmon spawners has ranged from 41 cm to 102 cm from carcass survey data from 1990 to 2000. The majority are in the 60- to 80-centimeter (cm) fork length (FL) range.

Emergence and Rearing. In 2007, DFG initiated bimonthly rearing surveys to assess the relative growth of known spring-run Chinook salmon juveniles with mixed stock juveniles captured in rotary screw traps. In 2007, surveys were initiated in January and juveniles were first detected in February. In 2008, surveys could not begin until March due to snow conditions, and juveniles were detected on the first survey of the season. Monitoring data indicate that emergence of juvenile Chinook begins in November, peaks around February and ends in April. These data are derived from an egg-temperature model to predict emergence based on redd placement and also from direct observation of newly emerged juveniles (Harvey-Arrison 2007).

Outmigration. Based on annual surveys by the DFG, outmigration of yearling spring-run Chinook salmon typically occurs from October or November through March or April depending on the year. Fry outmigration occurs from February through June, but since traps are located within the fall-run Chinook salmon spawning area, these fry migrations are a mix of fall-run and spring-run Chinook salmon progeny. In Deer and Mill creeks, many juveniles emigrate during the wet season more than a year after being spawned (Big Chico Creek Watershed Alliance 2000).

3.2.3 Population Size

Deer Creek

Table 3-2 shows annual escapement estimates for Deer Creek spring-run Chinook salmon. For the Central Valley Project Improvement Act (CVPIA) doubling period 1967 to 1991, the average spawning escapement of spring-run Chinook salmon in Deer Creek was 1,300 (USFWS 1995). From 1991 to 2008, the average is only 1,152.

Table 3-2.
Annual Escapement Estimates for Deer Creek

Year	Count	Year	Count	Year	Count
1963	2,302	1979	-	1995	1,295
1964	2,874	1980	1,500	1996	614
1965	-	1981	-	1997	466
1966	-	1982	1,500	1998	1,879
1967	-	1983	500	1999	1,591
1968	-	1984	0	2000	637
1969	-	1985	301	2001	1,622
1970	2,000	1986	543	2002	2,185
1971	1,500	1987	200	2003	2,759
1972	400	1988	371	2004	804
1973	2,000	1989	84	2005	2,239
1974	3,500	1990	496	2006	2,432
1975	8,500	1991	479	2007	644
1976	-	1992	209	2008	144
1977	340	1993	259		
1978	1,200	1994	485		

Source: DFG 2009

Mill Creek

Table 3-3 shows annual escapement estimates for Mill Creek spring-run Chinook salmon. For the CVPIA doubling period 1967 to 1991, the average spawning escapement of spring-run Chinook salmon in Mill Creek was 800 (USFWS 1995). From 1991 to 2008, the average is only 646.

Table 3-3.
Annual Escapement Estimates for Mill Creek

Year	Count	Year	Count	Year	Count
1960	2,368	1977	460	1994	723
1961	1,245	1978	925	1995	320
1962	1,692	1979		1996	253
1963	1,315	1980	500	1997	202
1964	1,539	1981		1998	424
1965		1982	700	1999	560
1966	-	1983	-	2000	544
1967	-	1984	191	2001	1,100
1968	-	1985	121	2002	1,594
1969	-	1986	291	2003	1,426
1970	1,500	1987	90	2004	998
1971	1,000	1988	572	2005	1,150
1972	500	1989	563	2006	1,002
1973	1,700	1990	844	2007	920
1974	1,500	1991	319	2008	306
1975	3,500	1992	237		
1976	-	1993	61		

Source: DFG 2009

3.2.4 Hatchery Influence and Interbasin Transfers

There is currently no hatchery program supporting fish populations on either of these streams. Between 1902 and 1940, the U.S. Bureau of Fisheries established a hatchery on Mill Creek near Los Molinos. During this time, fall-run Chinook salmon were spawned, with an average of 6,000,000 to 7,000,000 eggs taken annually. Juvenile salmon were reared and released in the spring. Attempts were made to spawn spring-run Chinook salmon at this site, but were prohibited by hatchery warm water temperatures during the summer months (Hanson et. al. 1940).

3.3 Butte Creek

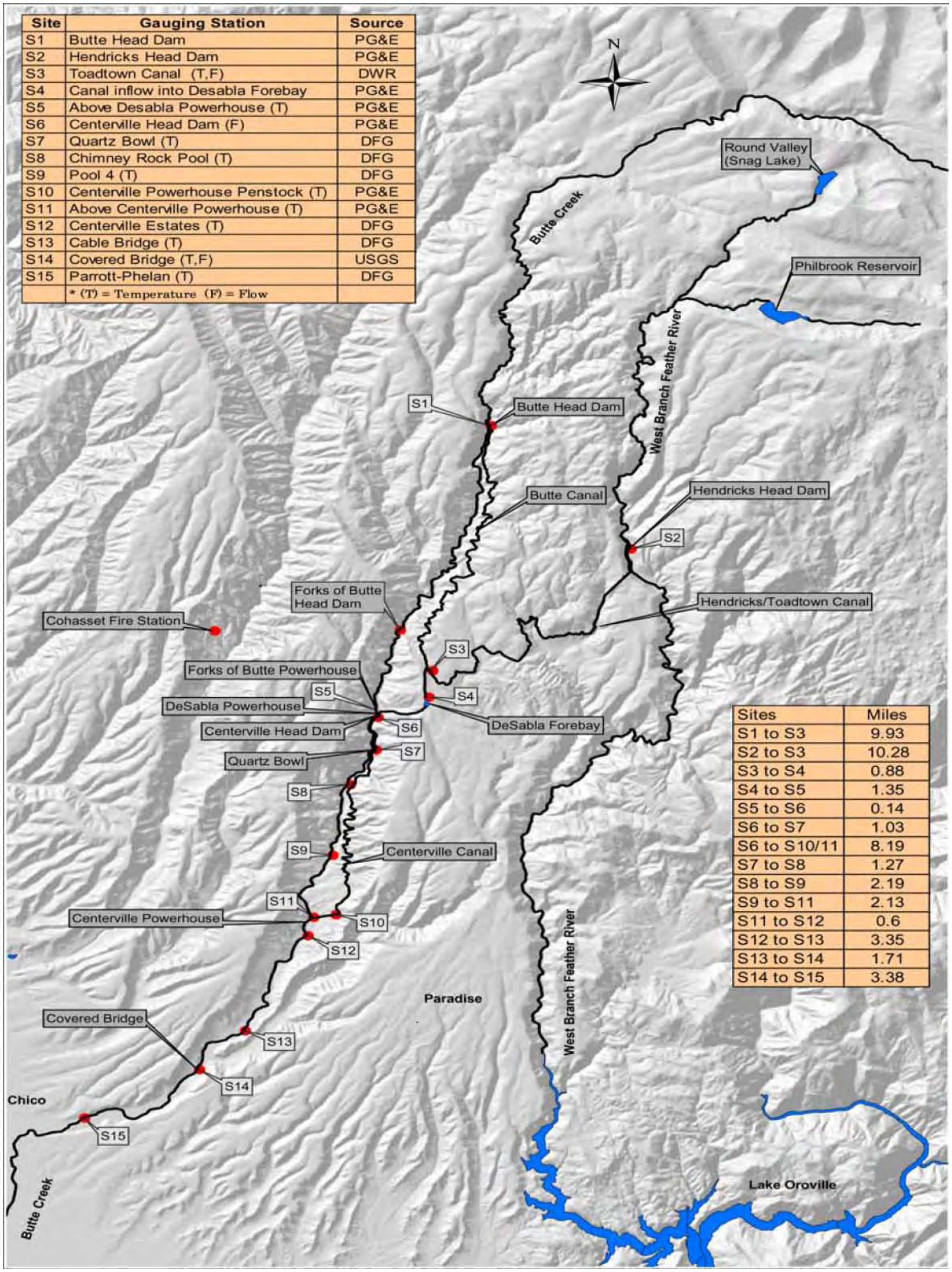
3.3.1 Introduction

Butte Creek is one of only three streams to sustain a genetically distinct and viably independent population of spring-run Chinook salmon (NMFS 2009). The spring-run Chinook salmon in Butte Creek are considered persistent and viable and is one of the most productive spring-run Chinook salmon streams in the California Central Valley (NMFS 2009). Lindley et al. (2007) indicated that the Butte Creek population is at a low risk of extinction due to the population size, general increases in production, and low hatchery influence. According to Moyle et al. (2008), there is a high likelihood of spring-run Chinook salmon going extinct in the next 50 to 100 years due to the vulnerability of a catastrophic event and due to the narrow physiological tolerances in the summer, where an increase in temperature due to climate change may drastically reduce survival. Population numbers have increased within the last 2 decades, and large pre-spawn mortalities have occurred in a few years (Williams 2006). The pre-spawn mortalities were due to a high number of fish concentrated in limited holding pools with high water temperatures, resulting in an outbreak of diseases.

3.3.2 Existing Conditions

Flow Regime

The flow regime of the adult holding and spawning habitat in Butte Creek is directly affected by the Pacific Gas & Electric (PG&E) DeSabla-Centerville Project (Figure 3-6) (FERC-083). The entire holding and spawning habitat for spring-run Chinook salmon is located downstream from the Centerville Head Dam. The water at this location comes from two water sources, Butte Creek and water from the west branch of the Feather River. From July through September, the west branch of the Feather River provides approximately 40 percent of the flows downstream from the Centerville Head Dam in the anadromous reach of Butte Creek. The water from the Feather River is diverted at the Hendricks Head Dam and flows through the Hendricks/Toadtown Canal where it merges with Butte Creek water from the Butte Canal that is diverted at the Butte Head Dam. The water continues through the DeSabla Forebay, and then reconnects to Butte Creek. Water also flows through the mainstem of Butte Creek between the Butte Head Dam and the DeSabla Forebay confluence. The water is again diverted at the Centerville Head Dam, where a majority of the water is sent down the Centerville Canal, and reconnects to Butte Creek at the Centerville Powerhouse. PG&E is required to maintain a minimum flow of 40 cfs in the mainstem of Butte Creek between the Centerville Head Dam and the Centerville Powerhouse from June 1 through September 14. In recent years, PG&E has voluntarily increased the minimum flow to 60 cfs during the onset of spawning, in late September. PG&E also has a contingency plan for when air temperatures exceed 105°F (typically in the middle of the summer), in which they alter the flow regime to provide colder water to the reach where spring-run Chinook salmon are over-summering above the Centerville Powerhouse.



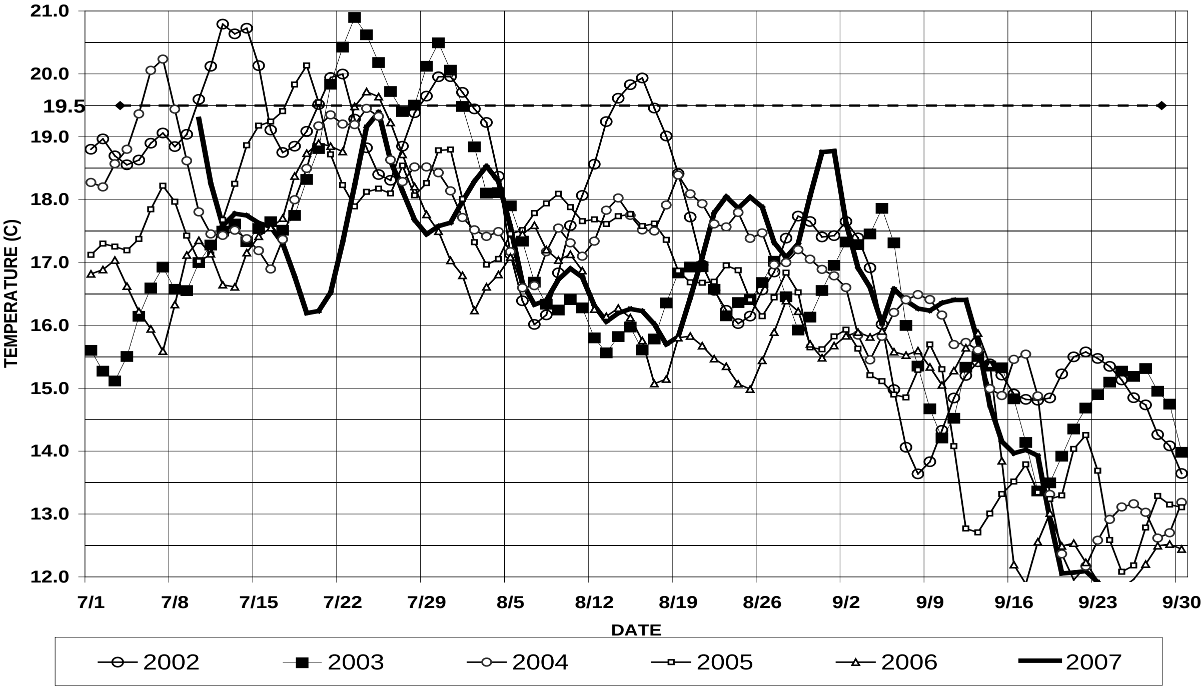
Site	Gauging Station	Source
S1	Butte Head Dam	PG&E
S2	Hendricks Head Dam	PG&E
S3	Toadtown Canal (T,F)	DWR
S4	Canal inflow into Desabla Forebay	PG&E
S5	Above Desabla Powerhouse (T)	PG&E
S6	Centerville Head Dam (F)	PG&E
S7	Quartz Bowl (T)	DFG
S8	Chimney Rock Pool (T)	DFG
S9	Pool 4 (T)	DFG
S10	Centerville Powerhouse Penstock (T)	PG&E
S11	Above Centerville Powerhouse (T)	PG&E
S12	Centerville Estates (T)	DFG
S13	Cable Bridge (T)	DFG
S14	Covered Bridge (T,F)	USGS
S15	Parrott-Phelan (T)	DFG
	* (T) = Temperature (F) = Flow	

Sites	Miles
S1 to S3	9.93
S2 to S3	10.28
S3 to S4	0.88
S4 to S5	1.35
S5 to S6	0.14
S6 to S7	1.03
S6 to S10/11	8.19
S7 to S8	1.27
S8 to S9	2.19
S9 to S11	2.13
S11 to S12	0.6
S12 to S13	3.35
S13 to S14	1.71
S14 to S15	3.38

Figure 3-6.
Reaches of Butte Creek and West Branch of the Feather River Controlled by Pacific Gas & Electric Company Affecting Butte Creek Spring-Run Chinook Salmon, Including Temperature and Flow Gage Locations and Distances

Water Temperature

Water temperatures are regularly monitored seasonally from June through September throughout the PG&E DeSabla-Centerville Project. PG&E in consultation with DFG, NMFS, and USFWS, has developed a Project Operations and Management Plan that includes a contingency for extreme heat events (beginning in 2004). PG&E prepares weekly weather forecasts, based on USFS weather stations, for the DeSabla-Centerville Project Area, which encompasses the Butte Creek spring-run Chinook salmon's holding and spawning area. If air temperatures will exceed 105°F (41°C) for 2 or more days then, in consultation with the Resource Agencies, PG&E changes the flow regime by altering the flow amount and location of release to reduce the water temperatures within the DeSabla-Centerville Project Area. The water temperature in the holding and spawning habitat frequently exceeds 59°F (15°C) from July through September (Figure 3-7). PG&E is required to maintain a minimum flow of 40 cfs in Butte Creek between the Centerville Head Dam and the Centerville Powerhouse from June 1 through September. Since 2004, PG&E has voluntarily increased the minimum flow in Butte Creek to 60 cfs during the onset of spring-run Chinook salmon spawning. This increase has reduced water temperatures in this section of river and has increased the amount of usable spawning gravel by approximately 26 percent.



Source: McReynolds et al. 2008

Figure 3-7.
Mean Daily Water Temperature (°C) at Quartz Bowl Pool for Period July Through September 2002-2007

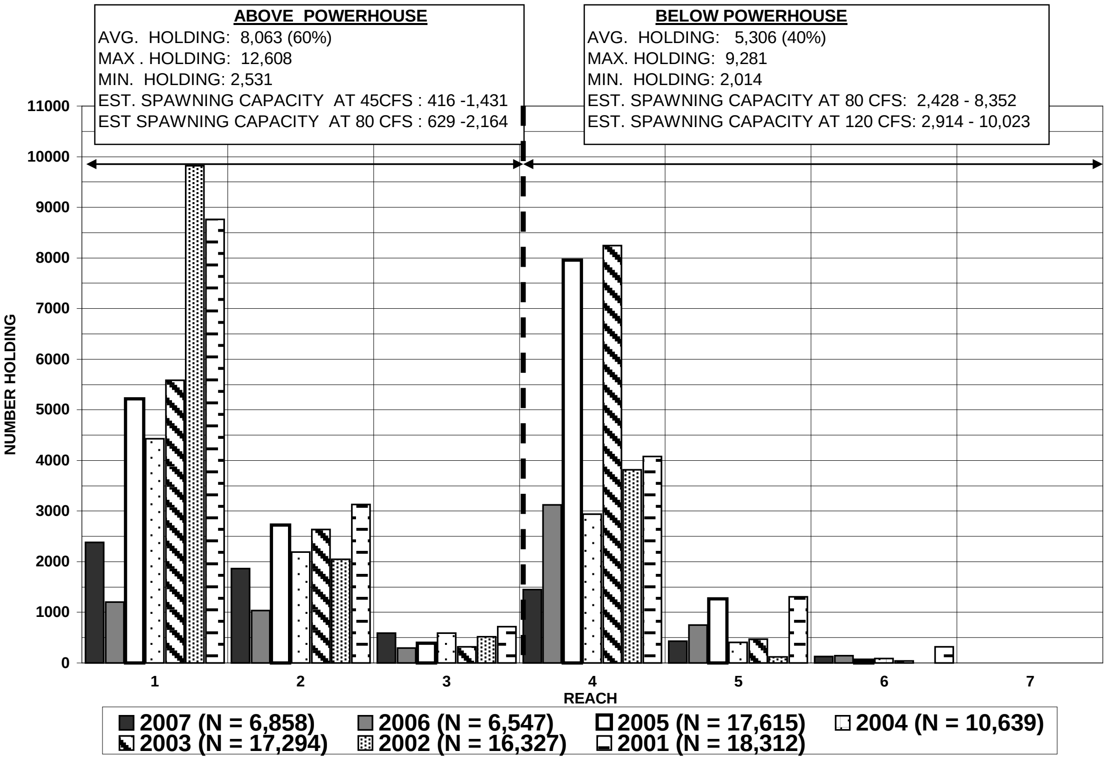
Observed disease outbreaks within the Butte Creek spring-run Chinook salmon population have generally occurred during the summer holding period. In 2002, there were approximately 3,431 pre-spawn mortalities out of an estimated population of 16,328; in 2003 there were approximately 11,231 pre-spawn mortalities out of an estimate population of 17,294; and during 2004 there were approximately 418 pre-spawn mortalities out of an estimated population of 10,639 (Ward et al. 2007). In 2003, fish mortality was attributed to the high number of fish concentrated in limited holding pools with high water temperatures, and an outbreak of two diseases *Flavobacterium columnare* (Columnaris) and the protozoan *Ichthyophthirius multiphilis* (Ich) (Williams 2006). The mortalities during 2002 and 2003 coincided with significant daily average water temperatures above 67 °F (19.5°C). The pre-spawn mortalities during 2004 were concluded to be the normal attrition for salmon holding in fresh water since early spring. During the 2004 summer months, the average air and water temperatures were generally lower than in 2002 and 2003, and Butte Creek flows were slightly higher. The pre-spawn mortalities in subsequent years (2005 through 2007) were also concluded to be due to normal attrition.

3.3.3 Life History/Phenotypic Expression

Upstream Migration and Holding

The entire available holding and spawning area for Butte Creek spring-run Chinook salmon is below 931 feet in elevation, due to a 15-foot waterfall barrier known as the Quartz Bowl Falls. The best holding and spawning habitat for the spring-run Chinook salmon is within approximately 11 miles of the river, from Quartz Pool downstream to the Centerville Covered Bridge (Ward et al. 2004). The highest quality and quantity of holding habitat is within the uppermost 3 miles (from Quartz Pool to Whiskey Flat). Another good holding location is directly below the Centerville Powerhouse, due to the cooler water found there. The diversion at the Centerville Head Dam, which sends water down the Centerville Canal to the Centerville Powerhouse, which significantly reduces water temperatures directly below the powerhouse due to reduced transition time and shading.

Butte Creek spring-run Chinook salmon adults migrate from February through June, with the peak in mid-April. Adult migration is frequently impaired by low flows and high water temperatures in June, and adult Chinook salmon that have not migrated above State Highway 99 by mid-June have a lower likelihood of surviving to spawn. DFG biologists also regularly observe large numbers of spring-run Chinook salmon holding directly below the Centerville Powerhouse. During the 7-year period from 2001 to 2007, approximately 60 percent of the fish held above the Centerville Powerhouse and 40 percent held below it (Figure 3-8) (McReynolds and Garman 2008).



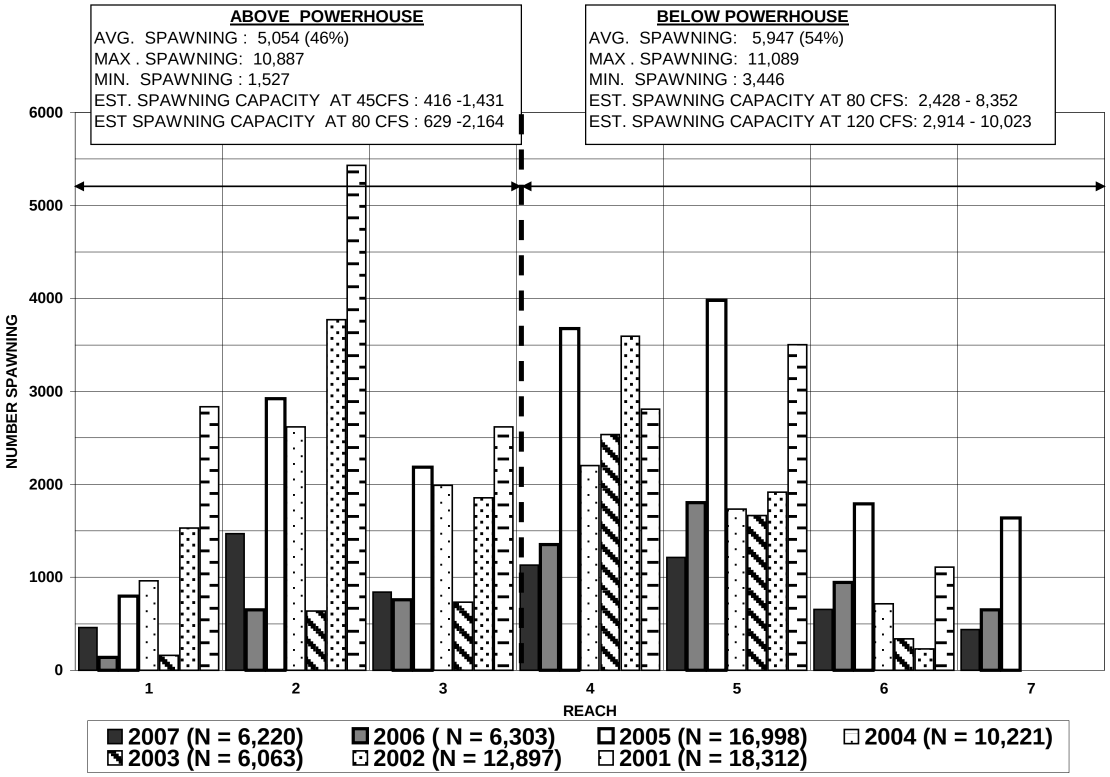
Source: McReynolds et al. 2008

Figure 3-8.
Distribution by Reach of the Number of Butte Creek SRCS Holding, During 2001-2007

Spawning

The highest quality and quantity spawning gravel is within the first 5 miles directly below the Centerville Powerhouse. Estimates of available spawning habitat based on maximum suitable flows (130 cfs) concluded that approximately 18 percent of the suitable spawning gravel is located above the Centerville Powerhouse and 82 percent below (Ward et al. 2004). The maximum number of spawners at these locations is 152 to 1,316 at 40 cfs above Centerville Powerhouse, and 270 to 2,352 at 40 cfs and 1,262 to 10,976 at 130 cfs below (Ward et al. 2004).

The spring-run Chinook salmon generally spawn between late-September through early November, with the peak in early October. During the 7-year period from 2001 to 2007, approximately 45 percent of the fish spawned above the Centerville Powerhouse and 55 percent below (Figure 3-9) (McReynolds et al. 2008). During 2004, PG&E increased the flow above the Centerville Powerhouse from 40 cfs to 60 cfs to provide additional habitat for the spawning spring-run Chinook salmon. The increase in flow increased the amount of usable spawning gravel by approximately 26 percent (Ward et al. 2004).



Source: McReynolds et al. 2008

Figure 3-9.
Distribution by Reach of the Number of Butte Creek SRCS Spawning, During 2001-2007

Outmigration

Butte Creek spring-run Chinook salmon generally outmigrate as fry from November through February, and rear below the Parrott-Phelan Diversion Dam. The outmigration movements are heavily influenced by flow. Most spring-run Chinook salmon rear in the Sutter Bypass from February through May, and then migrate into the Sacramento River and continue to the Sacramento-San Joaquin Delta (Delta). Some fish will rear above the Parrott-Phelan Diversion Dam, in the mainstem of Butte Creek. These fish will generally rear for 12 or more months before outmigrating.

Rearing

The highest quality and quantity of juvenile rearing habitat is located in the Sutter Bypass, due to the connection to the floodplain (Williams 2006). Butte Creek spring-run Chinook salmon generally rear in the Sutter Bypass. Floodplain productivity increases with spring temperatures and residence times provide advantageous resources for outmigrating juveniles. Juvenile Chinook salmon that rear in the floodplain have significantly higher growth rates than fish that rear in riverine habitats (Moyle et al. 2008). In fact, spring-run Chinook salmon were captured and tagged at the Parrott-Phelam Diversion Dam and recaptured in the Sutter Bypass. DFG biologists have calculated the average growth rate of juvenile spring-run Chinook salmon for the Sutter Bypass recaptures to be 0.52 millimeter (mm)/day during 1999, 0.66 mm/day during 2000, and 0.38 mm/day during 2002 (Ward and McReynolds 2004).

Every year there are generally a handful of yearlings observed during spring-run Chinook salmon surveys. These salmon rear above Parrott-Phelan Diversion Dam, in the mainstem of Butte Creek. These fish grow to approximately 150 mm FL and remain in Butte Creek above the Parrott-Phelan Diversion Dam for 12 months or more before leaving Butte Creek and outmigrating to the Delta as yearlings (Ward et al. 2004b).

3.3.4 Population Size

The data below is based on DFG escapement estimates for the years 1954 through 2006 (Table 3-4). The approximate averages for the last 30, 20, and 10 years are 3,000, 4,400, and 7,400, respectively.

Table 3-4.
Butte Creek Spring-Run Chinook Salmon Spawning Escapement Estimates for the Period 1954 Through 2008

Year	Run Size	Year	Run Size	Year	Run Size	Year	Run Size		
1954	830	1969	830	1984	23	1999	3,679*		
1955	400	1970	285	1985	254	2000	4,118*		
1956	3,000	1971	470	1986	1371		Snorkel	Prespawn Mortality	Spawn
1957	2,195	1972	150	1987	14	2001	9,605	193	18,312**
1958	1,100	1973	300	1988	1,300	2002	8,785	3,431	12,597
1959	500	1974	150	1989	1,300*	2003	4,398	11,231	6,063
1960	8,700	1975	650	1990	100*	2004	7,390	418	10,221
1961	3,100	1976	46	1991	100*	2005	10,625	617	16,998
1962	1,750	1977	100	1992	730*	2006	4,579	244	6,303
1963	6,100	1978	128	1993	650*	2007	4,943	638	6,220
1964	600	1979	10	1994	474*	2008	3,935		
1965	1,000	1980	226	1995	7,500*				
1966	80	1981	250	1996	1,413*				
1967	180	1982	534	1997	635*				
1968	280	1983	50	1998	20,212*				

Source: McReynolds 2008 and DFG 2009

Notes:

* Surveys before 1989 used various methods with varying precision. Snorkel surveys implemented since 1989 are thought to significantly underestimate the actual population size and should only be used as an index. Spawning surveys results for 2001 – 2006 were generated by a modified Schaefer Model carcass survey.

** Number as reported for 2001 (22,744) in error (Ward et al. 2004).

During a 7-year period from 2001 to 2007, the average size of females was 762 mm and the average size of males was 793 mm. The average size of both males and females were significantly higher in 2007, 2006, and 2003, with males averaging 833 mm and females averaging 775 mm, compared with 2001, 2002, 2004, and 2005, with males averaging 762 mm and females averaging 711 mm. This size distribution is likely due to the percentage of different age classes. Spring-run Chinook salmon generally return at Age 3 or Age 4, and the compositions of the two age classes vary each year. Between 2001 and 2007, Age 4 dominated the adult composition in Years 2006 and 2003, 75 percent and 69 percent, respectively. Whereas in the 2001, 2002, 2004, and 2005, the adult composition was dominantly Age 3, 89 percent, 86 percent, 89 percent, and 97.5 percent. In 2007, the adult composition was approximately evenly distributed, 53 percent of the population was Age 3 and 47 percent was Age 4.

3.3.5 Hatchery Influence

There is little hatchery influence on the Butte Creek spring-run Chinook salmon population. No hatcheries exist on Butte Creek and the stream has not historically and is not currently planted with hatchery fish. The only exception was in 1986, when 200,000 juvenile Feather River spring-run Chinook salmon hatchery fish were planted into Butte Creek due to the extreme low levels of returns of Butte Creek spring-run Chinook salmon (Moyle et al. 2008). However, it is not believed that this plant had any genetic effect on the Butte Creek population (Garza et al. 2008). Hatchery Chinook salmon occasionally stray into Butte Creek, but in very low numbers.

3.4 Other Central Valley Phenotypic Spring-Run Chinook Salmon Populations

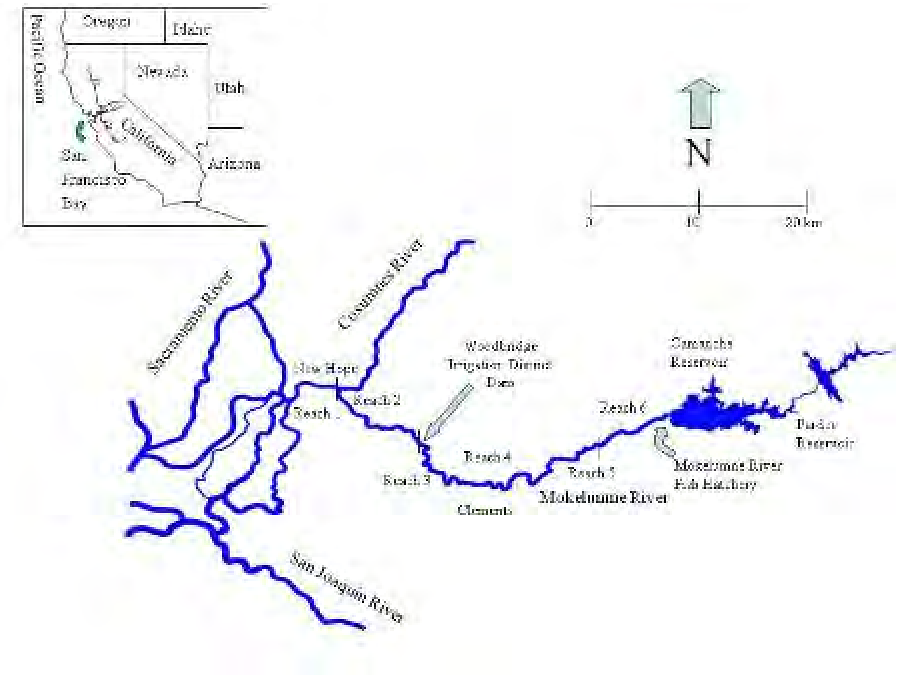
In addition to the recognized stocks listed above, evidence exists in other Central Valley watersheds of the occurrence of Chinook salmon displaying the spring-run Chinook salmon phenotype. These small localized occurrences warrant consideration because they occur in watersheds in closer proximity to the San Joaquin River geographically, and thus may be more adapted to the local conditions that will occur in the San Joaquin River. Two such watersheds in which data exists on phenotypic spring-run Chinook salmon are the Mokelumne River, an eastside tributary to the Delta, and the Stanislaus River, a tributary to the San Joaquin River.

3.4.1 Existing Conditions

Mokelumne River

The lower Mokelumne River is considered an Eastside Tributary to the Delta. Its confluence with the San Joaquin River is within the Delta proper boundaries. Flows in the Mokelumne River are regulated by a Joint Settlement Agreement (JSA) (1998) under Federal Energy Regulatory Commission (FERC) license. As such, the Mokelumne flow is based on water year types derived from precipitation, snow pack, and available storage in Camanche and Pardee reservoirs. Flow varies for the five water year types; wet, normal and above, below normal, dry, and critically dry. Minimum flow schedules are based on fall-run Chinook salmon life history and separated into fall (migration/spawning flows), winter (incubation flows), spring (emigration flows), and summer base flows. Minimum summer base flows range from 80 cfs in wet years to 20 cfs in dry and critically dry. Few holding pools are available for over-summering spring-run Chinook salmon on the Mokelumne, and summer temperatures typically reach 64°F (18^{o}C)

Camanche Dam is on River Kilometer (RKM) 103 and is the upper limit to anadromy on the Mokelumne River (Figure 3-10). Camanche Dam blocks approximately 80 percent of historical Chinook spawning habitat (DFG 1991). There are approximately 16 km of spawning habitat downstream from Camanche Dam available for salmonid spawning, and holding habitat is limited to a few large pools in the first river mile below Camanche Dam.

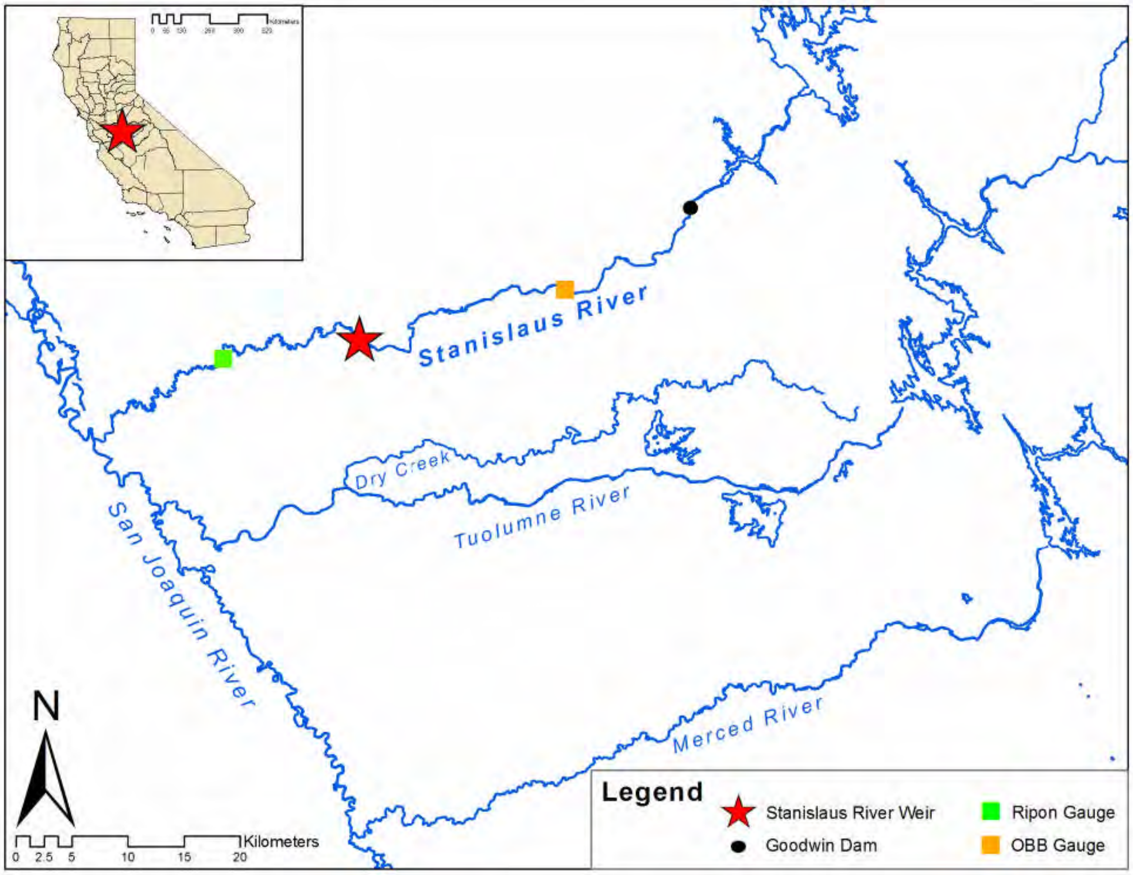


Source: East Bay Municipal Utility District

Figure 3-10.
Mokelumne River

Stanislaus River

The Stanislaus River is one of three major tributaries to the San Joaquin River (Figure 3-11). It is snow fed and its headwaters begin at an elevation of approximately 3,675 m. Like all San Joaquin River tributaries, multiple dams are located on the upper Stanislaus River. Historically, various life history types of Chinook salmon inhabited the Stanislaus River, including fall-, late fall-, and spring-runs (Reynolds et al. 1993). Currently, upstream migration for anadromous fishes ends at Goodwin Dam, RKM 94. Historically, upstream migration and spawning occurred well into the Stanislaus River's three forks, but miles of spawning and rearing habitat were lost due to dam construction (Fry 1961).



Source: Anderson et al. 2007

Figure 3-11.
Stanislaus River

3.4.2 Life History/Phenotypic Expression

Mokelumne River

Year-round video monitoring on the Mokelumne River began in 2001. Since that time, it has become clear that adult Chinook salmon are ascending the Mokelumne River from April through June on an irregular basis, in addition to the well-established population of fall-run Chinook salmon (escapement from August/September through January).

Migration. Phenotypic spring-run Chinook salmon observed on the Mokelumne River have passed video monitoring between April and June in low numbers.

Holding and Spawning. Limited holding opportunities exist on the Mokelumne River. There are few large pools in the uppermost reach just below Camanche Dam. No assessments of holding or spawning have been conducted.

Rearing. No assessment of spring-run Chinook salmon rearing has been conducted due to the confounding effects of spatial and temporal overlap with fall-run Chinook salmon, and the relatively small population size of phenotypic spring-run Chinook salmon spawners.

Outmigration. Yearling-sized juvenile Chinook (more than 100 mm FL) have been observed in rotary screw trapping in low numbers in December and January of some years (Workman 2006a, Workman 2002a). Rotary screw traps are typically installed in mid-December and operated until June or July, depending on water year type.

Stanislaus River

In 2002, a resistance board weir was installed on the Stanislaus River to assess escapement numbers and timing of Chinook salmon and steelhead trout (*Oncorhynchus mykiss*). In 2003, the weir was improved with the addition of an infrared camera.

Migration. Phenotypic spring-run Chinook salmon have been observed passing the weir on the Stanislaus River in May and June (Anderson et al. 2007).

Holding and Spawning. Chinook salmon have been reported in the Stanislaus River during the summer months. Snorkel surveys (Kennedy and Cannon 2005) conducted between October 2002 and October 2004 identified adults in June 2003 and June 2004 between Goodwin and Lovers Lead. Snorkel surveys also observed Chinook fry in December 2003 at Goodwin Dam, Two Mile Bar, and Knights Ferry, which indicates spawning occurring in September. In 2000, DFG (unpublished data) seined a deep pool at Bottonbush Recreation Area on five occasions, between June 29 and August 25, and captured 28 fish. Of these, eight were adipose fin-clipped and five had coded wire tags (CWT). All CWT fish originated from the FRFH.

Rearing. No assessment of spring-run Chinook salmon rearing has been conducted due to the confounding effects of spatial and temporal overlap with fall-run Chinook salmon, and the relatively small population size of phenotypic spring-run Chinook salmon spawners.

Outmigration. Rotary screw traps have captured low numbers of yearling smolts (defined as more than110 mm) on the Stanislaus River from February to April (Watry et al. 2007).

3.4.1 Existing Population Size

Mokelumne River

Phenotypic spring-run Chinook salmon on the Mokelumne River have numbered as high as 114 in the spring of 2002 between April and July, with four adipose fin clipped fish (i.e., hatchery origin fish) observed (Workman 2002b). Ninety-seven were observed in 2003 between March and July, with 21 adipose fin clipped fish observed (Workman 2003). None were observed in 2004, and in 2005, 2006, and 2007, limitations in video monitoring due to construction led to carcass survey data for escapement estimates, and no estimate of phenotypic spring-run Chinook salmon were attempted (Workman 2004, 2005, 2006b, Workman and Rible 2007, Workman et al. 2008).

Stanislaus River

In 2007, 11 phenotypic spring-run Chinook salmon were observed passing the weir between May and June. Future monitoring will determine if these fish are a typical occurrence or an anomaly (Anderson et al. 2007).

3.4.2 Hatchery Influence and Interbasin Transfers

Mokelumne River

The Mokelumne River has a DFG fall-run Chinook salmon production hatchery at the base of Camanche Dam. Historically, the hatchery has imported eggs and fry from both the Nimbus Fish Hatchery and the FRFH to meet production goals.

Stanislaus River

There is no hatchery on the Stanislaus River. Hatchery stock, identified by adipose fin clips, have been detected during weir operations denoting a small portion of hatchery influence is occurring in the watershed (Anderson et al. 2007). During carcass surveys in 2009, 11 percent of Chinook adults were adipose fin clipped (DFG unpublished data).

3.4.3 Genetics

Genetics work on these populations to determine if they are spring-run Chinook salmon has not been conducted, and although these populations exhibit the spring-run Chinook salmon phenotype, genetic analysis needs to be conducted to determine whether these fish are genetically or just phenotypically spring-run Chinook salmon.

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4.0 Population Genetics

There are only three stocks of spring-run Chinook salmon ESU Chinook salmon in the Central Valley that are possible donors for the reintroduction project in the San Joaquin River. These are the Butte Creek stock, the Mill Creek/Deer Creek stock, and the Feather River stock. Banks et al. (2000) and Garza et al. (2008) have shown that these three stocks are genetically distinct, and that the Mill Creek and Deer Creek populations are essentially the same stock. There are additional small populations of spring-run Chinook salmon in the Central Valley (e.g., Big Chico, Antelope, and Clear creeks, Mokelumne River, and Stanislaus River), but none of these, other than that on the Yuba River (Garza, unpublished data), have been confirmed to be from the Central Valley spring-run Chinook salmon ESU genetic lineage and may be early returning fall-run Chinook salmon. Even if these small populations were of Central Valley spring-run Chinook salmon ESU stocks, these runs are not appropriate as “sole donor” stocks for the SJRRP because they are too small and inconsistent to provide adequate numbers and diversity on which to base reintroduction. Only the three stocks mentioned above were, therefore, carefully evaluated as a potential primary or “sole donor” stock for the San Joaquin River reintroduction project.

The three remaining spring-run Chinook salmon lineages are all in the northern part of the Central Valley in the Sacramento River subbasin. The San Joaquin River subbasin has, unfortunately, either completely or almost completely lost its spring-run Chinook salmon populations, although there are persistent reports of a small number of spring-run Chinook salmon returning to the Mokelumne and Stanislaus rivers (Workman and Merz, field observations). The Deer/Mill Creek population is the northernmost of these and therefore the furthest from the San Joaquin River, with the Butte Creek population just to the south and the Feather River the geographically most proximate of these three potential donor stocks.

The Deer/Mill Creek population also has the lowest current abundance, with escapement estimates of about 3,389, 1,564, and 502 in 2006, 2007, and 2008, respectively. Butte Creek has a larger census population size, with current escapement estimates of 4,579, 4,943 and 3,935 in 2006, 2007, and 2008, respectively. However, these escapement estimates use different methodology (carcass counts vs. snorkel survey), so they are not directly comparable, and the Butte Creek estimates are likely more comprehensive than those for Deer/Mill Creek. Furthermore, it is important to note that, over the last 20 to 30 years the mean census size estimates of the two stocks have been similar, and both historical and current population sizes are important in determining levels of genetic variation.

Escapement estimates for the Feather River spring-run Chinook salmon populations are not complete, since the Feather River stock escapement estimates use a different methodology and only attempt to enumerate hatchery fish. The escapement estimates for the hatchery component only in 2006, 2007, and 2008, were 2,061, 2,674 and 1,418 fish, respectively. Since the non-counted, naturally spawning component of this stock is typically large, the census size of the Feather River stock is likely the largest of the three spring-run Chinook salmon stocks (DFG 2009).

There are three datasets available to evaluate the relative genetic diversity of the three potential spring-run Chinook salmon donor stocks for the San Joaquin River reintroduction project. The first of these is published in Banks et al. (2000) and consists of microsatellite data for the Deer/Mill Creek and Butte Creek stocks. While a substantial number of fish were sampled for this study, this dataset unfortunately does not include fish from the Feather River spring-run Chinook salmon stock. It also includes data from only a small number of microsatellite loci, with an average of only about seven loci per fish genotyped. As such, the two primary measures of genetic diversity are significantly affected by sampling variance. The first measure, observed heterozygosity, is essentially identical in the two stocks – 0.61 vs. 0.62 in the Deer/Mill and Butte Creek stocks, respectively). Allelic diversity, as measured by the average number of alleles observed per locus, is about 7 percent higher in the Deer/Mill Creek stock than in the Butte Creek stock (6.60 vs. 6.18 respectively). It is worth noting that, for microsatellite loci, the number of alleles is a more sensitive indicator of recent effective population size than heterozygosity (Garza and Williamson 2001), so these data are indicative of higher effective population size and consequent greater genetic diversity in Deer/Mill Creek than in Butte Creek spring-run Chinook salmon.

The second dataset available for evaluation is that of Garza et al. (2008) and consists of data for 20 microsatellite loci from Chinook salmon sampled in 2002 and 2003 throughout the Central Valley, including all three of the known, extant spring-run Chinook salmon ESU stocks. In this analysis, the Deer/Mill Creek spring-run Chinook salmon populations were considered separately and differences in the sample sizes for the different spring-run Chinook salmon stocks necessitated the use of allelic richness, a measure of the number of alleles that takes into account such differences (Petit et al. 1998). With this large microsatellite dataset, the mean allelic richness per locus of the Mill Creek, Deer Creek, Butte Creek, and Feather River stocks were 11.09, 10.85, 9.76 and 11.25, respectively. The observed heterozygosities were 0.77, 0.77, 0.74 and 0.78, respectively. It is worth noting that, aside from the Sacramento River winter-run Chinook salmon, the Butte Creek spring-run Chinook salmon stock had the lowest values of these two measures of genetic diversity of any Central Valley (or Klamath River) salmon population examined. It is also worth noting that, the Feather River spring-run Chinook salmon stock has been affected by hybridization with fall-run Chinook salmon, and at least some of the additional genetic diversity seen is likely due to the addition of fall-run Chinook salmon genes (Garza et al. 2008).

The third dataset consists of recent unpublished data from 169 SNP loci. These SNP loci were developed by the Genetic Analysis of Pacific Salmonids (GAPS) consortium and by the Molecular Ecology and Genetic Analysis Team of the Southwest Fisheries Science Center, (Garza unpublished). These loci were developed with the dual objectives of developing intergenerational genetic tags for parentage-based tagging (PBT) and as markers for genetic stock identification (GSI) in fishery and ecological investigations.

For these 169 SNP loci, data were available for the Deer/Mill Creek (N=71), Butte Creek (N=54), and Feather River (N=94) spring-run Chinook salmon stocks. Since SNP loci generally only have two alleles, smaller numbers of fish are necessary to estimate per-locus measures of genetic diversity for SNPs than for microsatellite loci. However, these SNP loci were discovered using a panel of fish that included Central Valley spring-run Chinook salmon, so ascertainment bias will affect measures of allelic diversity and they are expected to be less informative than the corresponding measures for microsatellites. This is because they represent the proportion of polymorphic loci, with the mean number of alleles equals two when all loci are polymorphic and equals one when all loci are monomorphic, but only SNPs that were variable in the Central Valley were included in this set of genetic markers. The SNP dataset found similar measures of the mean number of alleles, with 1.91, 1.88 and 1.91 in the Deer/Mill Creek, Butte Creek, and Feather River stocks, respectively. Observed heterozygosity was more variable, with values of 0.29, 0.26 and 0.31 in the Deer/Mill Creek, Butte Creek, and Feather River stocks, respectively.

In summary, all of the measures of genetic diversity in all of the datasets were the lowest for Butte Creek, intermediate for Deer/Mill Creek, and the highest for Feather River spring-run Chinook salmon. The effective population size of the Butte Creek spring-run Chinook salmon is, therefore, also the smallest of the three, since effective size determines the amount of genetic variation that is maintained in a population. The Butte Creek spring-run Chinook salmon stock then also has the highest risk of inbreeding in a reintroduction project. In contrast, the Feather River spring-run Chinook salmon stock has the highest genetic diversity of the three. However, this stock is known to have been affected by hybridization with fall-run Chinook salmon at the FRFH (Garza et al. 2008) and hybridization is ongoing (Kindopp pers. comm.). It is also likely that hybridization occurs in the spawning grounds of the lower Feather River. At least some of the additional genetic diversity seen in the Feather River stock is likely due to the addition of fall-run Chinook salmon genes. The Feather River spring-run Chinook salmon population is more genetically similar to fall-run Chinook salmon in the Feather River than to the spring-run Chinook salmon in the Deer/Mill Creek and Butte Creek populations, raising the potential for outbreeding depression during an introduction. This is unfavorable for the maintenance of phenotypic differentiation (i.e., spring-run Chinook salmon offspring returning as fall-run Chinook salmon); however, it also reduces the risk of inbreeding in a reintroduction project and the consequent reduction in fitness from inbreeding depression. Conversely, tagging studies have found that some offspring from Feather River spring-run Chinook salmon return as fall-run Chinook salmon, and vice versa (DFG 1998)

Another aspect of the genetic/demographic history of the three spring-run Chinook salmon stocks that needs to be considered is the relative influence of hatchery-produced fish on the naturally spawning stock. The FRFH, which began operation in 1967, has produced and released millions of juvenile salmon, both spring- and fall-run Chinook salmon, annually for more than 40 years. These fish have extensively introgressed with naturally spawning populations in the Feather River and elsewhere. In contrast, the Deer/Mill Creek and Butte Creek spring-run Chinook salmon stocks appear to be largely free of introgression from hatchery-produced fish. There is accumulating evidence that salmon from hatchery stocks are less fit than natural origin fish (Berejikian and Ford 2004, Myers et al. 2004), and that this is at least partly due to hatchery domestication selection, which often causes maladaptation to environmental conditions in natural areas. However, domestication selection from hatchery fish can be counteracted relatively quickly by crossing with natural origin fish and subsequent selection in natural areas (Quinn et al. 2000, Unwin et al. 2000), as long as the artificial selection is not coincident with a loss of genetic variation and an increase in inbreeding.

5.0 Lower San Joaquin River Existing Conditions

The Restoration Area, approximately 153 miles long, extends from Friant Dam at the upstream end near the town of Friant, downstream to the confluence of the Merced River, and includes an extensive flood control bypass system (Figure 5-1). The Restoration Area has been significantly altered by changes in land and water use over the past century.

Five river reaches have been defined to address the great variation in river characteristics throughout the Restoration Area. The reaches are differentiated by their geomorphology and resulting channel morphology, and by the infrastructure along the river. Hence, flow characteristics, geomorphology, and channel morphology are similar within each of the reaches. The characteristics of these Reaches are described in further detail in Chapter 2 of the FMP.

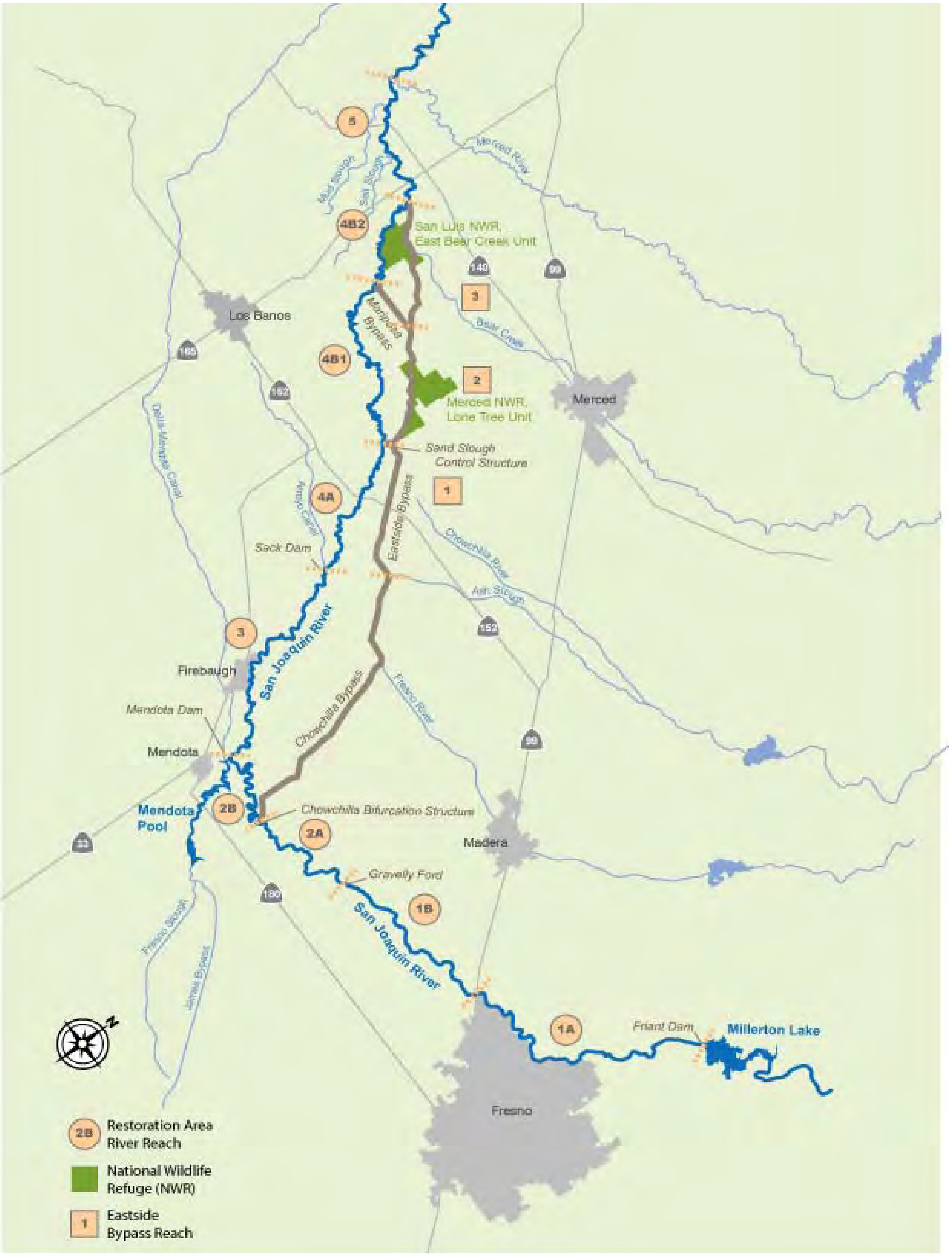


Figure 5-1.
San Joaquin River Restoration Area and the Defined River Reaches

6.0 Stock Comparison

6.1 Population Census

Impacts to the source population must be considered and evaluated before taking any fish for reintroduction. DFG maintains a database that contains estimates of Chinook adult returns. Table 6-1 only includes census information for the three candidate stocks, beginning in 1960. Monitoring techniques and adult census estimates have changed over the last 50 years; stocks are monitored differently now so direct comparisons are difficult, but the overall population trends can be viewed. It should also be noted that certain monitoring techniques, such as snorkel surveys or only relying on hatchery counts, may significantly underestimate the actual population size. In-river spawners may be of either hatchery or natural origin.

Table 6-1.
Population Census Size from the Three Candidate Stocks

	Mill/Deer Creeks		Butte Creek^	Feather River		Year	Mill/Deer Creeks		Butte Creek	Feather River	
	Mill*	Deer*		In River	Hatchery		Mill	Deer		In River	Hatchery
196	2,368		8,700			**1986**	291	543	1,371		1,433
196	1,245		3,082			**1987**	90	200	14		1,213
196	1,692		1,750			**1988**	572	371	1,290		6,833
196	1,315	2,302	6,100	600		**1989**[a]	563	84	1,300		5,078
196	1,539	2,874	600	2,908		**1990**	844	496	250		1,893
196			1,000	738		**1991**	319	479			4,303
196			80	297		**1992**	237	209	730		1,497
196			180		146	**1993**	61	259	650		4,672
196			280		208	**1994**	723	485	474		3,641
196			830		348	**1995**	320	1,295	7,500		5,414
197	1,500	2,000	285		235	**1996**	253	614	1,413		6,381
197	1,000	1,500	470		481	**1997**	202	466	635		3,653
197	500	400	150		256	**1998**	424	1,879	20,259		6,746
197	1,700	2,000	300		205	**1999**	560	1,591	3,679		3,731
197	1,500	3,500	150		198	**2000**	544	637	4,118		3,657
197	3,500	8,500	650		691	**2001**[aa]	1,100	1,622	9,605		4,135
197			46		699	**2002**	1,594	2,185	8,785		4,189
197	460	340	100		185	**2003**	1,426	2,759	4,398		8,662
197	925	1,200	128	2	202	**2004**	998	804	7,390		4,212
197			10		250	**2005**	1,150	2,239	10,625		1,771
198	500	1,500	226	400	269	**2006**	2,432	1,002	4,579		2,061
198			250	531	469	**2007**	644	920	4,943		2,674
198	700	1,500	534	90	1,910	**2008**	140	362	3,935		1,418
198		500	50		1,702						
198	191		23		1,562						
198	121	301	254		1,632						

Source: DFG 2009

Notes:

* For the CVPIA doubling period 1967-1991, the average spawning escapement of spring-run Chinook salmon in Deer Creek was 1,300 (USFWS 1995). From 1991 to present the average is 1,152.

** For the CVPIA doubling period 1967-1991, the average spawning escapement of spring-run Chinook salmon in Mill Creek was 800 (USFWS 1995). From 1991 to present the average is 646.

^ The Butte creek approximate population averages for the last thirty, twenty, and ten years are 3,000, 4,400, and 7,400, respectively.

[a] Surveys before 1989 used various methods with varying precision. For the non-Feather River populations, snorkel surveys implemented since 1989 are thought to significantly underestimate the actual population size and should only be used as an index. For the non-Feather River populations, Spawning surveys results for 2001 – 2006 were generated by a modified Schaefer Model carcass survey. Feather River Hatchery implemented a methodology change in 2005 for distinguishing spring-run from fall-run. Fish arriving prior to the spring-run spawning period were tagged and returned to the river. The spring-run escapement was the number of these tagged fish that subsequently returned to the hatchery during the spring-run spawning period.

[aa] Butte Creek number previously reported for 2001 (22,744) in error (Ward et al. 2004).

6.2 Life History/Phenotypic Characteristics

Source stock(s), which have behavioral and physiological characteristics that best fit conditions, expected to occur on the restored San Joaquin River have a higher likelihood for success. Table 6-2 summarizes the most frequently expressed life history characteristics.

Table 6-2.
General Life History Characteristics for the Three Candidate Stocks

Life History Characteristics	Feather River		Butte Creek		Deer/Mill Creeks	
Adult Run Timing	April – May		February – June, peaking in mid-April.		March – early July	
Spawning Timing	September		Late-September to early November, peaking in early October.		September	
Spawning adult age class structure*	Age 2	10.9%	Age 2	0%	Age 2	Unknown
	Age 3	46.9%	Age 3	53%	Age 3	Unknown
	Age 4	41.2%	Age 4	47%	Age 4	Unknown
	Age 5	0.68%	Age 5	0%	Age 5	Unknown
Sex Ratio**	1.2:1		1:1.18		Unknown	
Size Range (FL)	Females^ - 782 mm Males^ - 829 mm		Females*** - 762 mm. Males*** - 793 mm.		410 mm to 1002 cm with the majority 600-800 mm.	
Outmigration Timing (all three population show two primary life histories for young, fry emigrating within weeks of emergence and juveniles remaining in the river for roughly 1 year before emigrating)	Emergence: Nov. – Apr., peaking in Jan. Outmigration of yearlings: Unknown Outmigration of fry: Dec. – June, peaking Feb. to Apr.		Emergence: Nov. – Apr., peaking in Jan. Outmigration of yearlings to the Delta: Nov. – Apr. Initial outmigration of fry to Sutter Bypass – Nov. to Feb. Final outmigration of fry from Sutter Bypass to the Sac. River and Delta – Feb. to May.		Emergence: Nov. – Apr. peaking around Feb. Outmigration of yearlings: Oct. – Apr. Outmigration of fry: Feb. – June	
Straying Rate	High		Unknown		Unknown	

Notes:

* Feather River data is average percent by age of spring and fall spawning run returning to hatchery, 2000-2004. Butte Creek data based on tag recoveries in 2007, although age varied widely in the Butte Creek population. Age 3 fish were a much higher percentage in 2002, 2002, 2004, and 2005, and Age 4 were much higher in 2003 and 2006.

** Males:Females. Feather River data is averaged over 1997 through 2007. Butte Creek data averaged 2001-2006, from carcass surveys.

*** 2001-2007 Averages.

^ Based on 2006-2008 spring-run Chinook salmon broodstock. Personal communication from Ryon Kurth.

6.3 Environmental Conditions

It is presumed that Chinook salmon that currently experience selective pressures similar to that of the restored San Joaquin River will have a higher likelihood for success. Based on this evaluation, the Feather River and Butte Creek are more similar to the expected environmental conditions of the restored San Joaquin River than the Deer/Mill Creek Complex (Table 6-3). Further, Chinook in both Butte Creek and the Feather River experience higher water temperatures (Figures 6-1 and 6-2) than those in the Deer/Mill Creek Complex. Figure 6-1 provides temperatures for the highest elevation locations in Butte, Deer, and Mill creeks for which consistent temperature data was available over the period of interest. Figure 6-2 provides temperatures for the lowest elevation locations in Butte, Deer, and Mill creeks for which consistent temperature data was available over the period of interest. Both figures include FRFH water temperatures, and temperatures from the bottom of the LFC of the Feather River, where two-thirds of spring-run spawning takes place.

Table 6-3.
Population Census Size from the Three Candidate Stocks

Environment	Anticipated Restored San Joaquin River	Feather River	Butte Creek	Deer/Mill Creek
Elevation of holding	Approximately 300 feet	Approximately 200 feet	Approximately 931 feet	Approximately 5,000 feet
Temperature	Restoration flow water temperatures are unavailable at this time	See Figures 6-1 and 6-2	See Figures 6-1 and 6-2	See Figures 6-1 and 6-2
Hydrology	Highly regulated	Highly regulated	Highly regulated	

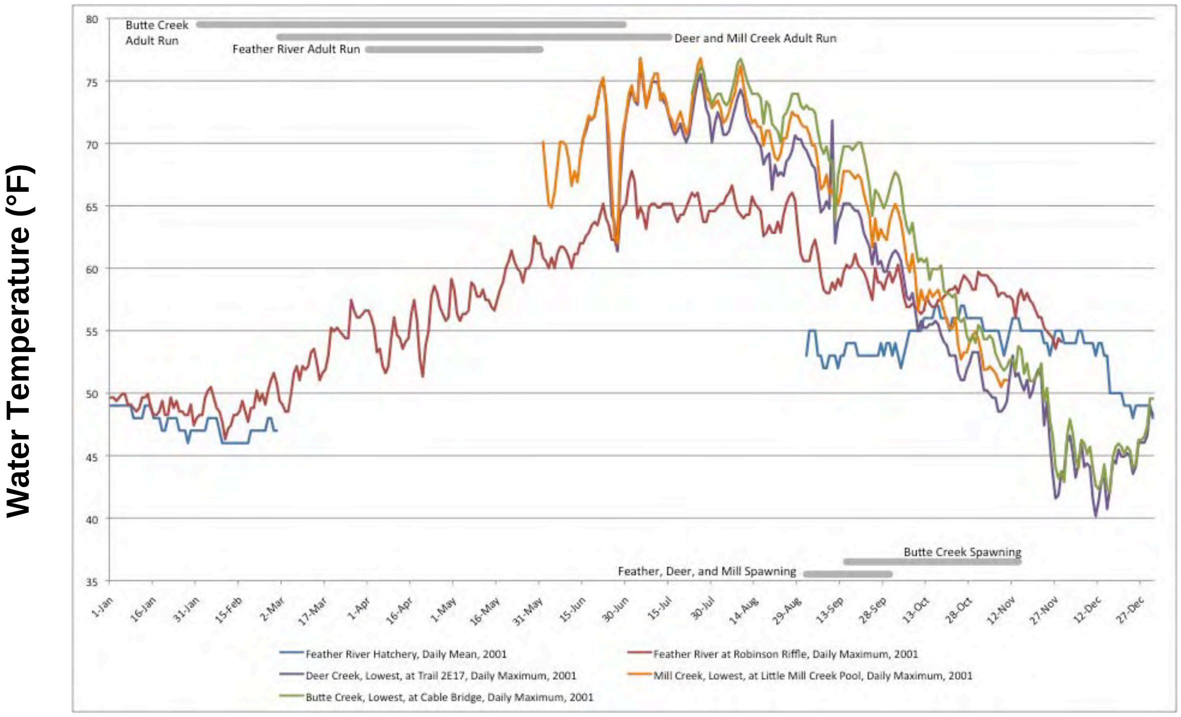


Figure 6-1.
Lower Elevation Water Temperature (°F) for Butte, Mill and Deer Creeks, Feather River, and Feather River Hatchery

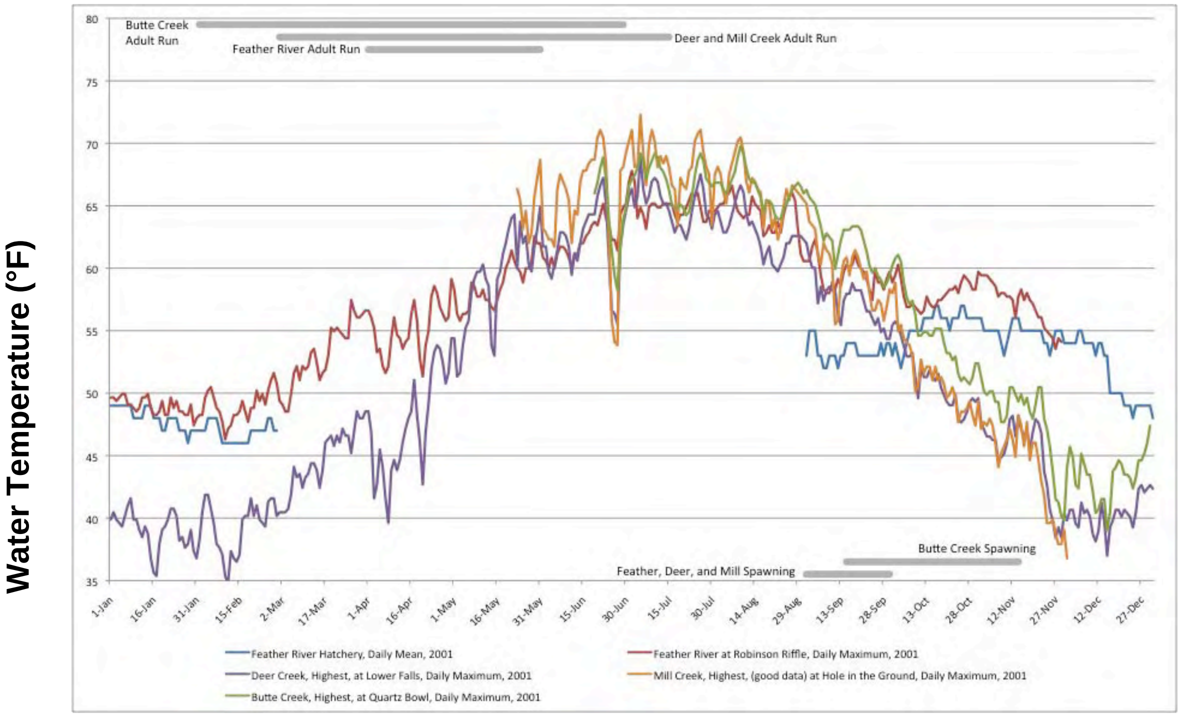


Figure 6-2.
Higher Elevation Water Temperature (°F) for Butte, Mill, and Deer Creeks, Feather River, and Feather River Hatchery

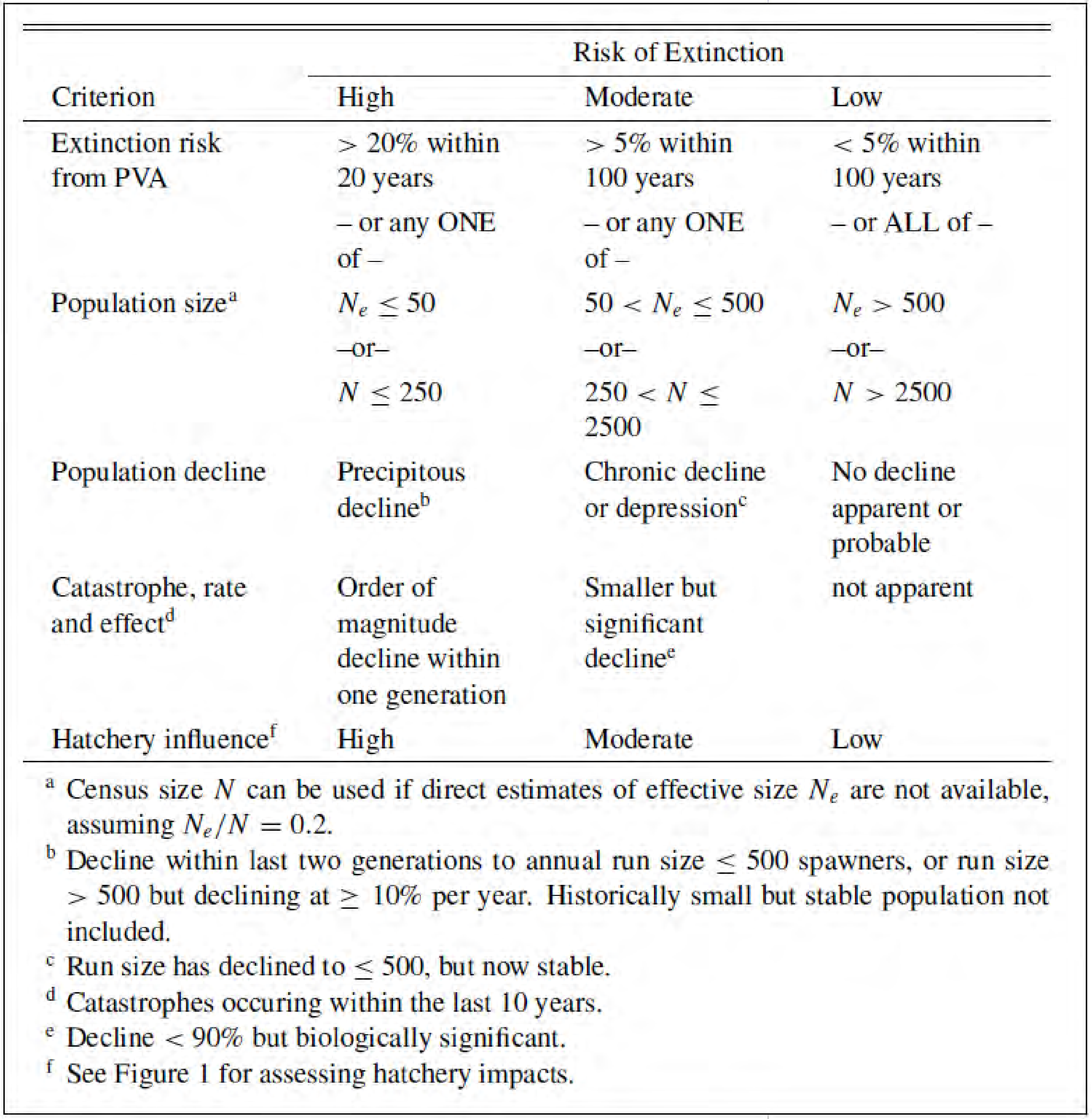
6.4 Population Genetics

Table 6-4 below summarizes the Population Genetic discussion from Chapter 4. The Population Viability Classification is from Lindley et al. (2004), where Chinook populations were classified as independent or dependent. Lindley et al. (2004) used McElhany el al (2000) independent definition: *An independent population is any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year period is not substantially altered by exchanges of individuals with other populations*. The Risk of Extinction comes from Lindley et al. (2007) where five quantitative criteria (Figure 6-3) were analyzed to determine the population's risk of extinction.

Table 6-4.
Genetic Characteristic Comparison

Genetics	Desired Restored San Joaquin River	Feather River	Butte Creek	Deer/Mill Creek
Effective Population Size	Large	Highest	Lowest	Moderate
Hatchery Influence	Little to none	High	None	None
Genetic Diversity	High	Highest	Lowest	Moderate
Natural Origin Spawners	High	Moderate	High	High
Population Viability Classification (Lindley et al. 2004)	Independent	Dependent	Independent	Independent
Risk of Extinction (Lindley et al. 2007)	Low	Data Deficient*	Low	Low – Moderate

Note:
* Insufficient data is available to assess status (Lindley et al. 2007).



	Risk of Extinction		
Criterion	High	Moderate	Low
Extinction risk from PVA	$> 20\%$ within 20 years – or any ONE of –	$> 5\%$ within 100 years – or any ONE of –	$< 5\%$ within 100 years – or ALL of –
Population size[a]	$N_e \leq 50$ –or– $N \leq 250$	$50 < N_e \leq 500$ –or– $250 < N \leq 2500$	$N_e > 500$ –or– $N > 2500$
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe, rate and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[e]	not apparent
Hatchery influence[f]	High	Moderate	Low

[a] Census size N can be used if direct estimates of effective size N_e are not available, assuming $N_e/N = 0.2$.

[b] Decline within last two generations to annual run size ≤ 500 spawners, or run size > 500 but declining at $\geq 10\%$ per year. Historically small but stable population not included.

[c] Run size has declined to ≤ 500, but now stable.

[d] Catastrophes occuring within the last 10 years.

[e] Decline $< 90\%$ but biologically significant.

[f] See Figure 1 for assessing hatchery impacts.

Source: Lindley et al. 2007

Figure 6-3.
Taken from Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin River Basin

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7.0 Assessment and Prediction of Stock Success for Restoration

7.1 Feather River

The observed introgression between the two (fall- and spring-run Chinook salmon) ESUs in the Feather River poses unique challenges for broodstock selection from this system. While the extent of this effect in unclear, these factors have the capability of reducing reproductive fitness and may influence the efficacy of recolonization. Research increasingly indicates that hatchery-reared anadromous salmonids exhibit reduced reproductive fitness compared to wild fish. This effect has been found to increase with each subsequent hatchery-reared generation (Araki et al. 2007) and may persist over multiple generations after return to the wild (Araki et al. 2009). Introgression has also influenced run timing, where some spring-run Chinook salmon express the fall-run Chinook salmon phenotype and vice versa. If these spring-run Chinook salmon are reintroduced into the Restoration Area there is a likelihood that a subset of fish, and/or their progeny, will return in the fall and mate with fall-run Chinook salmon. The use of Feather River fish may bring the introgression problems into the San Joaquin River; however, a separation weir and multi-run management plan may reduce these impacts. Nonetheless, the effect of introgression with fall-run Chinook salmon enriches the phenotypic diversity of adult fish in the Feather River. This effect has been observed in the fall-run Chinook salmon population where known fall-running fish have been observed returning in the spring (Kindopp pers. comm.). The introgression necessitates genetic methods to discriminate the run-origin of individuals, as phenotypic distinction between these two runs is unreliable. These factors have prompted the Technical Advisory Committee of the SJRRP to recommend against the use of the FRFH stock or any other hatchery origin stock for use in reintroduction (Meade 2007). The negative aspects of using broodstock from the FRFH, however, should also be weighed alongside the potential benefits of (1) possibly recovering a phenotypically spring-run Chinook salmon-type fish from FRFH, (2) the potential for distinct run timings to emerge when discrete spawning habitats are available, and (3) the potential to minimize impacts to natural spring-run Chinook salmon broodstock source populations.

In spite of these negative factors, several other characteristics of the Feather River stock may prove beneficial for reintroduction. Of the three major candidate stocks (Feather River, Butte Creek, and Deer/Mill Creek Complex), the Feather River stock historically had the largest population size and greater extent of habitat, and exhibits the most genetic diversity. While introgression has certainly influenced the breadth of genetic diversity, the Feather River stock may possess remnant alleles from the four presumably independent populations that once existed in the four Feather River tributaries above Oroville Dam. In addition, Lindley et al. (2004) indicated that of all 18 historic independent populations of spring-run Chinook salmon in the Central Valley ESU, the historic environmental conditions in the Feather River most resembled historic conditions in the San Joaquin River. In addition, over the past 40+ years, the presence of Oroville Dam has most certainly exerted significant selection pressure on the existing stock due to the dam's effects on temperature, distance and elevation of holding and spawning areas, loss of the natural flow regime, impact to aquatic biodiversity and distribution, and impact to habitat composition and quality (Bunn and Arthington 2002, Angilleta et al. 2008). This selection pressure could potentially benefit the Feather River stock, which would experience similar conditions in the Restoration Area.

The importance of ease of accessing the Feather River stock must also be considered. Multiple life stages of wild and hatchery fish are readily accessible from the hatchery, existing screw traps and easily accessible and seinable beaches. This is crucial for capturing enough unrelated individuals to provide the sufficient genetic diversity required to initiate a progenitor population with a reasonable effective population size. Therefore, the positive and negative consequences of selecting FRFH Chinook salmon to serve as broodstock should be given thorough and careful consideration.

7.2 Deer and Mill Creeks

Risks include lower survival potential in the San Joaquin drainage due to local adaptation to higher elevation holding areas and cooler stream temperatures. Currently these stocks have adapted growth rates to cold water and a larger proportion of them stay in their natal watersheds until emigrating as yearlings due to suitable temperatures. There are also risks to the parent stocks from collection for the Restoration effort on the San Joaquin. Population sizes in the past few years on these Sacramento River tributaries have been very low, and the populations may not support our harvest of adult individuals for the San Joaquin. Benefits of using these stocks for the San Joaquin are that the stocks are untouched by hatchery influence to this point so have not experienced any decreased fitness due to hatchery practices. All the available holding habitat in the Restoration Area is in low-elevation areas, and these stocks are accustomed to holding in high-elevation bedrock reaches in Deer and Mill creeks.

For the past 2 years, the Deer/Mill Creek adult escapement estimates have been below the 250 threshold that puts them at a high risk of extinction (Lindley et al. 2007). Through the reintroduction period for the SJRRP (2012 to 2017), it is expected that the population will not even reach a moderate risk of extinction. (Harvey-Arrison pers comm). The risks to the existing populations may be too great to allow for collection of these fish during the reintroduction period.

7.3 Butte Creek

The Butte Creek spring-run Chinook salmon stock has several characteristics that would be beneficial for reintroduction into the upper San Joaquin River. The stock is a genetically distinct Central Valley spring-run Chinook salmon (Lindley et al. 2004). The Butte Creek population is not dependent on nor is stocked with hatchery fish, which have lower reproductive fitness than wild fish (Araki et al. 2009), and the population is considered sustaining, persistent, and viable. Out of the three major spring-run Chinook salmon stocks under consideration, Butte Creek has had the largest census size for the last 9 out of 10 years (DFG 2009). The high pre-spawn mortalities experienced during years of high returns may indicate a density-dependent mortality (Williams 2006) and, based on the estimated available spawning habitat, Butte Creek may not have enough suitable habitat for the number of adult returns in those years. Therefore, taking fish from this population in years with high returns, as seen in 2002 and 2003, may have little impact on the population.

Genetically, the spring-run Chinook salmon from Butte Creek are “true” spring-run Chinook salmon, but have the lowest genetic diversity out of the three major source populations under consideration (Garza et al. 2008). This may increase the risk of inbreeding depression in the reintroduced population if only Butte Creek fish are used for reintroduction. The lower diversity also indicates that Butte Creek may have the lowest effective population size of the three stocks under consideration. Having a large census size in combination with a lower effective population size indicates that there is a lower risk of removing unique individuals from the source population. Therefore, having the lowest diversity out of the three stocks under consideration may be a benefit since genetic impacts to the source population must be considered.

In addition, the salmon in Butte Creek experience selective pressures that may be similar to those of the restored upper San Joaquin River. These include: (1) low elevation of holding and spawning habitats, (2) highly regulated hydrology, (3) warmer water temperatures, and (4) high air temperatures during the summer months. In addition, collection of all life stages for the purposes of reintroduction may be accomplished.

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8.0 Recommendations

The Genetics Subgroup considered a number of types of data comparisons and potential scoring and ranking systems to prioritize the three potential source stocks. In addition, the Genetics Subgroup took into consideration the Technical Advisory Committee's recommendations on restoring spring-run Chinook salmon in developing this analysis. During these discussions, the Genetics Subgroup debated stock selection criteria to be used, scoring/ranking systems, and the reliability of these methods. It was noted that there is a dearth of information and data that could be used in a predictive framework, as was a set of somewhat contradictory indicators of status. It was also noted that scoring/ranking systems are inherently bias, and may give us a number that in the end means very little. As a consequence, the Genetics Subgroup spent a significant amount of time evaluating an experimental multiple-stock reintroduction strategy.

8.1 Preferred Recommendation

Following several discussions, the majority, if not all, of the Genetic Subgroup members concurred that it would be nearly impossible to accurately predict the likelihood of success of the three spring-run Chinook salmon stocks in a San Joaquin River reintroduction project. There is a large amount of genetic data available to evaluate the genetic status of the different stocks, but even if more data were collected, genetic and otherwise, the consensus was that prospects for predicting fitness and success of the stocks would not improve.

Each of the three remaining spring-run Chinook salmon lineages has biological characteristics that might be favorable for a successful reintroduction project and each also has unfavorable characteristics. Spring-run Chinook salmon vary in a number of important traits like distinctive use of diverse aquatic habitats, timing of spawning migration and breeding, and natal fidelity. There is likely significant potential for evolution of traits to occur as a result of the strong, novel selective pressures being placed on the fish in the upper San Joaquin River. We suggest that a simultaneous multiple stock reintroduction experiment be pursued as an adaptive management program. Genetic evaluation and other methods would be used to evaluate the relative fitness and success of fish from the different stocks at various life stages following the reintroduction.

The multi-stock approach would include all available Central Valley spring-run Chinook salmon stocks, including the Feather River stock. There has been much debate on the use of Feather River fish for the reintroduction efforts. Spring-run Chinook salmon from the Feather River are introgressed with fall-run Chinook salmon, and are "clustered" with fall-run Chinook salmon in population clustering analyses (refer to Section 4.0). However, the Feather River spring-run Chinook salmon stock retains valuable genetic and phenotypic diversity worth conserving (refer to Section 4.0 and 7.1). Therefore, our preferred recommendation would be to reintroduce spring-run Chinook salmon from all three potential source populations, the two independent populations of Central Valley spring-run Chinook salmon from Deer/Mill Creek Complex and Butte Creek, and the Feather River population.

- Benefits: increase in overall genetic diversity and reduction in inbreeding levels, program flexibility, and availability of diverse reintroduction methods.
- Risks: outbreeding depression, fall-run Chinook salmon phenotype being expressed, monitoring the independent success of each source population's establishment in the Restoration Area would be an added challenge due to the high likelihood of introgression.

The Genetics Subgroup will work diligently to determine a range of appropriate collection, reintroduction, and monitoring strategies. These will be carefully evaluated to determine availability of source stocks at various life stages. It is currently unknown what criteria and population thresholds the regulatory fisheries agencies (NOAA and DFG) will use to determine if the program is able to mine fish from the three source populations and the number of fish that may be taken. If it is determined that the risks to the source stock(s) is too high, it is likely the SJRRP will limit the source stock to the use of two stocks, or in the worst case scenario, one stock, since spring-run Chinook salmon must be reintroduced by December 31, 2012.

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Exhibit E

Ecological Goals of the Restoration Flows

Fisheries Management Plan:
A Framework for Adaptive Management in the San Joaquin River Restoration Program

SAN JOAQUIN RIVER
RESTORATION PROGRAM

November 2010

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Abbreviations and Acronyms

cfs	cubic feet per second
cm/day	centimeters per day
Fall Period	Restoration Flow releases allocated during the period from October 1 through November 30
FMWG	Fisheries Management Work Group
Settlement	Stipulation of Settlement
SJRRP	San Joaquin River Restoration Program
Spring Period	Restoration Flows depicted in each flow schedule from March 1 through May 1

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1.0 Introduction

The Stipulation of Settlement (Settlement) (NRDC vs. Rodgers 2006) provides a specified Restoration Flow schedule. This document provides an overview of the water year types and flow schedule components, and describes the ecological goals (i.e., intent) of each seasonal flow schedule component.

The information presented here is a summary of the ecological goals of the Restoration Flow schedule as developed and documented during the Settlement process. The ecological goals described herein are therefore based entirely on the testimony given by several expert witnesses during pre-Settlement hearings in 2005, before the Settlement and implementation of the San Joaquin River Restoration Program (SJRRP). As part of the SJRRP, the Fisheries Management Work Group (FMWG) recently developed conceptual models for spring-run and fall-run Chinook salmon (Exhibit A) that include hypothesized life-history traits, habitat requirements, and limiting factors of reintroduced Chinook salmon populations. The conceptual models assume the Restoration Flow schedules will be implemented, and thus incorporate assumptions related to the ecological effects of the Restoration Flows on reintroduced salmon and their habitat in the San Joaquin River from Friant Dam to the Merced River confluence. However, neither the conceptual models nor this document address potential differences between the hypothesized effects of the Restoration Flows on reintroduced Chinook salmon and the pre-Settlement ecological goals of the Restoration Flows. For an assessment of the FMWG's understanding of the application of the Restoration Flow schedules, the reader is referred to Exhibit A.

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2.0 Restoration Flow Schedule

The Restoration Flow schedule identified in Exhibit B of the Settlement consists of a set of six flow schedules (Figure E-1) that vary in magnitude and volume according to the annual unimpaired runoff of the San Joaquin River at Friant Dam for a water year (October 1 through September 30).

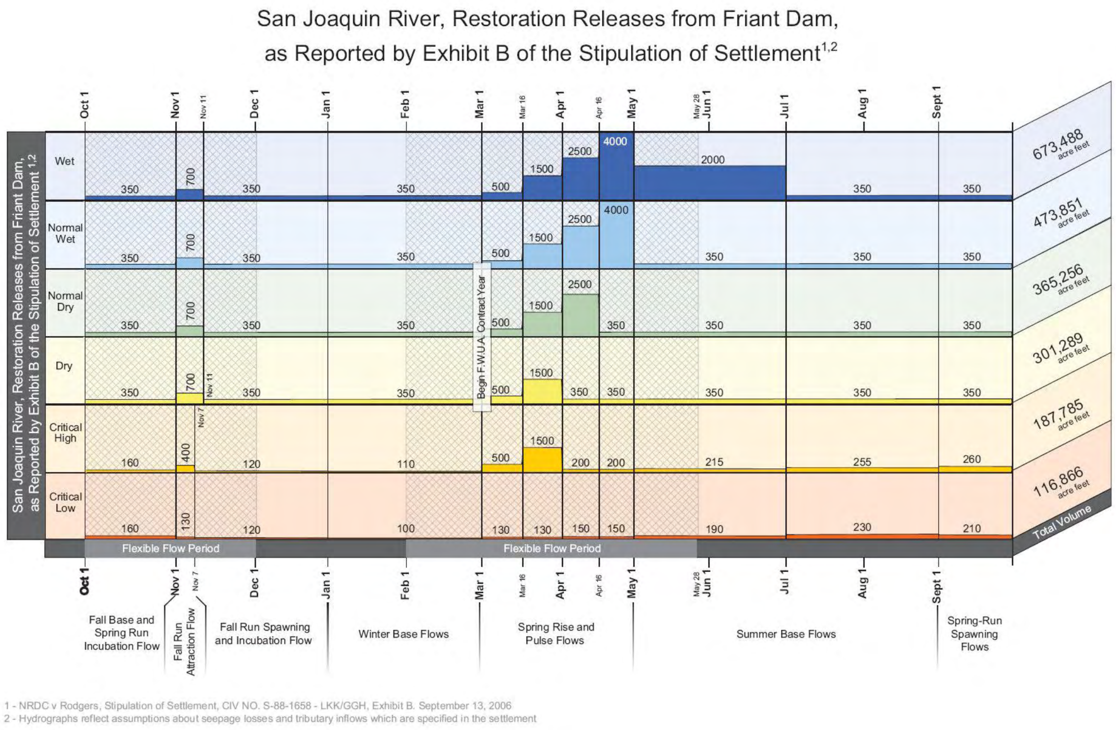

Figure E-1.
Restoration Flow Schedule

Exhibit B, Paragraph 3 of the Settlement requires that the stair-step flow schedules be transformed (i.e., “smoothed”) to continuous line flow schedules before December 31, 2008, before the initiation of Interim and Restoration flows. For additional information related to the transformation of the stair-step flow schedules, including the recommended approach, the reader is referred to the Program Environmental Impact Statement/Report.

2.1 Water Year Types

The six year types (referred to as Restoration Flow year types) are “Critical-Low,” “Critical-High,” “Dry,” “Normal-Dry,” “Normal-Wet,” and “Wet.” Based on the historical record of unimpaired flow for water years 1922 through 2004, Exhibit B of the Settlement includes a Restoration year type classification system based on percentage of occurrence in this 83-year period (Table E-1). The wettest 20 percent of these years are classified as "Wet." In order of descending wetness, the next 30 percent of the years are classified as "Normal-Wet," the next 30 percent of the years are classified as "Normal-Dry," and the next 15 percent of the years are classified as "Dry." The remaining 5 percent of the years are classified as "critical." A subset of the critical years, those with less than 400 thousand acre-feet (TAF) of unimpaired runoff, are classified as "Critical-Low"; the remaining critical years are classified as "Critical-High."

Table E-1.
Frequency of Occurrence of Water Year Types

Water Year Type	Frequency (%)
Wet	20
Normal-Wet	30
Normal-Dry	30
Dry	15
Critical-High	4
Critical-Low	1

2.2 Seasonal Flow Schedule Components

Components of the flow schedule are defined for each water year type, with flows in specified amounts throughout the year corresponding to key seasonal life-history requirements of salmon and other ecosystem components (Table E-2). Some of the seasonal flow components vary in amount and duration depending upon water year type classification. The ecological goals of the seasonal flow schedule components are described in subsequent sections of this Exhibit.

Table E-2.
Seasonal Flow Schedule Components

Component	Time Period
Fall Base and Spring-Run Incubation Flow	October 1 to November 1
Fall-Run Attraction Flow	November 1 to 11 (to Nov. 7 in critical years)
Fall-Run Spawning and Incubation Flow	November 11 to January 1
Winter Base Flows	January 1 to March 1
Spring Rise and Pulse Flows	March 1 to May 1
Summer Base Flows	May 1 to September 1
Spring-Run Spawning Flows	September 1 to October 1

2.2.1 Flexible Flow Periods

The Restoration Flow schedule includes two “flexible flow periods,” one in the fall and one in the spring, intended to allow flexibility with regard to the timing, magnitude, and ramping rates of flows released from Friant Dam. The flexible flow periods coincide with the timing of critical life history stages of Chinook salmon and other native fishes, with the intent of providing sufficient flow management flexibility to meet fish habitat requirements (e.g., suitable water temperature, floodplain inundation) in response to real-time river conditions and species responses. Restoration Flow releases allocated during the period from October 1 through November 30 (the “Fall Period”) in any year may be shifted up to 4 weeks earlier or later than what is depicted in the flow schedule for that year, and managed flexibly within that range, as long as the total volume of Restoration Flows allocated for the Fall Period is not changed. Similarly, the Restoration Flows depicted in each flow schedule from March 1 through May 1 (the “Spring Period”) may be shifted up to 4 weeks earlier or later as long as the total volume of Restoration Flows allocated during the spring flexible flow period (February 1 through May 28) is not changed (Settlement, Exhibit B, paragraph 4[b]).

2.2.2 Buffer Flows

The daily flows provided under the Restoration Flow schedule, or as modified by the application of flexible flows, may also be augmented by the application of Buffer Flows consisting of up to 10 percent of the daily flows. Buffer Flows from October 1 through December 31 are defined in the Settlement (Paragraph 4[c]) as 10 percent of the total volume of base flows during that period. These buffer flows may be managed flexibly as a block of water during the Fall Period, as described above and in Paragraph 4(b) of the Settlement. Up to 50 percent of the Buffer Flows available from May 1 through September 30, not to exceed 5 TAF, may be moved to augment flows during the Spring or Fall periods.

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3.0 Ecological Goals

The Restoration Flows are intended to meet a suite of ecological goals that will be instrumental in achieving the Restoration Goal. The ecological goals include providing: (1) conditions suitable to meet the requirements of each Chinook salmon life stage, (2) conditions suitable for native fishes and warm water game fishes, (2) sufficient water to periodically perform geomorphic functions, including mobilization (i.e., flushing) of salmonid spawning gravels, and (4) sufficient water for recruitment and maintenance of native riparian vegetation. Except during critically dry years (5 percent of years), the flow schedules were designed to provide continuous flow from Friant Dam to the Merced River at all times of year to achieve these goals.

The ecological goals of the Restoration Flows were defined and described during the Settlement process, and relied in large part on the testimony of several expert witnesses. The following description of the ecological goals is based on a review and summary of these testimonies, as cited throughout this section.

3.1 Chinook Salmon Life Stage Needs

The Restoration Flow schedules are intended to provide suitable conditions for each phase of the Chinook salmon life history, including: adult migration for spring- and fall-run Chinook salmon, adult holding for spring-run, spawning and incubation, juvenile rearing, and outmigration of juveniles. The primary focus in Reach 1 is Chinook salmon but the conditions will also foster a diverse assemblage of native fishes. Reach 1A is expected to provide suitable conditions for all life stages of spring-run Chinook salmon because of cold water dam releases, the presence of deep pools for adult holding habitat, and extensive riffles and runs for spawning and rearing of juvenile fish. In Reach 1B, the water will usually be too warm in summer to support rearing spring-run Chinook salmon, but it could be managed for early season (i.e., spring) rearing by juvenile spring-run and fall-run Chinook salmon.

Adult Chinook salmon migration requires continuous flow to the Merced River confluence and suitable water temperatures. Holding for adult spring-run Chinook salmon requires suitable water temperatures in Reach 1A. Spawning and incubation requires suitable water temperatures and adequate depths and velocities over spawning gravels in Reach 1. Juvenile rearing requires suitable water temperatures and inundated floodplains. Outmigration of juvenile Chinook salmon requires continuous flow to the Merced River confluence and cool water temperatures during the spring and early summer periods (Moyle 2005 (p. 27–43), Kondolf 2005 (p. 14–15)).

The Restoration Flow schedules were designed to take into account the interactions of temperature and flow (as modeled by Dr. Deas) so that flows for salmonids and other fishes are provided only if they create suitable temperature conditions for the life-history stages present (Moyle 2005 (p. 47), Deas 2005 (p. 27)).

The FMWG developed conceptual models for spring-run and fall-run Chinook salmon (Exhibit A) to lay the foundation for the Fisheries Management Plan. The conceptual models assume all restoration actions prescribed in the Settlement, including the flow schedules will be implemented. For an assessment of the FMWG's understanding of the application of the restoration flow schedules, the reader is referred to Exhibit A.

3.2 Support a Diverse Fish Assemblage

Reach 1 is expected to provide suitable conditions for native fishes. In Reach 2, flows are intended to provide connectivity to downstream and upstream reaches (for fish movement), to maintain native fishes, and to establish complex habitats generated by riparian vegetation and other factors (Moyle 2005 (p. 46)). Presumed members of the native fish assemblage expected to be present in Reaches 1 and 2 would include Kern brook lamprey, lamprey, Sacramento hitch, Sacramento blackfish, hardhead, Sacramento pikeminnow, Sacramento sucker, rainbow trout, tule perch, threespine stickleback, prickly sculpin and riffle sculpin. Reaches 3 through 5 will be dominated by nonnative fishes, such as various basses, sunfishes, and catfishes (Moyle 2005 (p. 24, 46)).

3.3 Geomorphic Processes

In Normal-Wet and Wet years, the flow schedule include a block of water averaging 4,000 cubic feet per second (cfs) from April 16 through April 30 to perform several functions, including but not limited to geomorphic functions such as flushing spawning gravels ("The Flushing Flows"). The Settlement states that the Flushing Flows will include a peak release as close to 8,000 cfs as possible for several hours and then recede (i.e., ramp down) at an appropriate rate. The primary goal of the Flushing Flows is to mobilize spawning gravels, reduce armoring, and flush fine sediments (Settlement, Exhibit B, paragraph 5).

By mobilizing gravels and flushing fine sediment, the Flushing Flows are expected to maintain suitable gravel quality for successful spawning and incubation by Chinook salmon. Gravel should be movable by female Chinook salmon, have a loose texture, and be free of sediment so eggs receive adequate intragravel flow and dissolved oxygen (Kondolf 2005 (p. 15)). Flows to mobilize spawning gravel are commonly considered to be needed approximately every 2 years on average (Kondolf and Wilcock 1996, Kondolf 1998, cited in Kondolf 2005 (p. 16)).

3.4 Riparian Vegetation Recruitment and Maintenance

The Settlement states that in Wet years, in coordination with the peak Flushing Flow releases, Restoration Flows should be gradually ramped down over a 60- to 90-day period to promote the establishment of riparian vegetation at appropriate elevations in the channel (Settlement, Exhibit B, paragraph 6). The flow schedules were therefore designed to establish and maintain native riparian tree species along all reaches (Kondolf 2005 (p. 17)).

Riparian vegetation, particularly large woody species such as Fremont cottonwoods that grow along the river banks, provides essential functions for numerous aquatic species including native and nonnative fish. Riparian trees and other riparian vegetation shade the channel and help maintain cooler water temperatures during the spring and summer months, create and maintain channel complexity, cycle nutrients, and provide food and cover for a variety of aquatic species. As large trees fall into the channel, they create hydraulic conditions that scour the bed, cause deposition of gravel, and create sheltered backwater areas important for juvenile salmonid rearing. Wood-sheltered areas of the stream margin may retain cooler groundwater and thereby serve as cold water refugia for adult and juvenile salmon (Keller and Swanson 1979, cited in Kondolf 2005 (p. 17)).

Recruitment and maintenance of cottonwood trees requires spring flows for seedbed preparation and seedling establishment, and summer flows for vegetation maintenance. Seedbed preparation requires pulses of high discharge for scouring bed and gravel bar surfaces, and for deposition of sands and silts on bars and floodplains, to produce patches of mineral soil suitable for seedling establishment (Kondolf 2005 (p. 22)). Seedling establishment requires relatively high flows during the spring germination period so that seedlings establish on surfaces high enough relative to the channel so that seedlings are not scoured or killed by prolonged inundation. Seedlings also require gradual recession of the spring flow schedule during and after the seed germination period so the growth of the newly established roots can keep pace with the declining water table well into the summer months (Kondolf 2005 (p. 17, 18)). The recession limb associated with cottonwood establishment should also create conditions suitable for other tree species such as black willow and narrow leaf willow (Kondolf 2005 (p. 18)). A flow suitable for riparian recruitment every 5 to 10 years (Wet years only) should be sufficient to ensure regeneration of a riparian forest (Kondolf 2005 (p. 17)). Spring Pulse Flows on the order of 1,500 to 4,000 cfs are needed in Dry, Normal-Dry and Normal-Wet years to scour encroaching seedlings or impede seedling establishment in the low-flow channel to maintain channel conditions (Kondolf 2005 (p. 24)). Mature trees require sufficient Summer Base Flows to provide adequate moisture (Kondolf 2005 (p. 18)). In critically dry years, one or more pulses of water should be released to flood-irrigate the riparian plants, increasing their survival rate during the period of desiccation (Kondolf 2005 (p. 25)).

3.5 Seasonal Flow Schedule Components

The ecological goals of each distinct seasonal flow schedule component (Figure E-1, Table E-2) are described below. The descriptions begin with the Fall Base and Spring-Run Incubation Flow, starting on October 1, to correspond with the beginning of the water year and the flow schedule depicted in Figure E-1.

3.5.1 Fall Base and Spring-Run Incubation Flow

The Fall Base and Spring-Run Incubation Flow maintains 350 cfs during October, except in critical years (Table E-3). In Critical-Low and Critical-High years, flows decrease to 160 from the Spring-Run Spawning flows (described in later text).

Table E-3.
Dates and Discharge of Fall Base and Spring-Run Incubation Flows

Date	Water Year Type and Discharge (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
10/1–10/31	160	160	350	350	350	350

Key: cfs = cubic feet per second

Ecological goals of the Fall Base and Spring-Run Incubation Flow include the following:

- Provide conditions suitable for spring-run Chinook salmon incubation in Reach 1
- Provide flows to maintain a diverse community of native fishes in Reaches 1 and 2

Fish Goals

The Fall Base and Spring-Run Incubation Flow schedule was designed to provide suitable water temperatures for spring-run Chinook salmon incubation and rearing in Reach 1. Fall Base Flows also provide general habitat for resident native fishes in Reaches 1 and 2 (Moyle 2005 (p. 47)). In all but critical years, Fall and Winter Base Flows are set at the level prevailing during spring-run Chinook salmon spawning in September, to prevent stranding and dewatering of their redds (Kondolf 2005 (p. 20)).

3.5.2 Fall-Run Attraction Flow

The Fall-Run Attraction Flow is a short increase in flow from the Fall Base and Spring-Run Incubation Flow in all years except Critical-Low years, in which flows are decreased (Table E-4). The duration of the Fall-Run Attraction Flow is 7 days in Critical-Low and Critical-High water years and 10 days in wetter water years.

Table E-4.
Dates and Discharge of Fall-Run Attraction Flows

Date	Water Year Type and Discharge (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
11/1–11/6	130	400	700	700	700	700
11/7–11/10	n/a	n/a	700	700	700	700

Key: cfs = cubic feet per second

Ecological goals of the Fall-Run Attraction Flow include the following:

- Provide conditions suitable for adult fall-run Chinook salmon migration
- Provide conditions suitable to stimulate emigration of juvenile spring-run Chinook salmon

Fish Goals

The Fall-Run Attraction Flow schedule was designed to provide suitable water temperatures for adult fall-run Chinook salmon spawning. After accounting for seepage losses, this flow is expected to provide a 400 to 500 cfs pulse flow at the mouth of the Merced River for 10 days during all but critical years and for 6 days in Critical-Low and Critical-High years, including 2 days for ramping up and down at each end. The pulse is designed to bring adult fall-run Chinook salmon upstream to spawn (USFWS 1994, cited in Kondolf 2005 (p. 15, 19–20); Moyle 2005 (p. 47)). The Fall-Run Attraction Flow occurs during the fall flexible flow period and the exact time of the pulse would be based on monitoring for the presence of fall-run Chinook salmon at the Merced River confluence, timing of fall run Chinook salmon entering the tributaries to the San Joaquin River and coordination with any pulse flows being released from these tributaries. The length of the release is based in part on estimated travel times of adult Chinook salmon to the potential spawning area in Reach 1 (3 to 7 days). This pulse should also enable some spring-run Chinook salmon fry to emigrate (as in Butte Creek) (Moyle 2005 (p. 47)).

3.5.3 Fall-Run Spawning and Incubation Flow

The Fall-Run Spawning and Incubation Flow begins on November 7 in Critical-Low and Critical-High water years, and on November 11 in wetter water years. The Fall-Run Spawning and Incubation Flow ramps down from the Fall-Run Attraction Flow to achieve the Fall Base Flow of 350 cfs, except in critical years, in which flows are further decreased (Table E-5).

Table E-5.
Dates and Discharge of Fall-Run Spawning and Incubation Flows

Date	Water Year Type and Discharge (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
11/7–11/10	120	120	n/a	n/a	n/a	n/a
11/11–12/31	120	120	350	350	350	350

Key: cfs = cubic feet per second

Ecological goals of the Fall-Run Spawning and Incubation Flow include the following:

- Provide conditions suitable for fall-run Chinook salmon spawning and incubation in Reach 1
- Provide conditions suitable to stimulate emigration of juvenile spring-run Chinook salmon

Fish Goals

Fall-Run Spawning and Incubation Flow schedule was designed to provide suitable water temperatures for fall-run Chinook salmon egg incubation. Releases of 350 cfs from Friant Dam, which should assure a minimum flow of 150 cfs throughout the river, would allow for continued upstream migration of adult fall-run Chinook salmon (Fry and Hughes 1958, USFWS 1994, Kondolf 2000, McBain and Trush 2002, Cain et al. 2003; all as cited in Kondolf 2005 (p. 20)). A base flow of 350 cfs is also needed to maintain wetted spawning habitat in Reach 1 (i.e., flow over redds) (Moyle 2005 (p. 48)).

3.5.4 Winter Base Flow

The Winter Base Flow maintains the Fall Run Spawning and Incubation Flow of 350 cfs for the months of January and February, except in critical years in which flows are further decreased (Table E-6).

Table E-6.
Dates and Discharge of Winter Base Flows

Date	Water Year Type and Discharge (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
1/1–2/28	100	110	350	350	350	350

Key: cfs = cubic feet per second

Ecological goals of the Winter Base Flow include the following:

- Provide conditions suitable for egg incubation of fall-run Chinook salmon in Reach 1
- Provide conditions suitable for rearing of spring-run and fall-run Chinook salmon in Reach 1
- Provide flows to maintain a diverse community of native fishes in Reaches 1 and 2

Fish Goals

The Winter Base Flow schedule was designed to provide suitable water temperatures for fall-run Chinook salmon egg incubation and for fry/juvenile rearing of both runs of salmon in Reach 1 (McCullough 1999, Moyle 2002, Ward et al. 2002, 2003, Stillwater Sciences 2003, Marine and Cech 2004; all as cited in Moyle 2005 (p. 36–39, 58); Deas 2005 (p. 27)). A base flow of 350 cfs is also needed to maintain wetted spawning habitat for Chinook salmon in Reach 1 (i.e., flow over redds) throughout the fall-run egg incubation period (Moyle 2005 (p. 48); McBain and Trush 2002, Cain et al. 2003, cited in Kondolf 2005 (p. 20-21)), as well as to provide general habitat for resident native fishes in Reaches 1 and 2 (Moyle 2005 (p. 47)).

3.5.5 Spring Rise and Pulse Flow

The Winter Base Flow ramps up to achieve the Spring Rise and Pulse Flow from March 1 through April 30 (Table E-7). The spring rise is accompanied by short-duration, high-discharge pulses of flow to facilitate salmon migration, vegetation recruitment and maintenance, gravel mobility and other channel conditions. This time period (March 1 to April 30) is included in the Spring Flexible Flow Period.

Table E-7.
Dates and Discharge of Spring Rise and Pulse Flows

Date	Discharge (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
3/1–3/15	130	500	500	500	500	500
3/15–3/31	130	1,500	1,500	1,500	1,500	1,500
4/1–4/15	150	200	350	2,500	2,500	2,500
4/16–4/30	150	200	350	350	4,000	4,000

Key: cfs = cubic feet per second

Ecological goals of the Spring Rise and Pulse Flow include:

- Provide suitable conditions for juvenile Chinook salmon outmigration of both runs
- Provide suitable conditions for adult spring-run Chinook salmon upstream migration
- Provide suitable conditions for spawning of resident native fishes
- Provide floodplain inundation for Chinook salmon rearing and other species (e.g., Sacramento splittail spawning) in wetter years
- Provide flows sufficient to initiate fluvial geomorphic processes (i.e., mobilization and flushing of spawning gravels) in wetter years
- Provide flows sufficient for riparian seedbed preparation, seedling establishment, and to prevent vegetation encroachment in wetter years
- Provide base flows to maintain established vegetation

Fish Goals

The Spring Rise and Pulse Flow schedule was designed to provide suitable water temperatures for critical life stages of Chinook salmon and other native fishes. The timing of Spring Pulse Flows should be coordinated with the abundance of adult Chinook salmon below near the confluence of the Merced River to maximize the number of salmon moving upstream to spawn (Moyle 2005 (p. 48)). In Normal-Dry, Normal-Wet and Wet years, flows should provide supplemental edge and side channel habitats and floodplain inundation for 2 to 3 weeks to allow for spawning of native fishes and rearing of juvenile salmon and other native fishes under highly productive conditions (Moyle 2005 (p. 49)).

Geomorphic Goals

The flexible timing and magnitude of releases during this period should be invoked to ensure that the flow schedule periodically includes a peak flow release of 8,000 cfs for about two hours, thence receding over the course of a few days or more to 4,000 cfs. This release is recommended in Normal-Wet and Wet years (50 percent of years) to mobilize spawning gravels, to maintain their looseness and flush fine sediments, thus improving salmon spawning habitat (Kondolf 2005 (p. 21), Moyle 2005 (p. 49–50)).

Riparian Vegetation Goals

In wetter years the geomorphic pulse flow (8,000 cfs) is also intended to prepare the seedbed for cottonwoods (Kondolf 2005 (p. 22), Jones and Stokes 1998, as cited in Kondolf 2005 (p. 23)). Vegetation recruitment flows of approximately 4,000 cfs (range: 3,000 to 6,000 cfs) combined with the high spring pulse recommended for wetter years are intended to disperse seeds and facilitate seed germination in the target zone 60 to 200 centimeters (2 to 6.5 feet) above the Summer Base Flow water level and to reduce vegetation encroachment in the low-flow channel (Kondolf and Wilcock 1996, Mahoney and Rood 1998, Cain 1997, Tsujimoto 1999, Stillwater Sciences 2003, Cain et al. 2003; all as cited in Kondolf 2005 (p. 18–19, 23–24)). Successful seedling establishment requires gradual recession of spring flows averaging approximately 3 to 4 percent over 60 to 90 days, corresponding to a general 2.5 centimeters per day (cm/day) rate of water table decline in wetter years (Mahoney and Rood 1998, Jones and Stokes 1998, Stillwater Sciences 2003, Cain et al. 2003; all as cited in Kondolf 2005, (p. 24–25)). In Normal-Dry and Dry years, Spring Pulse Flows of 1,500 to 2,500 cfs are expected to scour or otherwise impede detrimental encroachment of vegetation in the low-flow channel (Kondolf 2005 (p. 24)).

3.5.6 Summer Base Flow

The Spring Rise and Pulse Flow is ramped down in Normal-Wet and Wet years during May and June to achieve the Summer Base Flow (Table E-8). The Summer Base Flow in all years except critical years is 350 cfs. The Wet year block of water of 2,000 cfs in May through June is for shaping a riparian recruitment recession flow. In critical years, flows ramp up through August to achieve reduced Summer Base Flows ranging from 190 to 255 cfs. May 1 through May 28 is included in the flexible flow period.

Table E-8.
Dates and Discharge of Summer Base Flows

Date	Water Year Type and Discharge (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
5/1–6/30	190	215	350	350	350	2,000
7/1–8/31	230	255	350	350	350	350

Key: cfs = cubic feet per second

Ecological goals of the Summer Base Flow include the following:

- Provide flows to maintain adult holding and juvenile rearing habitat for spring-run Chinook salmon in Reach 1
- Provide flows to maintain a diverse community of native fishes in Reaches 1 and 2
- Provide flows to promote riparian seedling establishment in wetter years
- Provide base flows to maintain established riparian vegetation

Fish Goals

The Summer Base Flow schedule was designed to provide suitable water temperatures for adult spring-run Chinook salmon holding, and for fry/juvenile rearing of spring-run Chinook salmon in Reach 1. This may include yearling spring-run Chinook salmon. Summer Base Flows of 350 cfs are also intended to provide general habitat for resident native fishes, and a wetted channel down to the confluence of the Merced River to maintain populations of native fishes, game fishes, and other fishes, based on temperature models (Moyle 2005 (p. 47)). In Critical-Low years, only flows to satisfy riparian diversion rights would be released. These releases are expected to maintain continuous flow approximately to Gravelly Ford, thus maintaining holding and rearing habitat for Chinook salmon below Friant Dam and other native fish habitat throughout most or all of Reach 1. Under these conditions, the objective of maintaining continuous flow down to the Merced River confluence would be abandoned (Moyle 2005 (p. 50), Kondolf 2005 (p. 25)).

Riparian Vegetation Goals

In wetter years, spring vegetation recruitment flows are followed with a gradual stage recession (less than 2.5 cm/day rate of water table decline) to promote seedling establishment (Mahoney and Rood 1998, Jones and Stokes 1998, Stillwater Sciences 2003, Cain et al. 2003; all as cited in Kondolf 2005, (p. 24–25)). Summer Base Flows of 350 cfs are required to maintain established riparian vegetation (Kondolf 2005 (p. 18, 22)). In Critical-High years, one or more pulses of water should be released to flood-irrigate the riparian plants, increasing their survival rate during the period of desiccation (Kondolf 2005 (p. 25)). In Critical-Low years, flow releases would only be sufficient to meet riparian diversion needs, and riparian vegetation would be affected. Some trees (especially young, recently established plants without extensive and deep roots) may die during the period of desiccation while better established trees may be able to survive (Kondolf 2005 (p. 25)).

3.5.7 Spring-Run Spawning Flow

The Spring-Run Spawning Flow maintains 350 cfs during the month of September, except in critical years (Table E-9).

Table E-9.
Dates and Discharge of Spring-Run Spawning Flows

Date	Water Year Type and Discharge (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
9/1-9/30	210	260	350	350	350	350

Key:
cfs = cubic feet per second

Ecological goals of the Spring-Run Spawning Flow include the following.

- Provide conditions suitable for spring-run Chinook salmon spawning in Reach 1
- Provide flows to maintain a diverse community of native fishes in Reaches 1 and 2

Fish Goals

The Spring-Run Spawning Flow schedule was designed to provide suitable water temperatures for spring-run Chinook salmon spawning in Reach 1. Flows in September are set at 350 cfs to provide for continuous flow all the way to the Merced River for adult Chinook salmon migration, and to provide general habitat conditions suitable for resident native fishes (Moyle 2005 (p. 47), Kondolf 2005 (p. 20)).

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Exhibit F

EDT Proof of Concept

Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program

SAN JOAQUIN RIVER
RESTORATION PROGRAM

November 2010

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Abbreviations and Acronyms

DFG	California Department of Fish and Game
EDT	Ecosystem Diagnosis and Treatment
FMWG	Fisheries Management Work Group
PTA	Patient-Template Analysis
SJRRP	San Joaquin River Restoration Program

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1.0 Background

The Ecosystem Diagnosis and Treatment (EDT) model is a framework that views salmon as the indicator of the condition of the ecosystem (Lichatowich et al. 1995). The EDT framework was designed so that analyses made at different spatial scales (i.e., from tributary watersheds to successively larger watersheds) might be related and linked. Biological performance is a central feature of the framework and is defined in terms of three elements: life-history diversity, productivity, and capacity. These elements of performance are characteristics of the ecosystem that describe persistence, abundance, and the distribution potential of a population. The analytical model is the tool used to analyze environmental information and draw conclusions about the ecosystem. The model incorporates an environmental attributes database and a set of mathematical algorithms that compute productivity and capacity parameters for the diagnostic species (Lestelle et al. 2004).

The first step in an EDT analysis of a watershed is to diagnose the stream with respect to the target species. The EDT diagnosis is based on a concept called Patient-Template Analysis (PTA) (Lichatowich and Mobrand 1995). PTA compares potential fish performance under existing conditions (Patient) against a diagnostic reference condition (Template). The Template can be a reconstruction of historic or normative conditions. In this case, the diagnostic reference captures the unique characteristics and limitations of the watershed due to its combination of climate, geography, geomorphology, and history and provides a basis for assessing the current condition of the habitat. Although the normative Template is frequently used for EDT analysis, other diagnostic reference conditions are possible. The diagnosis forms a clear statement of understanding about the present conditions of the watershed as related to the diagnostic species.

Following the diagnosis, EDT may be used to evaluate and compare restoration alternatives. The diagnosis serves as a roadmap for construction of restoration alternatives, as well as assessing the relative importance of actions to reduce the effects of limiting factors. Alternatives can be compared in terms of progress toward an identified population goal or achievement of environmental goals for limiting factors.

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2.0 San Joaquin Ecosystem Diagnosis and Treatment

Development of the San Joaquin EDT tool is being conducted as part of the San Joaquin River Restoration Program (SJRRP). The Fisheries Management Work Group (FMWG) is charged with coordinating activities related to the Restoration Goal of the Stipulation of Settlement (Settlement). The FMWG elected to develop a computer model to assist them in developing fish restoration alternatives in the San Joaquin River. The FMWG reviewed several existing model systems and selected EDT (Exhibit G). Efforts began on the model during the summer of 2008. Initial work was described as development of a "Proof-of-Concept" version of the model. This proof-of-concept model employed the conventional EDT model and was intended to demonstrate the utility of the model and to identify issues that will need to be addressed to develop the complete San Joaquin-EDT tool.

This report summarizes the completion of the proof-of-concept San Joaquin EDT model. The task is described below:

Develop a demonstration model for salmon based on the existing SJRRP subreach designations and populate input with estimated values in collaboration with the FMWG. The proof-of-concept model will rely on existing EDT species-habitat relationships for Chinook salmon. Run the EDT model using the coarse structure to assist the FMWG in understanding the model structure and how EDT can be used to compare draft SJRRP alternatives, and assist in the development of the Fisheries Management Plan. Work with the FMWG to develop needs for the full application of EDT to the San Joaquin River Restoration Reach (i.e., San Joaquin River between Friant Dam and the confluence with the Merced River).

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3.0 Progress Summary

The proof-of-concept San Joaquin EDT model has been constructed. The completed model is available on-line at *http://edt.jonesandstokes.com*. The proof-of-concept model will serve as a prototype of the final San Joaquin-EDT tool. As a demonstration of the model, we have completed a preliminary diagnosis of the San Joaquin River (Friant Dam to Merced River) and estimated spring-run Chinook performance under Current and Template conditions.

3.1 Basic Model Structure

The EDT proof-of-concept model for spring-run Chinook salmon in the San Joaquin River has four major components:

1. **Spatial Structure –** The San Joaquin EDT model is based on stream reach structure. Stream reaches are the basic data record in the model and constitute the "pixels" of the picture developed by the model.
2. **Stream Reach Data –** This is a reach-level description of environmental conditions in the river between Friant Dam and the Merced River. Attribute data were assembled from existing stream habitat surveys, flow modeling, and other sources.
3. **Species-Habitat Rules –** EDT uses a library of species-habitat rules to relate reach-level conditions to life-stage performance of the target species. For the proof-of-concept model, we used the existing EDT rules for spring-run Chinook salmon developed over many years for streams in the Pacific Northwest.
4. **Fish Population Life History –** An EDT model constructs fish life-history trajectories to evaluate the environment. Trajectories link the reaches and life stages to complete the spring-run Chinook salmon life history. These trajectories are controlled by features of the life history such as timing, age distribution, fecundity and so on.

3.1.1 San Joaquin EDT Reach Structure

The FMWG had previously delineated the 150 miles between Friant Dam and the Merced River into five "super-reaches." These were judged to be too coarse for the EDT model. In consultation with the work group, these super-reaches were subdivided into a total of 21 EDT reaches that describe the historic channel, the East Side Bypass and connecting bypass reaches (Table F-1). The completed reach structure for San Joaquin EDT is shown in Figure F-1.

Table F-1.
Reach Structure of the San Joaquin EDT Model

Super Reach	Sub Reach	EDT Reach	Upstream Point	RM	Downstream Point	RM	Length (miles)
1	1A	1A1	Friant Dam	267.5	Highway 41	255.2	12.3
		1A2	Highway 41	255.2	Highway 99	243.2	12
	1B	1B1	Highway 99	243.2	Highway 145	234.1	9.1
		1B2	Highway 145	234.1	Gravelly Ford	229	5.1
2	2A	2A	Gravelly Ford	229	Bifurcation Structure	216.1	12.9
	2B	2B	Bifurcation Structure	216.1	Mendota Dam	204.8	11.3
3	3	3A	Mendota Dam	204.8	Mendota Bypass Return (proposed)	201	3.8
		3B	Mendota Bypass Return	201	Avenue 7.5 (Firebaugh)	195.2	5.8
		3C	Avenue 7.5 (Firebaugh)	195.2	Sack Dam	182	13.2
4	4A	4A1	Sack Dam	182	Highway 152	173.9	8.1
		4A2	Highway 152	173.9	Sand Slough CS	168.5	5.4
	4B	4B1	Sand Slough CS	168.5	Poso Drain (Turner Is. Rd.)	157.2	11.3
		4B2	Turner Is. Road	157.2	Mariposa	147.2	10
		4B3	Mariposa	147.2	Bear Creek	135.8	11.4
5	5	5A	Bear Creek	135.8	Salt Slough	127.7	8.1
		5B	Salt Slough	127.7	Mud Slough	121.2	6.5
		5C	Mud Slough	121.2	Merced River	118	3.2
	ESB	B1	Sand Slough CS		Mariposa		
		B2	Mariposa		Bear Creek		
		Bear Creek	Reach B2		Reach 5A		
		Mariposa	Cross Connection				

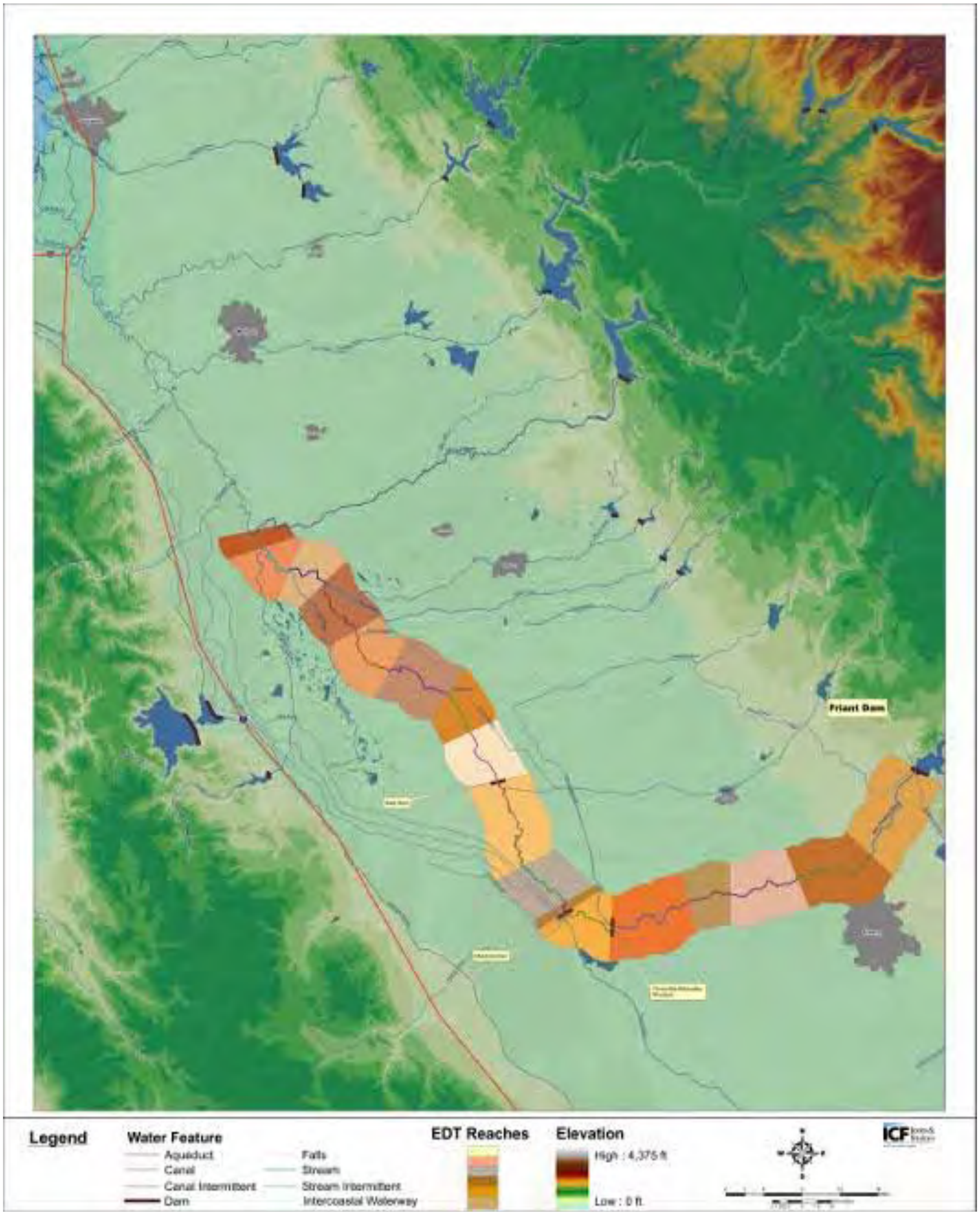


Figure F-1.
Reach Structure of the San Joaquin EDT Model

3.1.2 Stream Reach Data

EDT environmental attributes are listed and described in Table F-2. Many of these attributes were shaped monthly across the year in response to flow and temperature patterns. Reach data was assembled and organized in the San Joaquin Stream Reach Editor, an off-line tool that creates the EDT input file. The San Joaquin Stream Reach Editor and all EDT input data are available at the EDT Web site: *http://edt.jonesandstokes.com*.

Environmental attributes of each reach described in Table F-1 were estimated from available sources of information such as (Jones & Stokes 2002) and California Department of Fish and Game (DFG) reports. Documentation for all stream reach data can be found in the San Joaquin Stream Reach Editor.

3.1.3 Species-Habitat Rules

Species-habitat rules in EDT relate the condition of the environmental attributes in Table F-2 to life stage survival and capacity in each reach. Thus, the rules are the basis of viewing the environment “through the eyes of salmon” (Mobrand et al. 1997). The proof-of-concept San Joaquin EDT model used the existing EDT rules for spring-run Chinook salmon described in Lestelle et al. (2004). These rules are based on extensive review of the scientific literature and application to streams in the Pacific Northwest. Development of the San Joaquin EDT model will include review of the habitat-rating rules and possible revision to reflect genetic differences in southern Chinook salmon, if necessary.

3.1.4 Fish Population Life History

The assessment of environmental conditions in the San Joaquin study area from the perspective of spring-run Chinook salmon reflects the movement and duration of life stages across the species life history. Control of the shape and range of Chinook salmon life-history trajectories is controlled by the species life history table in EDT. For the proof-of-concept model, this table was based on previous EDT development on Butte Creek (Sacramento system) and on description of the probable spring-run Chinook salmon life-history developed by the FMWG Exhibit A).

3.1.5 Summary of Progress

The proof-of-concept San Joaquin EDT model has been completed. Input data has been reviewed and revised by the FMWG. It is emphasized that, as a proof-of-concept model, the current San Joaquin EDT model is provisional and the results described below are preliminary.

Table F-2.
Environmental Attributes and Survival Factors Used in the Proof-of-Concept EDT Model for the San Joaquin River

Environmental Attributes (Level 2)		Species Survival Factors (Level 3)
1 Hydrologic Characteristics		
1.1 Flow variation	High Flow – change from normative Low Flow – change from normative Flow – Intra-daily (diel) variation Flow – intra-annual flow pattern	Flow Withdrawals (entrainment)
1.2 Hydrologic regime	Hydrologic regime – natural	
2 Stream Corridor Structure		
2.1 Channel morphometry	Channel length Channel width – month maximum width Channel width – month minimum width Gradient	Channel length Channel stability Channel width Habitat diversity Key habitat Obstructions Sediment load
2.2 Confinement	Confinement – artificial Confinement – natural	
2.3 Habitat type	Habitat type – backwater pools Habitat type – beaver ponds Habitat type – glides Habitat type – large cobble/boulder riffles Habitat type – off-channel habitat factor Habitat type – pool tailouts Habitat type – primary pools Habitat type – small cobble/gravel riffles	
2.4 Obstruction	Obstructions to fish migration Water withdrawals	
2.5 Riparian and channel integrity	Bed scour Icing Riparian function Wood	
2.6 Sediment type	Embeddedness Fine sediment (intragravel) Turbidity (suspended sediment)	

Table F-2.
Environmental Attributes and Survival Factors Used in the Proof-of-Concept EDT Model for the San Joaquin River (contd.)

Environmental Attributes (Level 2)		Species Survival Factors (Level 3)
3 Water Quality		
3.1 Chemistry	Alkalinity Dissolved oxygen Metals – in water column Metals/Pollutants – in sediments/soils Miscellaneous toxic pollutants - water column Nutrient enrichment	Chemicals (toxic substances) Oxygen Temperature
3.2 Temperature variation	Temperature – daily maximum (by month) Temperature – daily minimum (by month) Temperature – spatial variation	
4 Biological Community		
4.1 Community effects	Fish community richness Fish pathogens Fish species introductions Harassment Hatchery fish outplants Predation risk Salmonid carcasses	Competition with hatchery fish Competition with other fish Food Harassment Pathogens Predation
4.2 Macroinvertebrates	Benthos diversity and production	

4.0 Proof-of-Concept San Joaquin-EDT Model

Spring-run Chinook salmon was extirpated from most of historic production areas of the San Joaquin River by construction of Friant Dam in the 1940s (Exhibit A). Since that time, flow restrictions below the dam as well as additional irrigation development eliminated or degraded habitat below Friant Dam. The San Joaquin River spring-run Chinook salmon population within the Restoration Area is considered extirpated (Yoshiyama et al. 2001).

EDT modeling of the present system results in the obvious conclusion that current habitat will not support spring-run Chinook salmon. To perform an EDT diagnosis, it was necessary to remove the effect of existing barriers and allow fish to move within the study area. With this important proviso, the proof-of-concept model was used to estimate habitat potential within the 150 river miles between Friant Dam and the Merced River under the current habitat condition and a provisional diagnostic reference condition (Template). Because of the preliminary nature of the data (including assumptions about survival below the Merced River, Bay/Delta, and ocean), the results are valuable as illustrations of the model capabilities but should not be considered useful estimates of habitat potential at this time.

All measures of spawning adult performance under the current habitat condition are considerably lower than Template conditions. Current modeled values for productivity, capacity, and abundance ranged from 3 to 17 percent of Template conditions (Table F-3). Current juvenile outmigrant performance is considerably higher relative to Template conditions than spawning adults, but is still well below Template conditions. For example, after including harvest effects, current habitat capacity is 42 percent of Template conditions, productivity is 57 percent of Template conditions, and abundance is 13 percent of Template conditions (Table F-4).

Table F-3.
Baseline Spawning Adult Population Performance Parameters for San Joaquin River Spring-Run Chinook Salmon

Scenario	Productivity	Capacity	Abundance
Current without harvest	2.4	2,614	1,539
Current with harvest	1.8	1,756	798
Template	14.3	30,272	28,148

Note: Results are preliminary and are based on proof-of-concept EDT model.

Table F-4.
Baseline Juvenile Outmigrant Population Performance Parameters for San Joaquin River Spring-Run Chinook Salmon

Scenario	Productivity	Capacity	Abundance
Current without harvest	87	185,885	78,022
Current with harvest	97	187,992	54,853
Template	169	449,067	410,230

Notes:
Model revisions based on FMWG comments.
Results are preliminary and are based on proof-of-concept EDT model.

The proof-of-concept model was revised based on comments received from the FMWG at the January 28, 2009, meeting in Sacramento. The FMWG reviewed the habitat ratings from the initial model and made changes as appropriate or identified data that could be used to populate the attributes. Major changes made to the initial model included:

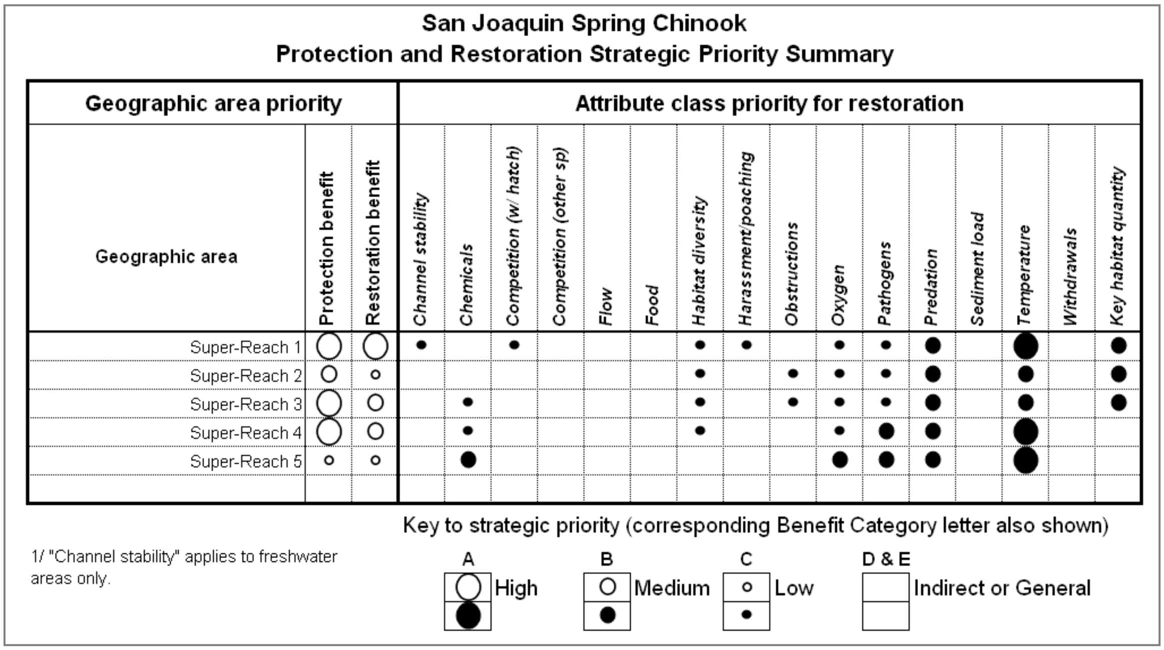
1. Stream reaches downstream of the Merced River were deleted. Fish survival through these reaches will be based on empirical estimates of juvenile, and possibly adult, survival rates.
2. Edgewater habitat area was removed from the analysis as the group noted that this habitat type is a subcomponent of other habitat types (runs, glides, etc.).
3. Temperature-maximum ratings and patterns were based SJR5Q model results using an average temperature value based on inflow and outflow to each reach.

The revised data set was uploaded to the EDT Web site and registered.

4.1 Preliminary Results of Proof-of-Concept Model

An EDT Diagnostic Report assessing the environmental factors affecting spring-run Chinook salmon production was based on the inputs from the proof-of-concept model. These results are highly preliminary because considerable model refinement is necessary based on data needs and assignment of an appropriate Template condition (see below). The model assumed successful fish passage at all potential obstructions (e.g., dams). Given these caveats, the proof-of-concept model indicated that maximum temperature, key habitat quantity, and predation were the primary factors limiting spring-run Chinook salmon habitat within the study area (Figure F-2). Increasing circle diameters in Figure F-2 indicate an increasing priority for restoration. Restoration strategies should therefore primarily focus on these three attributes, although other attributes are locally important (e.g., dissolved oxygen and chemicals in super-Reach 5 (Bear Creek to Merced River)). The large white circles in Figure F-2 indicate that super-Reach 1 (Friant Dam to Gravelly Ford) has the highest restoration potential of the five super-reaches modeled to date. In other words, improving habitat in this reach has the highest potential to increase spring-run Chinook salmon production.

The life-stage impacts are computed as the decline in productivity of the life stage under the current condition as compared to the diagnostic reference condition. In our preliminary analysis, the life stages most impacted by current habitat conditions are prespawning holding (-64.5 percent) and spawning (-40.9 percent), as shown in Figure F-3. The two environmental factors responsible for decreasing productivity in these life stages is again temperature and predation, as indicated by the diameter of the black circles. For the juvenile stage, 0-age migrant productivity has been reduced by 33.5 percent for similar reasons as for the adult life stages. Juvenile migrants are leaving the system at a time when stream temperatures are elevated and predators are active. Impacts would have been higher if stream reaches downstream from the study area were included in this run.



San Joaquin Spring Chinook
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Super-Reach 1	◯	◯	•		•				•	•		•	•	●		⬤		●
Super-Reach 2	○	∘							•		•	•	•	●		●		●
Super-Reach 3	◯	○		•					•		•	•	•	●		●		●
Super-Reach 4	◯	○		•					•			•	●	●		⬤		
Super-Reach 5	∘	∘		●								●	●	●		⬤		

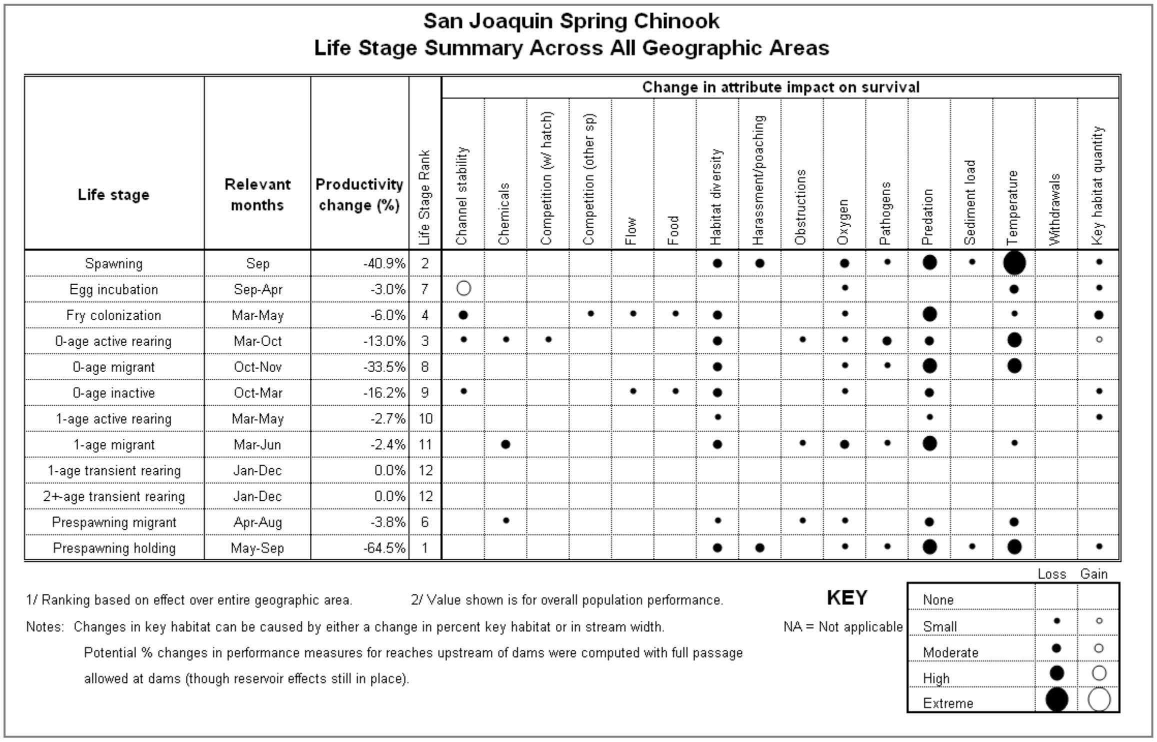
Key to strategic priority (corresponding Benefit Category letter also shown)

1/ "Channel stability" applies to freshwater areas only.

A	B	C	D & E
◯ High	○ Medium	∘ Low	Indirect or General
⬤	●	•	

Note:
Increasing circle diameters indicate an increasing priority for restoration. Results are highly preliminary and are based on proof-of-concept EDT model.

Figure F-2.
San Joaquin Spring-Run Chinook Salmon Protection and Restoration Strategic Priority Summary



San Joaquin Spring Chinook
Life Stage Summary Across All Geographic Areas

Life stage	Relevant months	Productivity change (%)	Life Stage Rank	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
				Change in attribute impact on survival															
Spawning	Sep	-40.9%	2							●	●		●	•	⚫	•	⬤		•
Egg incubation	Sep-Apr	-3.0%	7	⚪									•				●		•
Fry colonization	Mar-May	-6.0%	4	●			•	•	•	●			•		⚫		•		●
0-age active rearing	Mar-Oct	-13.0%	3	•	•	•				●		•	•	●	●		⚫		◦
0-age migrant	Oct-Nov	-33.5%	8							●			•	•	⚫		⚫		
0-age inactive	Oct-Mar	-16.2%	9	•				•	•	●			•		●				•
1-age active rearing	Mar-May	-2.7%	10							•					•				•
1-age migrant	Mar-Jun	-2.4%	11		●					●		•	●	•	⚫		•		
1-age transient rearing	Jan-Dec	0.0%	12																
2+-age transient rearing	Jan-Dec	0.0%	12																
Prespawning migrant	Apr-Aug	-3.8%	6		•					•		•	•		●		●		
Prespawning holding	May-Sep	-64.5%	1							●	●		•	•	⚫	•	⚫		•

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.

Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

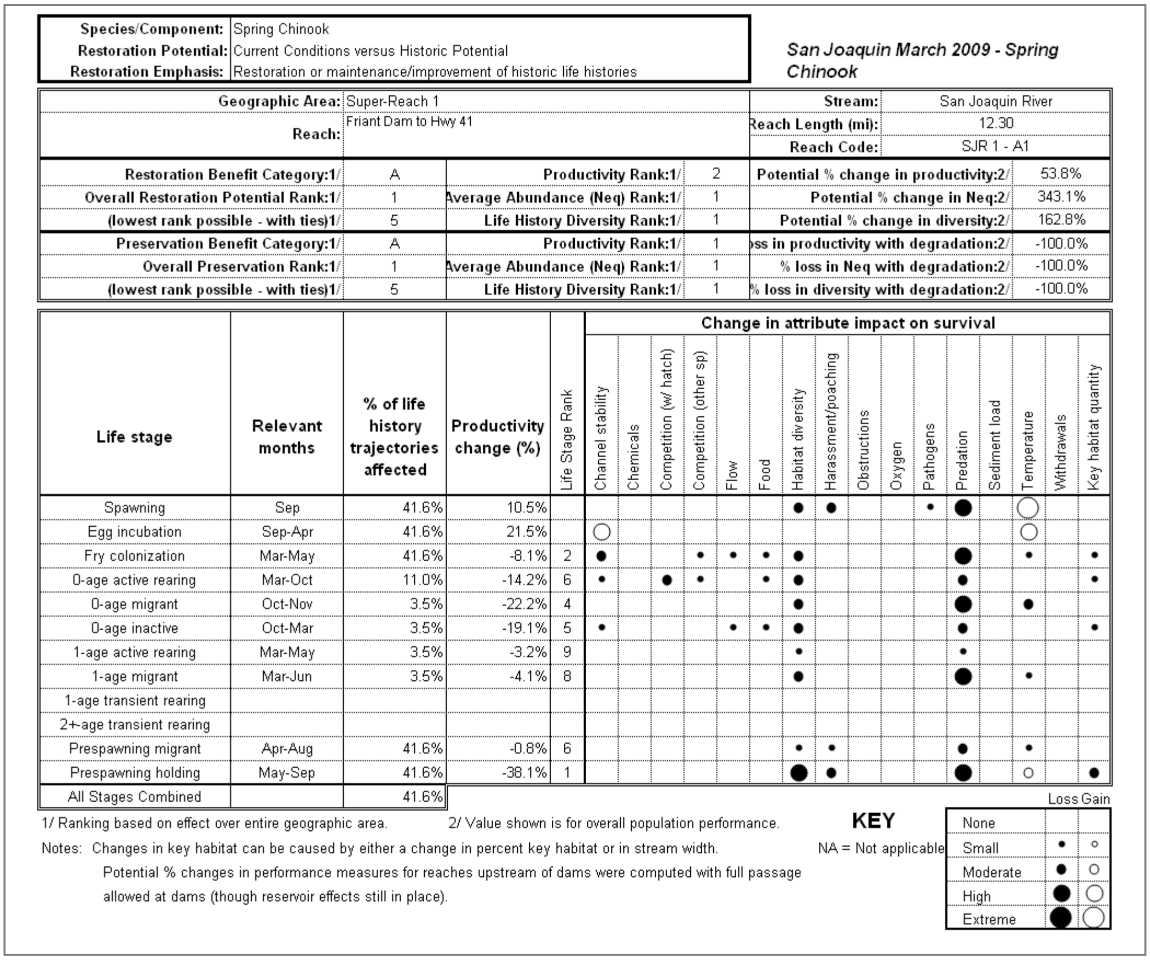
NA = Not applicable

	Loss	Gain
None		
Small	•	◦
Moderate	●	○
High	⚫	⚪
Extreme	⬤	◯

Note:
Increasing circle diameters indicate an increasing effect of an environmental attribute. Results are highly preliminary and are based on proof-of-concept EDT model.

Figure F-3.
San Joaquin Spring-Run Chinook Salmon Life-Stage Summary Across All Geographic Areas

An example of a similar analysis for a single reach (SJR-A1: Friant Dam to Highway 41) is shown in Figure F-4. Similar results are available for each of the study reaches in Table F-1. Of interest here is the large white circle for temperature. This open circle indicates that current stream temperatures are improved for spawning and egg incubation compared to the historic condition for this reach. This results from the presence of the dam and reservoir that discharges cold water to the reach. Additionally, in the upper right corner of Figure F-4 it can be seen that restoring this reach (plus all other subreaches in super-reach 1) to Template conditions results in a 343-percent increase in abundance and a 53.8-percent increase in population productivity. Figure F-4 also shows that if this area was further degraded, there would be a 100-percent loss in all population parameters. This occurs because this reach is important for prespawn holding, spawning, and egg incubation.



Species/Component:	Spring Chinook
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

San Joaquin March 2009 - Spring Chinook

Geographic Area:	Super-Reach 1	**Stream:**	San Joaquin River
Reach:	Friant Dam to Hwy 41	**Reach Length (mi):**	12.30
		Reach Code:	SJR 1 - A1

Restoration Benefit Category:1/	A	**Productivity Rank:1/**	2	**Potential % change in productivity:2/**	53.8%
Overall Restoration Potential Rank:1/	1	**Average Abundance (Neq) Rank:1/**	1	**Potential % change in Neq:2/**	343.1%
(lowest rank possible - with ties)1/	5	**Life History Diversity Rank:1/**	1	**Potential % change in diversity:2/**	162.8%
Preservation Benefit Category:1/	A	**Productivity Rank:1/**	1	**oss in productivity with degradation:2/**	-100.0%
Overall Preservation Rank:1/	1	**Average Abundance (Neq) Rank:1/**	1	**% loss in Neq with degradation:2/**	-100.0%
(lowest rank possible - with ties)1/	5	**Life History Diversity Rank:1/**	1	**% loss in diversity with degradation:2/**	-100.0%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	**Change in attribute impact on survival**															
					Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Sep	41.6%	10.5%								●	●			•	⬤		⚪		
Egg incubation	Sep-Apr	41.6%	21.5%		◯													◯		
Fry colonization	Mar-May	41.6%	-8.1%	2	●			•	•	•	●					⬤		•		•
0-age active rearing	Mar-Oct	11.0%	-14.2%	6	•		●	•		•	●					●				•
0-age migrant	Oct-Nov	3.5%	-22.2%	4							●					⬤		●		
0-age inactive	Oct-Mar	3.5%	-19.1%	5	•				•	•	●					●				•
1-age active rearing	Mar-May	3.5%	-3.2%	9							•					•				
1-age migrant	Mar-Jun	3.5%	-4.1%	8							●					⬤		•		
1-age transient rearing																				
2+-age transient rearing																				
Prespawning migrant	Apr-Aug	41.6%	-0.8%	6							•	•				●		•		
Prespawning holding	May-Sep	41.6%	-38.1%	1							⬤	●				⬤		○		●
All Stages Combined		41.6%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.

Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

NA = Not applicable

KEY

	Loss	Gain
None		
Small	•	∘
Moderate	●	○
High	⬤	◯
Extreme	⚫	⚪

Note:
Increasing circle diameters indicate an increasing effect of an environmental attribute. Results are highly preliminary and are based on proof-of-concept EDT model.

Figure F-4.
San Joaquin Spring-Run Chinook Salmon Life-Stage Summary Across a Single Reach
(SJR-A1: Friant Dam to Highway 41)

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5.0 Conclusion

The use of the proof-of-concept EDT model to perform a preliminary diagnosis shows its potential to address important issues associated with restoration of San Joaquin spring-run Chinook salmon. We have developed a spatial framework, parameterized the model with existing data, and produced a preliminary set of stream diagnostics. In the next phase, the San Joaquin EDT model will be considerably refined to address the complex hydrology of the study area and a custom interface will be developed to facilitate use by the FMWG. The data inputs will continue to be refined and the model adjusted to accommodate the flow and restoration alternatives.

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6.0 Data Needs and Further Model Refinements

In creating the proof-of-concept model for spring-run Chinook salmon in the Restoration Area, several data needs and model refinements have been identified.

6.1 Definition of Template Condition

The FMWG and others involved in the SJRRP must decide what condition the EDT model Template represents. The „true' Template—environmental attributes based on historic, unaltered conditions—may be difficult to document, impossible to achieve, and of questionable relevance given the magnitude of changes that have occurred in the system. At the January 2009 meeting, the FMWG was leaning toward the use of an idealized future condition. What environmental attributes this condition is likely to have must be defined. This should be done as soon as possible, as ratings for the current condition are partially based on the definition of the Template.

6.2 Reach Routing

The nature of the study area necessitates consideration of multiple migration routes. Classic EDT modeling assumes a single main corridor for migration, but the San Joaquin River has numerous bifurcations to bypasses that require modeling as additional routes. This will require considerable model refinement beyond what is possible in a standard EDT. For example, the FMWG thought that another reach just below Mendota Dam may be needed. Additionally, at some flows fish may actually enter the Mendota Reservoir, rather than being bypassed around. Associated with incorporation of bypass reaches is the need for habitat data for each bypass reach.

6.3 Data Needs

Data needs are summarized in Table F-5.

Table F-5.
Data Refinement Needs for the San Joaquin EDT Model

Data need	Source
Flood flow data to allow calculation of maximum flows. Graphs of the 1-, 2-, 5-, and 10-year flood flows would be adequate.	MWH flood flow group
Fish species diversity and richness	DFG 2007 report, to be provided by MWH[1]
Hatchery fish planting information	DFG[2]
Fine sediment data, summarized in millimeters (EDT uses fines less than 0.85 mm for fine sediment)	MWH to provide 2003 gravel permeability study and data
Metals in water column	MWH

Notes:

[1] Report has apparently since been provided.

[2] ICF Jones & Stokes will verify whether data already existing for CDFG Hatchery EIS/EIR are adequate.

Key:
DFG = California Department of Fish and Game
EDT = Ecosystem Diagnosis and Treatment

7.0 References

Jones & Stokes. 2002. San Joaquin River Restoration Plan Background Report (Draft). Prepared by Jones and Stokes Associates for Friant Water Users Authority and Natural Resources Defense Council, Sacramento, California.

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Lichatowich, J.A., and L.E. Mobrand. 1995. Analysis of Chinook salmon in the Columbia River from an ecosystem perspective. Bonneville Power Administration, DOE/BP-25105-2,102 pages.

Lichatowich, J.A., L.E. Mobrand, L. Lestelle, and T. Vogel. 1995. An approach to the diagnosis and treatment of depleted Pacific salmon populations in freshwater ecosystems. Fisheries 20: 10-18.

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San Joaquin Fisheries Management Work Group. 2007. Chinook salmon temporal occurrence and environmental requirements: preliminary tables. San Joaquin River Restoration program, 16 pages.

Yoshiyama, R.M., E.R. Gertstung, F.W. Fisher, and P.B. Moyle. 2001. Historical and present distribution of Chinook salmon in the Central Valley of California. Fish Bulletin 179: 71-176.

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Appendix F

Coordination Act Report

Draft
Program Environmental Impact Statement/Report

SAN JOAQUIN RIVER
RESTORATION PROGRAM

Draft
April 2011

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

In Reply Refer To:
81420-2007-FA-0042
81420-2001-CPA-0081

APR 15 2011

Memorandum

To: Regional Director, Mid-Pacific Region, Bureau of Reclamation, Sacramento, California

Daniel Russell

From: ACTING Assistant Field Supervisor, Sacramento Fish and Wildlife Office, Sacramento, California

Subject: Draft Fish and Wildlife Coordination Act Report on the San Joaquin River Restoration Program

The enclosed draft Fish and Wildlife Coordination Act (FWCA) report programmatically assesses the potential effects to fish and wildlife species and their habitats resulting from the implementation of the U.S. Bureau of Reclamation's proposed San Joaquin River Restoration Program. This report is prepared under the authority of, and in accordance with, the provisions of section 2(b) of the Fish and Wildlife Coordination Act (48 stat. 401, as amended: 16 U.S.C. 661 et seq.).

This draft report is being coordinated with the California Department of Fish and Game (DFG) and the National Marine Fisheries Service (NMFS). If formal comments are received from DFG or NMFS that differ from previous agency input or if the project changes in a way that would affect fish and wildlife resources to an extent not previously analyzed, additional or new analysis will be necessary and revised recommendations to avoid, minimize or compensate for adverse impacts to fish and wildlife species or their habitats will be provided in the final report.

The Fish and Wildlife Service appreciates the opportunity to provide comments on this substantial restoration action and looks forward to discussing this draft report with your staff.

We propose a 30-day period for review and comment on the draft report. Please send written comments to Stephanie Rickabaugh at the above address or via electronic mail to Stephanie_Rickabaugh@fws.gov.

Attachment

cc:
Ali Gasdick, Bureau of Reclamation, Sacramento, California
Rhonda Reed, National Marine Fisheries Service, Sacramento, California
Kevin Faulkenberry, Department of Water Resources, Fresno, California
Gerald Hatler, California Department of Fish and Game, Fresno, California

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

In reply refer to:
81420-2007-FA-0042; SJRRP
81420-2011-CPA-0081

APR 15 2011

Ms. Maria Rea
Central Valley Office Supervisor
Central Valley Area Office
National Marine Fisheries Service
650 Capitol Mall Rm 5-100
Sacramento, California 95814

Mr. Jeff Single
Regional Manager, Central Region
California Department of Fish and Game
1234 East Shaw Avenue
Fresno, California 93710

Dear Ms. Rea and Mr. Single:

Enclosed is the Fish and Wildlife Service's draft Fish and Wildlife Coordination Act Report for the San Joaquin River Restoration Program. This report is prepared under the authority of, and in accordance with, the provisions of section 2(b) of the Fish and Wildlife Coordination Act (48 stat. 401, as amended: 16 U.S. C. 661 et seq.).

The report assesses potential programmatic effects on fish and wildlife resources and provides our preliminary recommendations to avoid, minimize, rectify or compensate for potential adverse effects. This report is being submitted to the California Department of Fish and Game, National Marine Fisheries Service and U.S. Bureau of Reclamation for review and comment. Details of the project's effects on federally listed species, pursuant to section 7 of the Endangered Species Act of 1973, as amended, are being addressed separately.

We propose a 30-day period for review and comment on the draft report. Please send written comments to Stephanie Rickabaugh at the above address or via electronic mail to Stephanie_Rickabaugh@fws.gov.

Any questions regarding this report should be directed to Stephanie Rickabaugh at (916) 978-5463.

Sincerely,

Daniel Russell

Dan Russell
Acting Assistant Field Supervisor

Enclosure

cc:
~~**Ali Forsythe, USBR, Sacramento, California (without enclosure)**~~
Rhonda Reed, NMFS, Sacramento, California
Gerald Hatler, CDFG, Fresno, California

United States Department of the Interior

Fish and Wildlife Service

Draft Fish and Wildlife Coordination Act Report

for the

SAN JOAQUIN RIVER RESTORATION PROGRAM

Prepared for:
U.S. BUREAU OF RECLAMATION
SACRAMENTO, CALIFORNIA

Prepared by:
U.S. FISH AND WILDLIFE SERVICE
SACRAMENTO FISH AND WILDLIFE OFFICE
SACRAMENTO, CALIFORNIA

April 2011

INTRODUCTION

This report constitutes the Fish and Wildlife Service's (Service) draft Fish and Wildlife Coordination Act (FWCA) report, as provided for in section 2(b) of the FWCA (Public Law 85-624; 16 U.S.C. 661-667e), regarding proposed restoration of the San Joaquin River. A final FWCA report will be prepared by the Service taking into consideration review comments on this draft, as well as any new information that we receive. The final FWCA report will be completed after the biological opinion pursuant to section 7 of the Endangered Species Act of 1973, as amended (ESA), has been completed. It is our intent to prepare a final FWCA report for inclusion in the final Programmatic Environmental Impact Statement/Environmental Impact Report (PEIS/R). The planning for the proposed restoration of the San Joaquin River is authorized through the Central Valley Project Improvement Act and the San Joaquin River Restoration Settlement Act.

Background

In 1942, the Bureau of Reclamation (Reclamation) began construction on the 319-foot tall Friant Dam across the San Joaquin River and diverted most of the San Joaquin River water into irrigation canals; thus leading to the dewatering of one of California's largest salmon rivers. In 1988, the Natural Resource Defense Council (NRDC), along with a coalition of environmental groups and commercial fishermen, sued Reclamation, later citing a violation of California Fish and Game Code 5937, which requires dam owners to "keep in good condition" fish below the dam. More than 60 miles of the river have been dry in non-flood flow conditions ever since the dam was constructed.

On September 13, 2006, a Settlement Agreement was entered into by NRDC, Friant Water Users Authority (FWUA), and the U.S. Departments of the Interior and Commerce. The parties agreed on terms and conditions which were subsequently approved by the U.S. Eastern District Court of California (Court) on October 23, 2006. The Settlement establishes two primary goals:

> Restoration Goal- To restore and maintain fish populations in "good condition" in the mainstem San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.
>
> Water Management Goal- To reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

The Settlement also establishes a framework for accomplishing the Restoration and Water Management goals that will require National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) compliance for the project design, construction, and monitoring over the multi-year period. On March 30, 2009, President Obama signed the San Joaquin River Restoration Settlement Act (SJRRS Act) giving the U.S. Department of the Interior full authority to implement the Settlement.

To achieve the Restoration Goal, the Settlement calls for a combination of channel and structural modifications which incorporate the following: new floodplain and related riparian habitat along the San Joaquin River downstream of Friant Dam; releases of water from Friant Dam to the confluence of the Merced River; modifications to control and diversion structures; filling or isolating high priority gravel pits in Reach 1 to ensure fish passage; and the reintroduction of spring and fall-run Chinook salmon.

To achieve the Water Management Goal, the Settlement calls for downstream recirculation, recapture, reuse, exchange or transfer of Restoration Flows to reduce, avoid, or offset the quantity of expected water supply impacts to Friant Division long-term contractors resulting from the release of the Interim and Restoration flows. In addition, the Settlement establishes a Recovered Water Account (RWA) and allows the delivery of surplus water supplies to Friant Division long-term contractors during wet hydrologic conditions.

The San Joaquin River Restoration Program (SJRRP) is comprised of several Federal and State of California agencies responsible for implementing the Settlement. Implementing Agencies responsible for managing and implementing the SJRRP are: the Service, Reclamation, National Marine Fisheries Service (NMFS), California Department of Water Resources (DWR), California Department of Fish and Game (DFG), and California Environmental Protection Agency. Reclamation and DWR initiated environmental compliance in August 2007 for implementing the SJRRP consistent with requirements of NEPA and CEQA. Reclamation is the lead NEPA agency and DWR is the lead CEQA agency in preparing the Program Environmental Impact Statement/Environmental Impact Report (PEIS/R).

All of the Implementing Agencies are working collaboratively on the development and planning of the SJRRP to implement the Settlement. The Service is partnering with Reclamation on developing the NEPA/CEQA documents and permits, primarily in regard to fish and wildlife.

Location of the Study Area

The proposed project area is located in California's Central Valley and extends from the Sacramento-San Joaquin River Delta (Delta) to the base of the Tehachapi Mountains south of Bakersfield, California. The river restoration area is 153 miles long and stretches from Friant Dam to the confluence of the Merced River and crosses into the counties of Fresno, Madera, Merced and Stanislaus (Figure 1). Five river reaches have been defined to address the variation in river characteristics throughout the Restoration Area (Figure 2). Reach 1 begins at Friant Dam

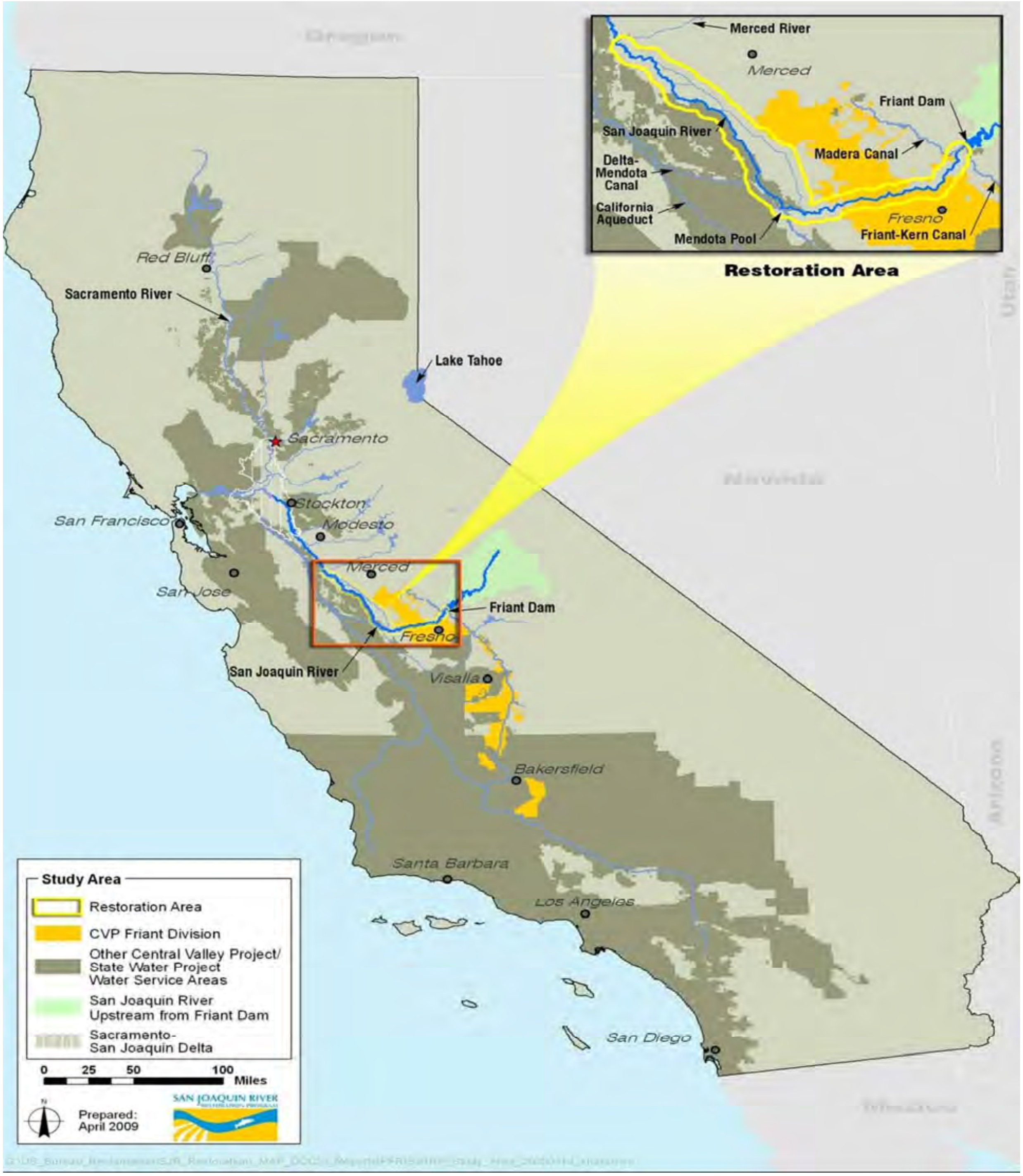


Figure 1. The San Joaquin River Restoration Area and downstream reaches.

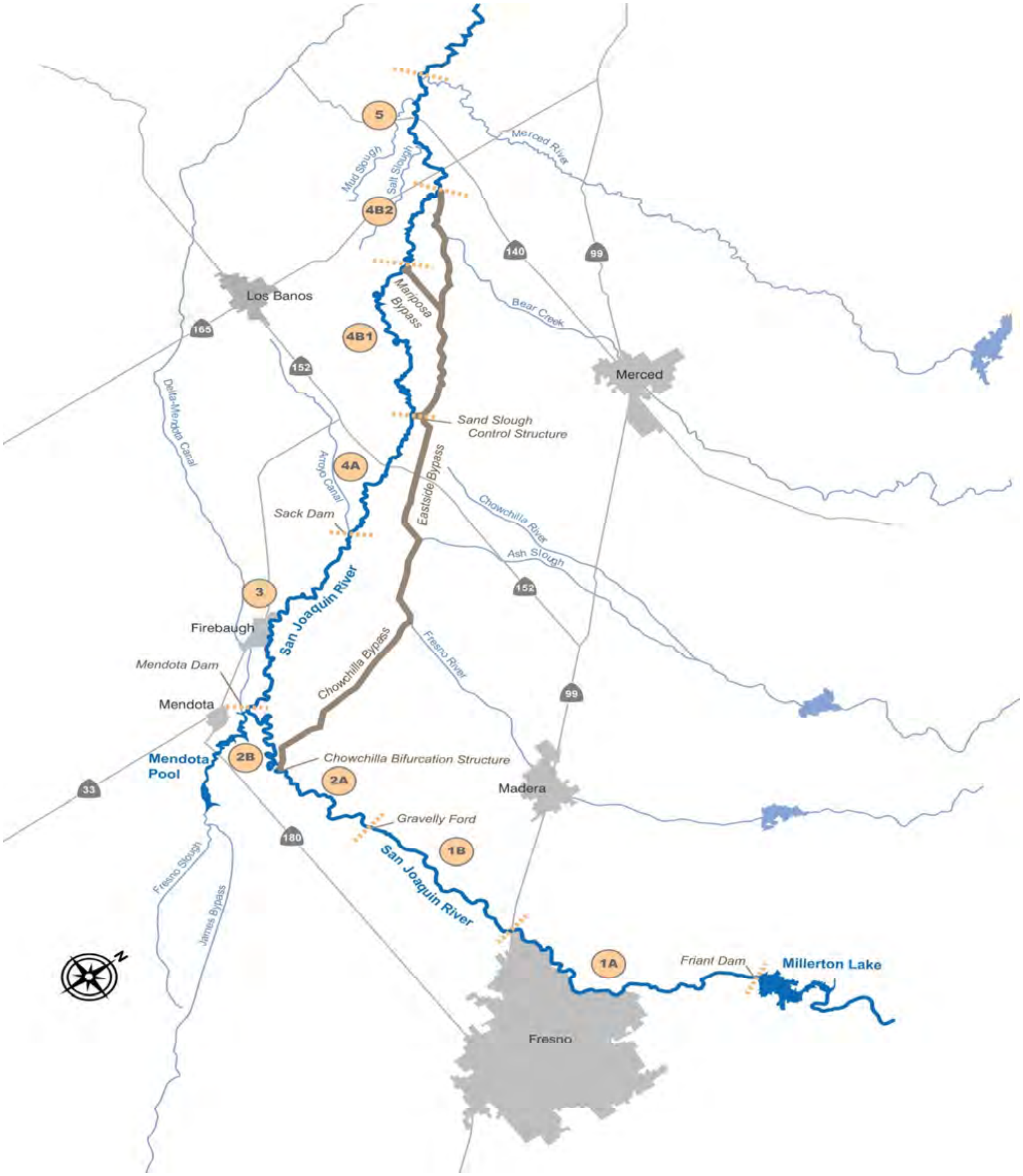


Figure 2. Detailed map showing the Restoration Area and the project reaches.

and continues for approximately 37 miles downstream to Gravelly Ford. Reach 1 is subdivided into 1A and 1B by Highway 99. Reach 2 starts at Gravelly Ford and extends downstream to Mendota Dam. Reach 2 is subdivided at the Chowchilla Bypass Bifurcation Structure into two sub-reaches, Reach 2A and Reach 2B. Reach 3 extends from Mendota Dam at the upstream end to Sack Dam at the downstream end. Reach 4 is located between Sack Dam and the confluence with Bear Creek and the Eastside Bypass. Reach 4 is subdivided into three sub-reaches: 4A (Sack Dam to Sand Slough Control structure), 4B1 (Sand Slough Control structure to Mariposa Bypass) and 4B2 (Mariposa Bypass to Bear Creek). Reach 5 extends from the confluence of the Eastside Bypass downstream to the Merced River confluence. The proposed project area also includes sections of the Eastside Bypass and Mariposa Bypass.

PROJECT DESCRIPTION

The Settlement and the SJRRS Act authorize and direct specific physical and operational actions to occur in order to implement the SJRRP. Within the Settlement itself those actions are described within paragraphs 11-16 and are distinguished as two levels of environmental analysis; Program and Project. Program level actions are potential actions that will require additional environmental analysis, whereas the Project level actions are being analyzed completely and are necessary for the initial implementation of the SJRRP.

Alternatives

The following summarizes the SJRRP alternatives as described in the September 2009, Second Administrative Draft (AD) EIS/R; though ongoing modification to the project description continue. This draft FWCA report attempts to capture a more up-to-date project description based on revisions that have been provided to us since the Second ADPEIS/R. Any others that may have been missed will be addressed in the Service's final FWCA report for the SJRRP.

All six of the action alternatives include features that may occur after additional evaluation and environmental permitting is completed on each feature. They include: re-operation of Friant Dam and Downstream Flow Control Structures, recapture of flows, and a grouping of potential actions referred to as the "Common Restoration Actions." The Common Restoration Actions are stipulated in Paragraph 11, of the Settlement– they are the high priority channel improvements that may be needed to provide channel capacity for full Restoration flows to be analyzed on a Program level in the SJRRP draft EIS/R. The Common Restoration Actions include:

- Construct Mendota Pool Bypass and Modify Reach 2B to convey at least 4,500 cubic feet per second (cfs)
- Modify the Sand Slough Control Structure to Enable Fish Passage
- Screen Arroyo Canal and Provide Fish Passage at Sack Dam
- Modify Reach 4B1 for conveyance of at least 475 cfs and up to 4,500 cfs

- Modify San Joaquin River Headgate Structure to enable flow routing between 500 cfs and 4,500 cfs
- Modify Eastside and Mariposa Bypasses for Fish Passage
- Enable Deployment of Seasonal Barriers at Mud and Salt Sloughs
- Modify Chowchilla Bypass Bifurcation Structure
- Fill or Isolate High Priority Gravel Pits
- Enhance Spawning Gravel
- Reduce Potential for Redd Superimposition and/or Hybridization
- Supplement the Salmon Population
- Modify Floodplain and Side-Channel Habitat
- Enhance In-channel Habitat
- Reduce Potential for Aquatic Predation of Juvenile Salmonids
- Reduce Potential for Fish Entrainment
- Enable Fish Passage
- Modify Flood Flow Control Structures

Differences are minimal between the six Proposed Action Alternatives for the Program, and include combining variations in recapture locations and maximum flow releases (specific to Reach 4B1 only). All other modifications and associated alternatives will be addressed in the Project-specific documents.

Table 1. Breakdown of Proposed Action Alternative Differences for the Program

Alternative	Water Recapture Opportunity	Channel Capacity (Reach 4B1)
A1	Recapture in R and D only	475 cfs
A2	Recapture in R and D only	4,500 cfs
B1	Recapture in R, D and Additional Recapture in OE	475 cfs
B2	Recapture in R, D, and Additional Recapture in OE	4,500 cfs
C1	Recapture in R, D, OE and Additional Recapture at a New San Joaquin River Pumping Plant	475 cfs
C2	Recapture in R, D, OE and Additional Recapture at a New San Joaquin River Pumping Plant	4,500 cfs

R= Restoration Area, D=Delta, OE=Outside the Restoration Area w/ Existing Facilities

Alternative A1
Alternative A1 includes re-operation of Friant Dam and a range of actions to achieve the Restoration and Water Management goals. Reach 4B1 would convey at least 475 cfs and the Eastside and/or Mariposa Bypasses would be used to convey the remaining flows above 475 cfs. Also included is the potential for recapture of flows in the Restoration Area (R) and/or Delta (D) using existing diversion facilities, operated under existing operating criteria.

Alternative A2
Alternative A2 includes the same Restoration and Water Management actions as A1, plus additional restoration actions to increase Reach 4B1 channel capacity to at least 4,500 cfs with integrated floodplain habitat. Under this alternative the Eastside Bypass would not convey flows after completion of Reach 4B1 channel modifications.

Alternative B1
Alternative B1 includes the same Restoration and Water Management actions as A1, plus the additional Water Management actions for potential recapture of flows in the San Joaquin River downstream of the confluence with the Merced River using existing facilities.

Alternative B2
Alternative B2 includes the same Restoration and Water Management actions as B1 plus the additional Restoration Actions to increase Reach 4B1 channel capacity to at least 4,500 cfs with integrated floodplain habitat included in A2.

Alternative C1
Alternative C1 includes the same Restoration and Water Management actions as B1, plus additional Water Management actions for recapture of flows through a new pumping plant on the San Joaquin River downstream of the confluence with the Merced River.

Alternative C2
Alternative C2 includes the same Restoration and Water Management actions as C1, plus the additional Restoration actions to increase Reach 4B1 channel capacity to at least 4,500 cfs with integrated floodplain habitat included in A2.

Conservation Strategy

A number of actions that are proposed to be implemented may substantially alter not only the aquatic ecosystem of the San Joaquin River, but also the river's riparian and wetland ecosystems, and some adjacent upland ecosystems. Riparian, wetland, and upland ecosystems of the Central Valley, such as those along the San Joaquin River, provide habitat for a large number of species, including several Federally and State-listed species.

As part of the SJRRP, a strategic habitat conservation approach is being developed for the conservation of sensitive habitats along the river and associated with project implementation. The development of a more clearly defined project footprint for the Program actions and associated base vegetation map are underway to facilitate the implementation of the strategic habitat conservation approach. The approach allows Reclamation and DWR, in coordination with the Service, NMFS and DFG to develop a Conservation Strategy with the current unknowns of the SJRRP are in development. The Conservation Strategy's overall goal is to stipulate strategic parameters for design and planning, which would avoid, minimize and/or compensate for adverse effects on sensitive habitats and species that may otherwise result from flows or construction. The Conservation Strategy will be consistent with the Recovery Plans for Federally listed species, the Service's Mitigation Policy, Migratory Bird Treaty Act, Clean Water Act, and the Magnuson-Stevens Act.

Modeling

The SJRRP is currently utilizing several models to test conceptual designs and analyses of the system to assist in determining the best ways to restore the system while meeting the Settlement goals.

Conceptual and quantitative models are critical tools to understanding how the San Joaquin River system would respond to the various proposed modifications and flows. Several state-of-the-art models are available for analyzing water quality conditions in complex (riverine) systems and several models are being developed. The analyses will continue as the various components that are called out in the Settlement are planned and constructed and as the system changes over time. Some of the models that the SJRRP is developing are specific to salmon and riparian floodplain development including the Ecosystem Diagnosis and Treatment (EDT) model and hydraulic models.

The EDT model is a framework that views salmon as the indicator or diagnostic species for the ecosystem. The EDT framework was designed so that analyses made at different spatial scales (i.e., from tributary watersheds to successively larger watersheds) might be related and linked. Biological performance is a central feature of the framework and is defined in terms of three elements: life history diversity, productivity, and capacity. These elements of performance are characteristics of the ecosystem that describe persistence, abundance, and distribution potential of a population. Other fish modeling approaches, and the addition of individual based models, will developed to improve the evaluation of specific restoration actions.

One dimensional models, including HEC-RAS, SRH-1D, and SRH-1DV, perform 1-D hydraulic analyses on networks of natural or constructed open channels. The software is capable of performing steady flow calculations and unsteady flow calculations, and additional models build on these results to perform sediment transport and mobile bed computations (SRH-1D), water temperature modeling (HEC-5Q, based on HEC-RAS), and vegetation modeling (SRH-1DV). The basic steady flow computational procedure involves solving the 1-D energy equation, including friction and contraction/expansion energy losses. The momentum equation is utilized for rapidly changing water surfaces. The models also accommodate channel obstructions, such as bridges, culverts, and weirs, and can assess changes due to channel modifications and levees. The output of the 1-D hydraulic model provides water surface elevation, depth and velocity. These data from the HEC-RAS model are then used to produce inundation maps by depth. These maps when combined with estimated acreages provide a picture of the depth in the existing channel and on the floodplain for baseline vegetation and flow conditions. Since the HEC-RAS model is 1-D, only average velocities over each cross-section can be obtained from the model results. Once the field data is collected, the parameters needed for a 2-D hydraulic model would allow the SJRRP to obtain water surface elevations and velocities on a grid throughout the Restoration Area. These offer the potential to predict the local pattern and timing of inundation depth and velocity which will assist in development of the alternative designs for the SJRRP.

A 2-D hydraulic model provides the ability to simulate lateral changes in flow including edge water, eddies, side channels, and ponding. 2-D models improve the ability to identify floodplain and gravel pit interactions as well as other situations where computing hydraulics with a uniform cross section does not adequately resolve the physical processes.

Conceptual designs for several aspects of the SJRRP are also being entered into models to analyze hydraulic capacity, sediment transport characteristics, vegetation response, and other physical aspects of potential fish habitat.

The SJRRP has two temperature models available: CE-QUAL-W2 is a vertical 2-D temperature model of Millerton Reservoir, and HEC-5Q is a temperature model of the San Joaquin River based on 1-D hydraulic routing. These models allow for projection of temperatures depending on different flow release patterns.

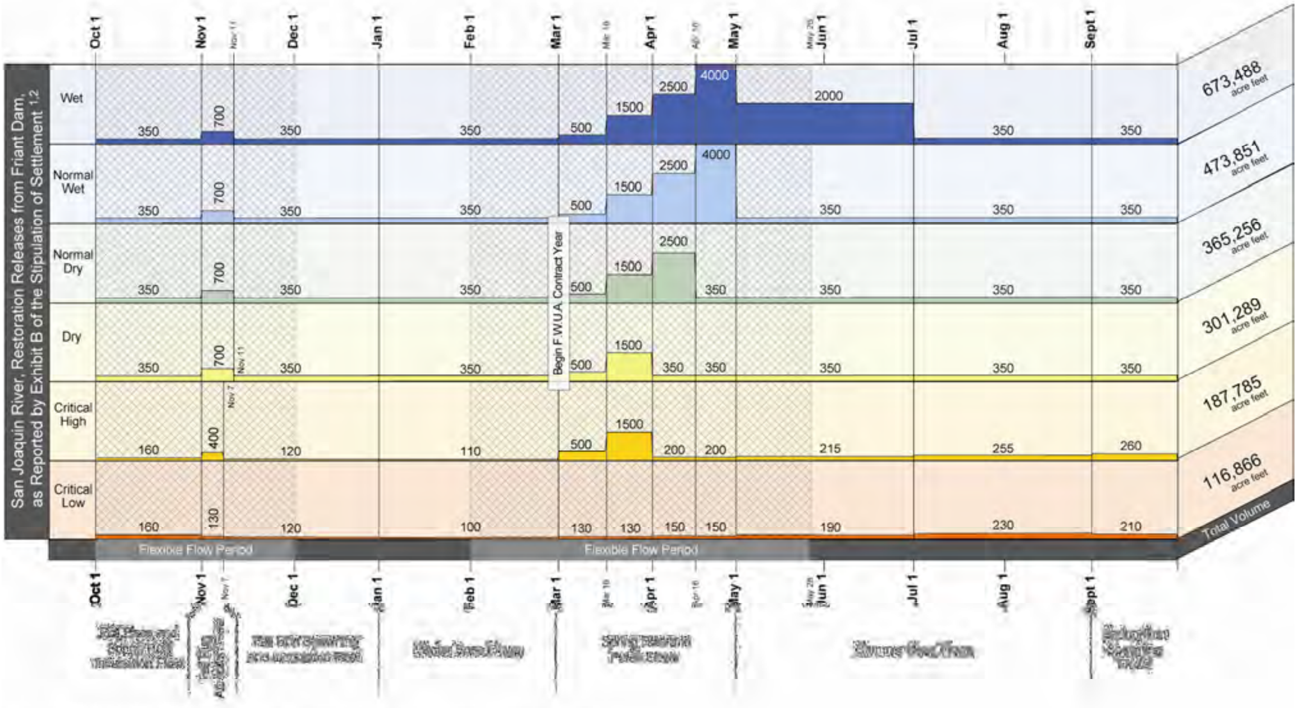
Flows

The re-operation of Friant Dam would allow release of Interim and Restoration flows into the San Joaquin River according to the six flow schedules specified in the Exhibit B of the Settlement (Figure 3). The maximum downstream extent and rate of flow releases would be limited to existing downstream channel capacity. As channel or structural modifications are completed flow releases out of Friant Dam would increase until they met full restoration flows. The Implementing Agencies are developing a real-time flow management framework (adaptive process) in preparation for fish reintroduction. Once completed, the real-time flow management framework is intended to make real-time monitoring data available to best manage releases to meet needs for salmon to complete their life cycle.

The hydrograph in the Settlement outlines average targets for each water year type for the SJRRP as well as a provision for the release of pulse flows in Normal-Wet and Wet-Years to attempt to perform geomorphic functions such as flushing spawning gravel (Figure 3). The hydrographs contain flexible flow periods. The spring and fall base flows can be shifted up to four weeks earlier or later than what is depicted in the hydrograph for a given year so long as the total flow volume is not changed. The flushing flows include a peak release of 8,000 cfs for several hours but the maximum sustained flow would be at 4,500 cfs.

The Settlement has specific flow targets that vary by Restoration Year Type, and range from zero cfs (in Reaches 3, 4A, and 4B in Critical-Low water years) to 4,055 cfs (at the confluence of the Merced River in Wet and Normal-Wet water years). Appendix A shows the San Joaquin River flows by Reach as reported by Exhibit B of the Settlement.

San Joaquin River, Restoration Releases from Friant Dam, as Reported by Exhibit B of the Stipulation of Settlement[1,2]



1 – NRDC v Rodgers, Stipulation of Settlement, CIV NO. S-88-1658 - LKK/GGH, Exhibit B, September 13, 2006
2 – Hydrographs reflect assumptions about seepage losses and tributary inflows which are specified in the settlement

Figure 3. Restoration flow release by restoration water year-type, as specified in Exhibit B of the Settlement.

Monitoring

Interim Flows

The Settlement requires "a program of Interim Flows in order to collect relevant data concerning flows, temperatures, fish needs, seepage losses, recirculation, recapture and reuse." The Implementing Agencies are currently collecting relevant data through a monitoring network and a series of studies designed to address uncertainties related to Settlement implementation. Modeling to predict conditions for different conceptual designs and formulate future operations relies on this monitoring data for calibration and validation.

The following is a list of the monitoring activities and other studies that the Program is actively doing or planning for the Interim Flow period: Flow Monitoring, Water Quality Monitoring, Tissue Collection, Invertebrates Sampling, Bathymetry Studies, Temperature Data Logging, Spawning Gravel Evaluation, Bed Material Study, Micro-Habitat Spawning Quality Study, Hills Ferry Barrier Evaluation, Fall-run Chinook Salmon Fish Survival and Migration Pilot Study, Egg Survival, Habitat and Vegetation Mapping, Preparations for a Steelhead Plan, Sediment Sampling, and Groundwater and Seepage Monitoring.

Restoration Flows

To meet the goals of the Settlement, the Restoration Flows would be monitored at no less than six locations between Friant Dam and the confluence with the Merced River. This monitoring will ensure that the flow targets at or immediately downstream of Friant Dam, at Gravelly Ford, downstream of the Chowchilla Bifurcation Structure, downstream of Sack Dam, at the top of Reach 4B, and at the confluence with the Merced River are being met. Fish populations would be monitored to assess if the goal of a naturally producing and sustainable salmon population has been obtained. Additional monitoring is likely to continue for a variety of water and biological variables that have yet to be determined.

Recapture and Recirculation

The SJRRS Act and the Settlement authorize and direct the Secretary of the Interior to implement a plan for recirculation, recapture, reuse, exchange or transfer of Interim Flows and Restoration Flows for the purpose of reducing or avoiding impacts, caused by the SJRRP, for water deliveries to all of the Friant Division long-term contractors. The plan is also required to, among other things, "ensure that any recirculation, recapture, reuse, exchange or transfer of the Interim Flows and Restoration Flows have no adverse impact on the Restoration Goal, downstream water quality or fisheries."

Recapture of the SJRRP Flows is analyzed at a project-level in the draft PEIS/R and would occur within the Restoration Area (e.g. Mendota Pool), lower San Joaquin River (e.g. Patterson Irrigation District), and/or in the Delta (i.e. William "Bill" Jones and Harvey O. Banks Pumping

Plants). Recapture in the Restoration Area would only occur when it is necessary to direct SJRRP Flows: to avoid exceeding non-damaging channel capacity; to allow for construction of restoration actions; to permit maintenance of diversion and flood control facilities; and under unusual or emergency conditions.

Recirculation to the Friant Division long-term contractors of the available recapturable SJRRP flows would be accomplished through exchange, transfer, and direct delivery. Recirculation is evaluated on a program-level and will be evaluated at a project-level in a future document.

Construction Actions

The Settlement includes a list of Common Restoration Actions that may be needed to meet the goals of the Settlement and the SJRRS Act. These actions may have a construction component to them and will have supplemental environmental analysis completed as they move forward. Currently, several of the actions are in the preliminary stages of planning and design. They include: Construct Mendota Pool Bypass/ Reach 2B Channel Improvements, Arroyo Canal Fish Screen and Fish Passage at Sack Dam, Modify Eastside Bypass and Mariposa Bypass for fish passage, Modify Reach 4B1 to convey at least 475 cfs and install temporary fish barriers at Mud and Salt sloughs.

BIOLOGICAL RESOURCES

The San Joaquin Valley historically contained a diverse and productive natural environment. However, the current biological resources of the San Joaquin River Watershed are highly altered from the historical conditions. In order to implement the Settlement and restore California's second-longest river it is important to understand how and why the San Joaquin River has been substantially modified.

The San Joaquin River and the Eastside and Mariposa Bypasses, although highly modified from conditions 60 years ago, support a patchwork of diverse and highly valuable areas for biological resources. Several portions of the river and bypasses are in State or Federal designated protected areas and contain important areas of annual grasslands, riparian forest and scrub-shrub, bare sand and gravel, and surface waters of the river and its associated sloughs and ponds.

HISTORICAL

The natural flow regimes of the Central Valley rivers, including the San Joaquin River, historically had greater variation in the timing and magnitude of stream discharge than under managed flow regimes. The variability in stream flow prior to the construction of dams and increased agricultural production created unique and diverse riverine habitat, providing conditions suitable for salmonids and other native fishes as well as other aquatic and riparian species. The historical, unregulated flows scoured the stream bed, displaced sediments and formed new channels during seasonal flood events, and deposited the sediments in downstream reaches on the receding hydrograph. These dynamic processes continually created and maintained high-quality aquatic and terrestrial habitat forming a complex network of side channels, sloughs, and floodplains in the alluvium of the lower reaches, supporting fish, wildlife and diverse riparian vegetation. Extensive marshes were a dominant feature along the water courses of the valley, some large enough to be almost impassable (Ornduff 1974). The most prominent feature was the free flowing San Joaquin River and its riparian and floodplain areas.

The side channels, floodplains and braided network of smaller channels were especially important in the life cycle of salmonids, as these provided spawning areas and quality rearing habitat for salmonid fry and juveniles (McBain and Trush 2002). These habitats often remained inundated for prolonged periods, significantly increasing the total amount of available aquatic habitat and providing spatial and habitat heterogeneity (Sommer et al. 2004; Sommer et al. 2002; Power et al. 1995). Often shallower aquatic habitats offer lower water velocities and warmer temperatures (Turner et al. 1994; Scheidegger and Bain, 1995) providing greater abundance of invertebrate prey (Holland and Huston 1985; Grosholz and Gallo 2006), which research indicates leads to enhanced growth and survival for juvenile fishes (Sommer et al. 2005; Ribeiro et al. 2004). Based on the Central Valley stream native fish assemblages defined by Moyle (2002), the fishes listed in Table 2 may have historically occurred in the San Joaquin River Restoration Area.

When large numbers of Chinook salmon and other native fishes historically spawned in the Central Valley rivers, their carcasses provided significant benefits to the stream and riparian ecosystem. Carcasses provide marine-derived nutrients to invertebrates, wildlife, and aquatic biota (Bilby et al. 1998, Helfield and Naiman 2001, Hocking and Reimchen 2002) and the nutrients are also readily absorbed by adjacent riparian vegetation (Helfield and Naiman 2001, Merz and Moyle 2006).

EXISTING CONDITIONS

The Restoration Area has been significantly altered by changes in land and water use over the past century. Five river reaches have been defined to address the great variation in river characteristics throughout the Restoration Area. The reaches are differentiated by their geomorphology and resulting channel morphology, and by the infrastructure along the river (SJRRP 2010).

Table 2. Potential native and introduced fish species historically or currently occurring in the San Joaquin River Restoration Area			
Species	**Scientific Name**	**Native (N) or Introduced (I)**	**Current Presence[1]**
Spring-run Chinook salmon	*Oncorhynchus tshawytscha*	N	No
Fall-run Chinook salmon	*O. tshawytscha*	N	Periodic
Rainbow trout/ steelhead	*O.mykiss*	N	Yes
Pacific lamprey	*Lampetra tridentata*	N	Yes
River lamprey	*Lampetra ayersi*	N	Unknown
Kern brook lamprey	*Lampetra hubbsi*	N	Yes
Western brook lamprey	*Lampetra richardsoni*	N	Unknown
White sturgeon	*Acipenser transmontanus*	N	Yes[2]
Green sturgeon	*Acipenser medirostris*	N	No
Hitch	*Lavinia exilicauda*	N	Yes
California roach	*Lavinia symmetricus*	N	Yes
Sacramento blackfish	*Orthodon microlepidotus*	N	Yes
Sacramento splittail	*Pogonichthys macrolepidotus*	N	Yes
Hardhead	*Mylopharodon conocephalus*	N	Yes
Sacramento pikeminnow	*Ptychocheilus grandis*	N	Yes
Sacramento sucker	*Catostomus occidentalis*	N	Yes
Threespine stickleback	*Gasterosteus aculeatus*	N	Yes
Prickly sculpin	*Cottus asper*	N	Yes
Riffle sculpin	*Cottus gulosus*	N	Yes
Sacramento perch	*Archoplites interruptus*	N	Extirpated
Tule perch	*Hysterocarpus traski*	N	Yes
Threadfin shad	*Dorosoma petenense*	I	Yes
Common carp	*Cyprinus carpio*	I	Yes
Fathead minnow	*Pimephales promelas*	I	Yes
Red shiner	*Cyprinella lutrensis*	I	Yes
Bullhead catfish	*Ameiurus nebulosus*	I	Yes[3]
Black catfish	*Ameiurus melas*	I	Yes[3]
White catfish	*Ameiurus catus*	I	Yes
Striped bass	*Morone saxatilis*	I	Yes
Black crappie	*Pomoxis nigromaculatus*	I	Yes
Bluegill sunfish	*Lepomis macrochirus*	I	Yes
Green sunfish	*Lepomis cyanellus*	I	Yes
Largemouth bass	*Micropterus salmoides*	I	Yes
Redear sunfish	*Lepomis microlophus*	I	Yes
Spotted bass	*Micropterus punctulatus*	I	Yes
White crappie	*Pomoxis annularis*	I	Yes

Notes:

[1] DFG 2007a

[2] DFG Report Card Data, 2009

[3] USBR 2003

Flows

The most dramatic alteration to waterways of the San Joaquin Valley has been the construction of reservoirs on the San Joaquin River and its major tributaries. Dam construction peaked with the initiation of the Central Valley Project (CVP), from the 1930s to the 1960s, with Friant Dam being completed in 1942. Friant Dam was designed to divert most of the San Joaquin River water flows to about 1 million acres of farmland along the eastern portion of the San Joaquin Valley. At present, most of the water that previously flowed through the main stem of the San Joaquin River upstream of the Merced River is now stored in Millerton Lake (the reservoir behind Friant Dam) and is transferred via canals both south to Kern County and north to Madera County. Diversions began with the completion of the Madera Canal in 1945 and the Friant-Kern Canal in 1949, which coincides with the demise of the spring-run Chinook salmon population in the San Joaquin River. During most years, there is low to no flow between Friant Dam and Mendota Pool (Clifton and Gilliom, 1989). Downstream riparian water users along the San Joaquin River now receive water supply from the Delta via the Delta-Mendota Canal to replace the natural flow which used to course down the San Joaquin River. Even with this supplemental imported water, withdrawals during the irrigation season typically eliminate surface flows in portions of the lower San Joaquin River between Mendota Pool and the confluence with the Merced River. These modified environmental conditions have caused considerable changes to the native wildlife and plant communities along the San Joaquin River.

In addition to Friant Dam, numerous other in-stream structures were constructed to facilitate the delivery of water or modify flood flows, and include various diversion dams (Gravelly Ford, Mendota and Sack), bypasses (Eastside and Mariposa), drop structures (Eastside and Mariposa bypasses), head gates (Sand Slough Control Structure), radial gates (Chowchilla Bifurcation Structure) and a seasonal weir at Hills Ferry. These existing structures are clear impediments to the migration of salmonids and many other native fishes historically present in the San Joaquin River system. Thus, the barriers coupled with inadequate flows severely limit the quality and the availability of suitable habitat for native aquatic biota.

Vegetation and Terrestrial Habitat

Plant communities and community composition found in the Restoration Area are described in the draft PEIS/R. Plant communities were classified by DWR (2002) using a modified Holland system (Holland 1986). The dominant plant communities within the five Reaches include: mixed riparian forest, cottonwood riparian forest, willow riparian forest, and riparian scrub (USBR 2009) and are shown in Table 3. Mixed riparian forest is a multilayer winter-deciduous forest generally found on the intermediate terrace of the floodplain of the San Joaquin River. Cottonwood riparian forest is a multilayered riparian forest found on the active low floodplain of the San Joaquin River. Willow riparian forest is dominated by willows, most frequently black willow with dense cover. Riparian scrub includes willow scrub, riparian scrub and elderberry savanna and consists of woody shrubs and herbaceous species and is dominated by different species depending on the reach(Reclamation 2009b).

Table 3. Plant Communities Delineated by Reach for the Restoration Area

Vegetation Type	Reaches and Bypasses (acres)									
	Reach 1A	Reach 1B	Reach 2A	Reach 2B	Reach 3	Reach 4A	Reach 4B1	Reach 4B2	Reach 5	Bypasses
Cottonwood Riparian Forest	166	79	30	48	429	16	18	14	29	0
Cottonwood Riparian Forest LD1	27	114	41	1	23	4	2	2	0	0
Willow Riparian Forest	198	119	43	110	116	68	177	330	506	2
Willow Riparian Forest LD	28	0	4	6	8	14	88	100	249	0
Mixed Riparian Forest	439	260	0	0	0	6	0	0	0	0
Mixed Riparian Forest LD	65	19	2	0	0	0	0	0	1	0
Valley Oak Riparian Forest	265	0	0	0	0	0	16	7	35	0
Willow Scrub	214	113	76	38	188	38	101	18	70	0
Willow Scrub LD	73	32	124	15	41	10	0	13	10	0
Riparian Scrub	53	48	209	67	56	61	55	3	71	20
Elderberry Savanna	2	0	3	63	0	0	0	0	0	0
Emergent Wetlands	204	5	11	64	8	41	164	139	217	0
Nonnative Tree	54	22	9	0	0	0	0	0	12	0
Giant Reed2	3	4	6	0	0	0	0	0	0	0
Grassland/Pasture	1,513	286	470	227	157	201	620	2,131	2,955	1
Agricultural Uses	1,450	2,821	2,569	1,858	4,669	2,775	3,768	111	580	18
Alkali Sink	0	0	0	0	0	0	0	0	2	0
Open Water	1,307	220	327	279	341	113	140	123	440	5
Riverwash[3]	34	47	170	3	22	68	3	0	6	0
Disturbed	1,998	335	181	243	654	401	452	183	110	1
Urban	158	0	0	0	332	0	0	0	0	0
No Data[4]	2,412	642	255	1,622	1011	780	909	157	41	19,576
Total[5]	10,663	5,166	4,530	4,644	8,058	4,595	6,513	3,331	5,333	19,622
Ratio of Natural Habitat[6] Per River Mile	194.2 acres/m	48.0 acres/m	79 acres/m		47.5 acres/m	14.8 acres/m	512.8 acres/m		508.0 acres/m	unknown

Source: DWR 2002.
Key: LD = low density.
Notes:
[1] Canopy cover less than 30 percent.
[2] In reaches 1A, 1B, and 2A, by 2008, giant reed acreage had increased to 16.4, 7, and 17.5 acres, respectively (R. Stephani, pers. comm.).
[3] Riverwash partially depends on flow at the time of the survey/photograph, and values should not be presumed to be precise.
[4] No data exist for areas within the Restoration Area that were not mapped by DWR (2002).
[5] Columns do not all sum exactly to total acreage because of round off error.
[6] Natural habitat used in this calculation includes all categories except agricultural uses, open water, disturbed, urban, and no data.

A description of the SJRRP reaches and bypasses is below.

Reach 1

Reach 1 conveys continuous flows through an incised, gravel-bedded channel. It is generally confined by periodic bluffs and terraces. Subreach 1A, which extends to State Route 99, has the most gravel, and supports continuous riparian vegetation except where the channel has been disrupted by gravel mining and other development. Subreach 1B, continues from State Route 99 to Gravelly Ford and is more narrowly confined by levees. Gravel mining and agriculture are the primary land uses in Subreach 1B.

Reach 2

Reach 2 is a meandering, low-gradient channel characterized by seasonal drying of the channel in the summer and fall. In most years, Reach 2 is dry except under flood release conditions from Gravelly Ford to Mendota Dam. Mendota Pool is formed from the back water of Mendota Dam. Subreaches 2A and 2B are intermittently wet and sand-bedded with confining levees build to protect the adjacent agricultural lands. Riparian vegetation in 2A is sparse or absent due to the usually dry conditions of the river and groundwater overdrafting (McBain and Trush 2002).

Reach 3

Reach 3 receives continuous in-flows from the Delta-Mendota Canal, which are then diverted into the Arroyo Canal at Sack Dam. The sandy river channel meanders through a predominantly agricultural area, except where the City of Firebaugh borders the river's west bank. Here the river has a low stage but is perennial and supports a narrow riparian corridor along the edge of the river channel.

Reach 4

Reach 4 is sand-bedded and usually dewatered because of the diversion at Sack Dam. The upstream portion is bounded by canals and local dikes down to the confluence with the Mariposa Bypass at the San Luis National Wildlife Refuge (NWR). The floodplain of Reach 4A is broad, with levees set back from the active channel and sparsely vegetated. The water table is also closer to the surface than in the other reaches (DWR 2002). Subreach 4B1 which extends from the Sand Slough Control Structure to the confluence with the Mariposa Bypass has been dry for more than 40 years. Therefore the channel itself is poorly defined because it usually remains dry, with the only exception being when the channel receives varying amounts of agricultural return flow. Only a single fish species, the non-native inland silverside, has been documented in Reach 4 in the past 25 years (Saiki 1984, DFG 2007). Subreach 4B2 begins at the confluence of the Mariposa Bypass, where flood flows in the bypass system rejoin the mainstem of the San Joaquin River and extend to the confluence of the Eastside Bypass.

Reach 5

Reach 5 is perennial because it receives varying amounts of agricultural return flows from Mud and Salt sloughs. It is more sinuous that the other reaches and contains oxbows, side channels and remnant channels. The habitat within Reach 5 includes large expanses of grassland with woody riparian vegetation in the floodplain. Less agricultural land conversion has occurred in Reach 5, with the majority of the land held in Federal and State ownership and managed for wildlife habitat.

Bypasses

The Chowchilla and Mariposa bypass systems consist of a series of dams, bifurcation structures, bypasses, levees and portions of the main river channel. The bypass system is managed for flood conveyance thus any occurrences of fish or establishment of aquatic habitats in the bypasses depends on intermittent routing of flood flows through the bypass system. The Chowchilla Bypass is 600-700 feet wide with sand deposits and vegetation that are occasionally dredged and removed. (SJRRP 2010). Much of the bypasses contain upland vegetation consisting of grasses and ruderal vegetation with some side patches of riparian vegetation.

Mariposa Bypass

Reach 2 of the Eastside Bypass extends from the Sand Slough Bypass confluence to the head of the Mariposa Bypass. Reach 3 of the Eastside Bypass extends from the head of the Mariposa Bypass to the head of San Joaquin River Reach 5 and receives flows from Deadman, Owens, and Bear creeks. The Mariposa Bypass extends from the Mariposa Bypass Bifurcation Structure to the head of San Joaquin River Reach 4B2. A drop structure located near the downstream end of the Mariposa Bypass dissipates energy from flows before they enter the mainstem San Joaquin River (Reclamation 2009a).

Eastside Bypass

The Eastside Bypass extends from the confluence of Ash Slough and Chowchilla Bypass to the confluence with the San Joaquin River at the head of Reach 5.

Upland vegetation at the Eastside Bypass consists of grassland and ruderal vegetation. In the Grasslands Wildlife Management Area (WMA), riparian trees and shrubs have a patchy distribution along the banks of the Eastside Bypass. The lower Eastside Bypass has some side channels and sloughs that support remnant patches of riparian vegetation (SJRRP 2010).

Aquatic Habitat

The existing fish and wildlife resources have been described in the draft Biological Assessment dated October 2009, Fish Management Plan dated November 2010, and the Second ADPEIS/R dated September 2009. Additionally, many reports and papers have been written over the years that discuss the evolution of the San Joaquin River and California's Central Valley. Primarily these reports and papers emphasize how water supply needs have dictated river channelization and control of flows for agricultural needs. The San Joaquin River no longer is a dynamic river system with meandering channels and oxbows. In its current state much of the San Joaquin River is dry almost year round. The high demand for water has depleted the ground water table, increased salt concentrations and can increase contaminant loading at certain times of the year.

Throughout the project area, physical barriers, reaches with poor water quality or no surface flow, and the presence of false migration pathways have reduced habitat connectivity for anadromous and resident native fishes. Structures that impede both upstream and downstream fish movements are located throughout the reaches, and include drop structures, head and radial gates, control structures, gravel mining pits, and dams. Potential false pathways are formed by the bypass and canal systems, including Salt Slough, Mud Slough, Bear Creek, Lone Willow Slough, Mariposa Bypass, Eastside Bypass, and Arroyo Canal.

These modifications to the river channel, coupled with stream flow regulations, have altered the fish assemblages in the San Joaquin River by providing habitat for invasive species, including largemouth bass, spotted bass, green sunfish, black crappie, and striped bass (McBain and Trush 2002, DFG 2007). Furthermore, current land use practices and associated modifications have substantially reduced the size and diversity of riparian habitat along the river channel, thus limiting habitat for riparian- and floodplain-dependent species and providing less shaded riverine aquatic (SRA) cover area for native stream fishes, resulting in higher water temperatures. The current and past gravel mining operations likely increase fine sediment deposition in the San Joaquin River, which potentially embeds spawning gravels and reduces aquatic invertebrate production by filling in the interstitial space between gravels where invertebrates reside.

Water Quality

Water quality in the San Joaquin River is degraded by point and non-point discharges from agricultural runoff (tailwater and subsurface irrigation water), urban runoff of pesticides and other organic compounds, with additional contributions from other industrial sources not completely characterized. The California State Water Resources Control Board designated 100 miles of the San Joaquin River, including the reach in Merced County, as an impaired water body in 1990 (SJVDP 1990). Additionally, the river is currently listed as impaired for 53 pollutants such as metals, pesticides and pathogens, but only 14 of the listed pollutants have approved Total Maximum Daily Load requirements. The stretch of river downstream of the confluence with the Merced River is impaired by around half of these 53 pollutants; upstream of Mud Slough, by 16 of the 53 pollutants. The major source of selenium contamination downstream of Mud Slough is from agricultural subsurface drainwater discharge, managed mainly by the ongoing Grassland Bypass Project.

Endangered Species

There are 38 special status species that may occur in the project area according to the Service’s species list and the California Natural Diversity Database, and include: blunt-nosed leopard lizard (*Gambelia sila*), giant garter snake (*Thamnophis gigas)*, vernal pool crustaceans (*Branchinecta* spp.) and valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*). Critical habitat is designated within the area for several species including: vernal pool plants and crustaceans, California tiger salamander (*Ambystoma californiense*), delta smelt (*Hypomesus transpacificus*), San Joaquin kit fox (*Vulpes macrotis mutica*), blunt-nosed leopard lizard, and palmate-bracted birds beak (*Cordylanthus palmatus*). The Service has jurisdiction for all of the species listed above under the ESA. A list of all the special status species and habitats and the proposed conservation measures is in Appendix B.

The DFG has responsibility for State-listed species and species of concern such as the delta-button celery (*Eryngium racemosum*) and Swainson's Hawk (*Buteo swainsoni)*. The DFG should be contacted regarding any State-listed species or species of concern that may be impacted by project activities.

Per the Settlement and the SJRRS Act, NMFS has responsibility to permit the reintroduction of Central Valley spring-run Chinook salmon (*Oncorhynchus tshawytscha*) as threatened species within their jurisdiction, along with designating an experimental population. This permitting process is on-going. NMFS also has responsibility for four species that may occur in the project area including: green sturgeon (*Acipenser medirostris),* Central Valley steelhead *(Oncorhynchus mykiss*), Sacramento Valley winter-run Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley spring-run Chinook salmon, in addition to critical habitat for Central Valley steelhead under the ESA.

Under the Magnuson-Stevens Fishery Conservation and Management Act, NMFS also has responsibility for Essential Fish Habitat for Pacific salmonids and starry flounder (*Platichthys stellatus)*, both of which are present in the SJRRP footprint.

FISH AND WILDLIFE RESOURCES WITHOUT THE PROJECT

If the Project was not implemented, the overall degraded aquatic habitat conditions would remain throughout most of the Reaches and invasive plant species would continue to spread, and wildlife value within the riparian corridor would decline. Furthermore, aggregate mining activities within the floodplain would continue until aggregate sources were depleted and agricultural and grazing activities in the river floodplain would also continue.

Flow

Water releases from Friant Dam into the San Joaquin River would likely remain minimal without the Project. The only flows into the Restoration Area would be the occasional release of flood flows and the releases to meet the riparian rights holding contracts between Friant Dam and Gravelly Ford, agriculture return water and Delta water via the Delta-Mendota Canal operations. Much of the year the remaining Program reaches would remain dry.

Aquatic Habitat

Reclamation proposed that, without the project, the Restoration Area would continue to be managed under the current operations strategy. As a result, fishery resources downstream of Friant Dam within the area would likely decline, as adequate flows and temperatures would not be present during peak spawning and migration periods, and habitat availability would continue to be severely limited during critical larval and juvenile fish rearing periods. The current warm water fishery and trout fishery would continue to be supplemented by DFG.

Vegetation and Terrestrial Habitat

The remnant patches of riparian forest and shrub scrub would likely undergo some changes typically associated with a riparian system, but constrained and limited by the restriction associated with water demands and regulated flow releases. Regeneration of riparian species, especially willows and cottonwoods, in the area downstream of the dam would slowly decline, as this area is limited in its exposure to flooding because of the dam and water demands. This area would also continue to lose older heritage trees as they reach senescence and die off.

There would likely be no change to the types of wildlife species found in the area under existing conditions and without the project.

Water Quality

Currently water quality within the San Joaquin River system is impaired on many levels. Without additional flows into the system it is anticipated that the water quality would remain impaired and likely worsen as the demand for water increases across the Central Valley.

FISH AND WILDLIFE RESOURCES WITH THE PROJECT

The restoration goal of the SJRRP is to restore and maintain fish populations in “good condition” within the Restoration Area. To achieve this goal, the SJRRP will implement a number of actions that will substantially alter not only the aquatic ecosystem of the San Joaquin River, but also could substantially alter the river's riparian, wetland and some adjacent upland ecosystems. The Program is still in the early planning and alternative development stages for many of these actions, thus specific details will be addressed in subsequent documents.

Under the Settlement, riparian floodplain restoration is required in both the 2B and 4B Reaches of the San Joaquin River, which would incorporate about 8.5 river miles and 32.6 river miles, respectively, for a total of at least 40 miles of river restoration. The restoration of riparian areas adjacent to the San Joaquin River, and the preservation of current riparian habitat, could provide habitat for migratory and resident birds, nesting sites for birds of prey and colonial nesting waterbirds, and migratory corridors for forest-dependent wildlife.

Flows

Under the existing conditions, the San Joaquin River channel is not a hydrologically connected system, as bypass structures are currently used to divert water around sections of the historical river channel. The restoration and the re-connection of the San Joaquin River with its historical river channel in Reach 4B1 would provide substantial benefits for both fish and wildlife species. The riparian corridor along the historical channel can offer shaded overhead cover for aquatic biota and diverse habitat for terrestrial species, heterogeneous aquatic habitat, and a greater abundance of food resources for both aquatic and terrestrial biota. Furthermore, the naturally formed pools in the historical channel can stratify water temperatures, thus offering unique and suitable in-stream conditions for aquatic biota that cannot be duplicated in the uniform, riparian-deficient channels of the bypasses and flood conveyance networks.

In Normal-Dry, Normal-Wet and Wet years (based on the Restoration water-year type), Spring Rise and Pulse Flows in March and April would inundate floodplain areas and provide vital side channel habitats that could be used for spawning and rearing by salmonids and other native fishes (Moyle 2002). With higher flows in wetter years, the spring pulse could also increase vegetation recruitment by dispersing seeds above base flow water levels, and facilitate their germination (Kondolf 2005).

The numerous in-stream structures that were constructed to facilitate the delivery of water or modify flood flows (i.e., diversion dams, bypasses, drop structures, head gates, and radial gates) would be evaluated as part of the Project. The removal or the modification of these existing structures would provide clearer migratory pathways for adult salmonids, and greatly enhance passage for other native fishes and the outmigrating juvenile Chinook salmon.

Using the 1-D modeling, preliminary inundation maps have been developed. The mapping was developed to provide initial estimates of potential inundation depths and acres of existing areas along the San Joaquin River. The difference between water surface elevation and terrain elevation created a depth map. Several assumptions were made in the development of the preliminary mapping and include: removal of areas not considered existing floodplain or low-flow channel habitat (agricultural lands and gravel pits); all areas within levees are habitat; steady-state Friant releases. The results of the 1-D modeling over 3-D terrain surfaces ignores barriers to flow that could limit inundation in side channel at periods of lower flows. The preliminary inundation mapping results are displayed in Figure 4 and Figure 5.

A large amount of floodplain habitat exists in Reach 1A and Reach 5. About 17,000 acres would be inundated at 4,500 cfs without any channel improvements for Reaches 2B and 4B.

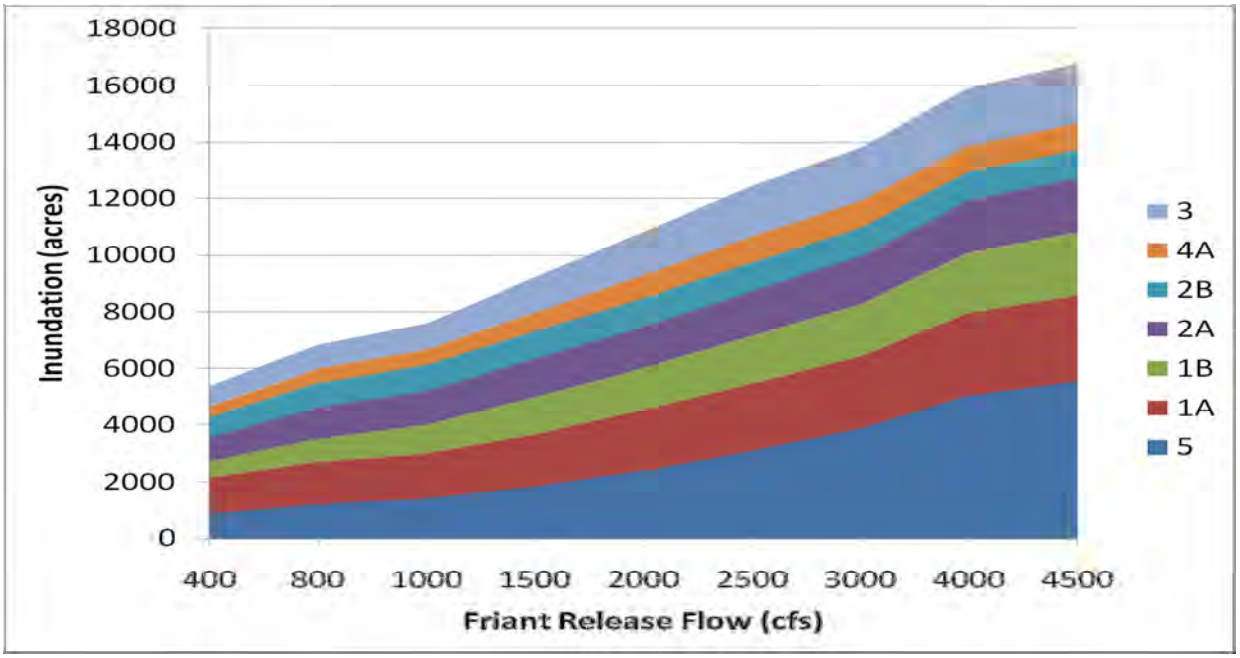


Figure 4. Total inundated acres by SJRRP Reach, under existing conditions.

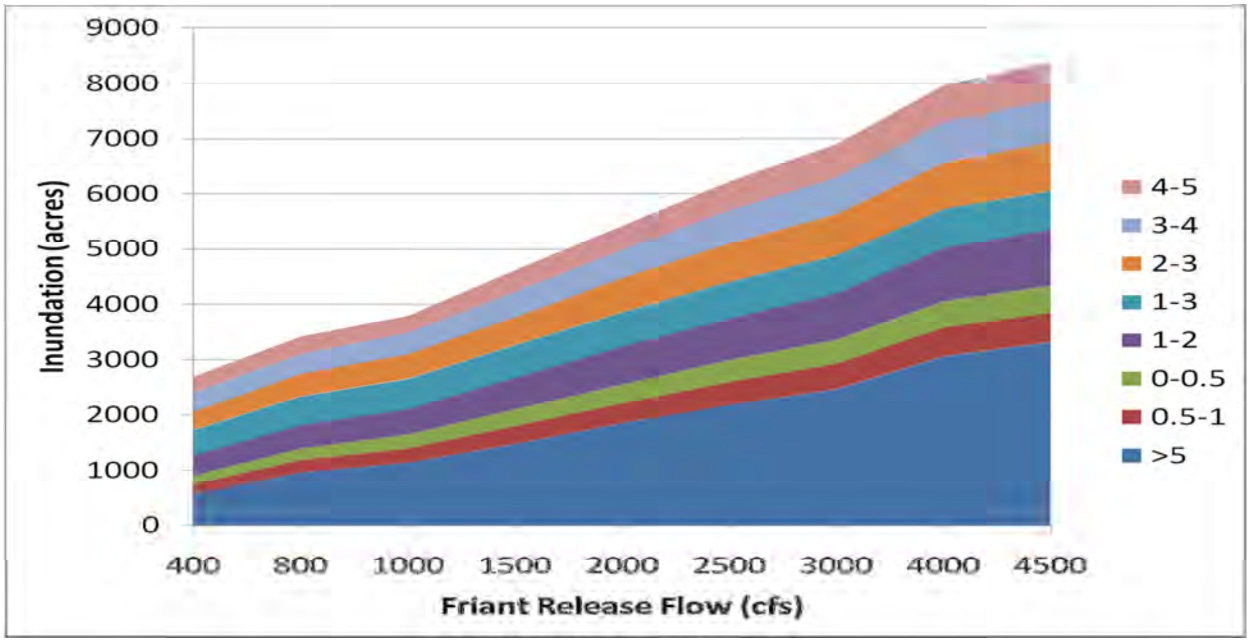


Figure 5. Total inundation acreages by depth (in feet) for the entire Restoration Area, under existing conditions.

Aquatic Habitat

As documented in the Second ADPEIS/R, the restoration activities, floodplain creation, structural modifications, and Restoration flows associated with the Project would provide an array of benefits for the aquatic biota of the San Joaquin River.

In general, the re-creation of the historical floodplain of the San Joaquin River could provide a significant benefit, as floodplains can harbor flood flows and buffer flood risk, as well as considerably increase the amount and diversity of available aquatic areas, by providing low-velocity refuge, overhead cover and an abundant food source for aquatic organisms. These factors could enhance the populations of declining Central Valley fish species and imperiled fauna, such as the Federally-listed spring-run Chinook salmon and the State-listed western pond turtle.

The availability of floodplain habitat along the San Joaquin River may enhance juvenile salmonid survival and increase the likelihood of adults returning to spawn, thus achieving one of the Settlement goals by restoring naturally reproducing, viable spring and fall-run Chinook salmon populations. The Fisheries Management Plan (SJRRP 2010) describes in more detail how Restoration flows can further assist in achieving this Settlement goal and thus provide conditions suitable for the enhancement of salmonid populations and those of other native fauna. By implementing and adaptively managing the Restoration flows, releases could provide sufficient flows to ensure habitat connectivity throughout the San Joaquin River system and allow for unimpeded upstream passage and migration of salmonids and other fishes.

Once spring-run Chinook salmon are established in the San Joaquin River system, the range of spring-run would be substantially increased and could provide a possible future source of fish to help bolster declining populations, if local habitat conditions or climate change impacts occur in other tributaries. The return of salmonids to the San Joaquin River could also have substantial localized effects on the riverine system as well. The marine derived nutrients from carcasses deposited in the San Joaquin system would likely increase the diversity, abundance and fitness of species utilizing that system. For instance, it could increase macroinvertebrate abundance and thus provide a greater food source for numerous species.

Vegetation and Terrestrial Habitat

Restored riparian vegetation would not only provide shaded habitat for instream biota, but could connect historic riparian tracts and woodlands that serve as forested habitat for a diversity of breeding and migratory songbirds, provide nesting sites for birds of prey and colonial nesting waterbirds, and act as travel corridors for wildlife.

Riparian systems are one of our most important and most neglected natural resources in California. While small in total area when compared to California's size, they are of special value as wildlife habitat. Over 135 species of birds such as the willow flycatcher, yellow-billed cuckoo and red-shouldered hawk either completely depend upon riparian habitats or use them preferentially at some stage of their life history. Riparian habitat provides food, nesting habitat, cover, and migration corridors. Another 90 species of mammals, reptiles, invertebrates and amphibians; such as California red-legged frog, valley elderberry longhorn beetle and riparian brush rabbit, depend on riparian habitats. Riparian habitat also provides riverbank protection, erosion control and improved water quality, as well as numerous recreational and aesthetic values.

The SJRRP Invasive Species Management Plan (ISMP) includes ways to remove and control invasive and exotic species as well as monitoring for the potential spread of invasive due to restored flows. Reclamation is working to develop and implement the ISMP.

Water Quality

The Restoration Flows in the San Joaquin River channel would provide continuous flows throughout the year, which would help buffer high temperatures and provide adequate dissolved oxygen levels for aquatic species during the summer months. With increased releases, the agricultural run-off would be diluted, and effects of in-stream contaminants would be minimized. However, more water quality monitoring is still needed to gain a better overall understanding of the system and to inform decisions regarding the timing and magnitude of Restoration Flow releases to obtain appropriate water quality standards.

FISH AND WILDLIFE PLANNING OBJECTIVES

Planning Objectives

Public trust doctrine obligates the State and Federal governments to actively manage and conserve fish and wildlife resources for current and future public benefits. The States have broad responsibilities for all wildlife within their borders, and the Service has particular responsibility for certain species and habitats under the Migratory Bird Treaty Act (MBTA), ESA, and the designated National Wildlife Refuge lands.

To fulfill public trust responsibilities, the Service has regulations and policies that recognize the importance of riparian and wetland habitats to fish and wildlife. Thus, one of the Service's long-term planning objectives is to maintain existing habitats and enhance and restore degraded habitats. These objectives are consistent with section 2(a) of the FWCA "…with a view to the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof in connection with such water-resource development."

The mission of the National Wildlife Refuge System is to conserve a network of lands and water for the conservation and management of fish, wildlife and plant resources of the United States for the benefit of present and future generations. As part of the system, the three units – Merced NWR, San Luis NWR and Grasslands WMA - addressed in the Comprehensive Conservation Plan provide a haven for a unique assemblage of both wetland (particularly waterfowl and other waterbirds) and upland dependent wildlife species of California's Central Valley.

Responsibilities and Evaluation

Reclamation is the lead Federal agency responsible for compliance with the NEPA. Compliance with NEPA and CEQA has resulted in preparation of the ADPEIS/R. Reclamation is also consulting with the Service and NMFS pursuant to section 7 of the ESA.

The Service is one of five Implementing Agencies responsible for the implementation and management of the SJRRP and has been participating in the planning associated with the NEPA/CEQA process for this project for some time. The Service continues to provide technical assistance and recommendations to the SJRRP planning and permitting processes through the staff working in the co-located SJRRP Office, the Environmental Compliance and Permitting Working Group, and the Fisheries Management Work Group. The Service has provided comments and recommendations to Reclamation regarding the SJRRP since October 2006. The partnership opportunities fostered by this coordination have served as a key underpinning of successful efforts to streamline environmental reviews and help create positive solutions for the Program and natural resource conservation.

DISCUSSION

The decisions and recommendations regarding impacts and compensation by specific habitat type cannot be determined at this time. Further development of the Program level actions and investigation of the Common Restoration Actions mentioned in the Settlement needs to occur. Additionally, other considerations may arise through further modeling and monitoring and these may influence future SJRRP planning. These include: new understanding about the specific needs of salmon for the San Joaquin River, vegetation and planting plans, toxicity monitoring of the system, fish passage needs, and groundwater stabilization. The Implementing Agencies will continue to work together in the development of the SJRRP and additional environmental compliance, including FWCA reports, will be completed which evaluate impacts more specifically.

The recommendations provided herein for the protection of fish and wildlife resources are in accordance with the Service's Mitigation Policy as published in the Federal Register (46:15; January 23, 1981). The Mitigation Policy provides Service personnel with guidance in making recommendations to protect or conserve fish and wildlife resources. The policy helps ensure consistent and effective Service recommendations, while allowing agencies and developers to anticipate Service recommendations and plan early for mitigation needs. The intent of the policy is to ensure protection and conservation of the most important and valuable fish and wildlife resources, while allowing reasonable and balanced use of the Nation's natural resources.

Under the Mitigation Policy, resources are assigned to one of four distinct Resource Categories, each having a mitigation planning goal which is consistent with the fish and wildlife values involved. The Resource Categories cover a range of habitat values from those considered to be unique and irreplaceable to those believed to be much more common and of relatively lesser value to fish and wildlife. The Mitigation Policy does not apply to threatened and endangered species, Service recommendations for completed Federal projects or projects permitted or licensed prior to enactment of Service authorities, or Service recommendations related to the enhancement of fish and wildlife resources.

In applying the Mitigation Policy during an impact assessment, the Service first identifies each specific habitat or cover-type that may be impacted by the project. Evaluation species which utilize each habitat or cover-type are then selected for Resource Category analysis. Selection of evaluation species can be based on several rationales, as follows: (1) species known to be sensitive to specific land- and water-use actions; (2) species that play a key role in nutrient cycling or energy flow; (3) species that utilize a common environmental resource; or (4) species that are associated with Important Resource Problems, such as anadromous fish and migratory birds, as designated by the Director or Regional Directors of the Fish and Wildlife Service. (Note: Evaluation species used for Resource Category determinations may or may not be the same evaluation species used in a Habitat Evaluation Procedures (HEP) application, if one is conducted). Based on the relative importance of each specific habitat to its selected evaluation species, and the habitat's relative abundance, the appropriate Resource Category and associated mitigation planning goal are determined.

Mitigation planning goals range from “no loss of existing habitat value” (i.e., Resource Category 1) to “minimize loss of habitat value” (i.e., Resource Category 4). The planning goal of Resource Category 2 is “no net loss of in-kind habitat value;” to achieve this goal, any unavoidable losses would need to be replaced in-kind. “In-kind replacement” means providing or managing substitute resources to replace the habitat value of the resources lost, where such substitute resources are physically and biologically the same or closely approximate those lost.

In addition to mitigation planning goals based on habitat values, Region 8 of the Service, which includes California, has a mitigation planning goal of no net loss of acreage and value for wetland habitat. This goal is applied in all impact analyses.

In recommending mitigation for adverse impacts to fish and wildlife habitat, the Service uses the same sequential mitigation steps recommended in the Council on Environmental Quality's regulations. These mitigation steps (in order of preference) are: avoidance, minimization, rectification of measures, measures to reduce or eliminate impacts over time, and compensation.

Resource Categories

Table 4 shows a breakdown of the potential cover-types, Resource Category designation and mitigation goal for the habitats in the Restoration Area. Open water was not placed in a Resource Category because it would be benefitted by the project.

Table 4. Resource categories and mitigation planning goal for the habitats possibly impacted by the proposed SJRRP.

COVER-TYPE	RESOURCE CATEGORY	MITIGATION GOAL
Riparian Scrub Shrub	2	No net loss of in-kind habitat value or acreage.
Riparian Forest	2	No net loss of in-kind habitat value or acreage.
Emergent Marsh	2	No net loss of in-kind habitat value or acreage.
Annual grassland	3	No net loss of habitat value while minimizing loss of in-kind habitat value.
Agriculture/Orchard	4	Minimize loss of habitat value

Riparian Forest and Riparian Scrub Shrub

Evaluation species for the riparian forest and riparian scrub-shrub habitats that would be impacted are: red-shouldered hawks, wood ducks, and northern orioles. Woody riparian vegetation provides important cover, roosting, foraging, and nesting habitat for these species. Large diameter trees also provide critical nesting sites for species such as wood ducks and red-shouldered hawks. Riparian forest and riparian scrub-shrub cover-types are of generally high value to the evaluation species, and are overall, extremely scarce (less than 2 percent remaining from pre-development conditions). Therefore, the Service designates that any riparian forest or riparian scrub-shrub cover-type that would be impacted by the project should be placed in

Resource Category 2, with an associated mitigation planning goal of "no net loss of in-kind habitat value."

Emergent Marsh

The emergent marsh habitat in the project area consists of narrow areas of cattails and bulrush on the edge of the river channels, around sloughs and upstream of Mendota Pool. Evaluation species selected for the emergent marsh cover-type are the marsh wren, red-winged blackbird, and song sparrow. These species were selected because of the Service's responsibility for the protection and management of these species under the Migratory Bird Treaty Act. The Service designates the emergent marsh areas in the project as Resource Category 2. Our associated mitigation goal for these areas is "no net loss of in-kind habitat value."

Annual Grassland

Annual grassland areas include grasslands, levee slopes, and other mainly herbaceous areas. An evaluation species for the grassland habitat type is the red-tailed hawk, which utilizes these areas for foraging. This species was selected because of the Service's responsibility for its protection and management under the Migratory Bird Treaty Act. Grassland areas potentially impacted by the project would vary in their relative values to the evaluation species, depending on the degree of human disturbance, plant species composition, availability of prey species, juxtaposition, and magnitude and frequency of flooding and irrigation. Therefore, the Service designates the grassland areas in the project as Resource Category 3. Our associated mitigation goal for these areas is "no net loss of habitat value while minimizing loss of in-kind habitat value."

Agriculture/Orchard

The agriculture/orchard cover-type for this project consists of managed almond, apricot, pistachio and citrus orchards, and row crops such as tomatoes and alfalfa. An evaluation species for this cover-type includes raptors and mourning doves. Orchards provide raptors and mourning doves perching sites, cover and foraging areas. This cover-type in the project area is assumed to be low to moderate quality and value. The Service designates the orchard habitat as Resource Category 4. Our associated mitigation planning goal is "minimize loss of habitat value."

Determination of Mitigation Ratios

Mitigation recommendations provided by Service are made pursuant to the FWCA and are consistent with the Service's Mitigation Policy. Avoiding, minimizing, and/or rectifying adverse impacts to fish and wildlife species is the Service's goal in making mitigation recommendations. When compensatory mitigation is recommended it is generally quantified using a habitat assessment procedure such as Habitat Evaluation Procedures (HEP). HEP is a methodology developed by the Service and other State and Federal resource and water development agencies which can be used to document the quality and quantity of available habitat for selected fish and wildlife species. HEP provides information for two general types of habitat comparisons:

(1) the relative value of different areas at the same point in time; and (2) the relative value of the same areas at future points in time. By combining the two types of comparisons, the impacts of proposed or anticipated land-use and water-use changes on habitat can be quantified. In a similar manner, any compensation needs (in terms of acreage) for the project can also be quantified, provided a mitigation plan has been developed for specific alternative mitigation sites.

For planning purposes, an understanding of possible compensatory mitigation scenarios associated with habitat types which may be impacted from construction and changes in inundation is important. The footprints for the various elements of the SJRRP are still in development; therefore a habitat assessment to attain specific values for those habitats has not been completed. However, as the Common Restoration Actions are investigated further and developed, a HEP could be completed.

Some plausible mitigation ratios that could be used for current planning needs are the general mitigation standards for CALFED related projects that are contained in the Programmatic Record of Decision (ROD) (CALFED 2000a) and Multi-Species Conservation Strategy (MSCS) (CALFED 2000b). These standards and recommendations include compensation ratios for adverse effects on habitats (Table 5).

Table 5. A range of compensation ratios for potential impacts to habitats from the SJRRP, for planning purposes.

Habitat Types	Compensation Ratios (acres) CALFED MSCS
Riparian Forest/Scrub	2:1 to 5:1
Woodland/Savanna	2:1 to 5:1
Emergent Marsh	2:1 to 5:1
Annual Grassland	1:1 to 3:1
Agriculture/Orchard	1:1 to 3:1

The following benefits are expected from the SJRRP and thus would influence the ratios and compensation recommendations in future supplemental FWCA reports for the SJRRP.

1. SJRRP is expected to Benefit Riparian Vegetation.

Increased instream flows from the Restoration Project are expected to benefit riparian vegetation. To assume a benefit, present flow regimes must be assumed to limit the area and/or quality of riparian habitat. This assumption appears valid since prior to the SJRRP Interim Flows, the flow regime was much reduced. The SJRRP will release flows into Reaches 2A, 4A and 4B1, which have historically been dry, and will increase flows in Reach 1, 2B, and 3, which historically only included water supply deliveries except during flood releases. Riparian ecosystems are also maintained, in part, by groundwater (Ewing 1978). Higher flows provided by the Project could potentially increase levels of groundwater along the San Joaquin River and area tributaries over time, and enable establishment of more riparian vegetation and wider riparian corridor than at present. Because newly established vegetation must keep close contact with groundwater as instream flows recede in the summer, higher elevations of groundwater also should increase survival of newly established vegetation.

In addition, research suggests that riparian vegetation is especially sensitive to minimum and maximum instream flows (Auble et al. 1994). Flows would be increased dramatically (up to 3000 percent in some locations) during the primary growing season of riparian vegetation. Because positive correlations between rate of instream flow and rate of tree ring growth have been observed for riparian vegetation in California (Stromberg and Patten 1990), increased minimum flows would be expected to increase growth rates of riparian habitat. Pulse flows to move sediment can create aquatic habitat downstream that can be colonized by pioneering riparian vegetation, but also used as important fish habitat. To assume a riparian habitat benefit from increased minimum flows combined with pulse flows, it must be assumed that the net effect on riparian habitat over time would be positive due to large areas of increased instream flow provided by the Project.

2. Spatial Extent of Expected Benefit is Large.

Increased minimum instream flows and floodplains are expected to re-establish and/or enhance riparian habitat over a substantial spatial area. The extent of possible restored floodplain within existing levees is about 17,000 acres. However, the existing levee system may not be sufficient to hold the sustained flows called for in the Settlement, so new levee alignments may be developed for sections for the Restoration Area.

The distance that riparian habitat would be benefited perpendicular to the river varies depending on geologic composition and topography. The land area that would be affected by increased groundwater and have suitable slopes and soils for establishing riparian vegetation is unknown, but a positive correlation might exist between this area and wetted habitat area.

3. Expected Benefit Would Occur in Proximity to Adverse Effects.

The location of expected habitat benefits is within the Project area.

4. Expected Habitat Benefits Are In-kind.

Benefits from the Restoration to riparian habitat would be in-kind with riparian habitat values lost. It is expected that riparian habitat that is re-established and/or enhanced due to increased instream flows would have similar plant composition and be used by similar assemblages of animal species as habitat lost.

5. Expected Benefits to Habitat Would Benefit Fish and Wildlife.

Establishment of new riparian habitat areas and enhanced growth of existing riparian vegetation would be expected to benefit fish and wildlife species affected by, or using, the riparian zone. The multiple layers of riparian vegetation along rivers and streams, in association with edges of adjacent plant communities and streams, create a diverse physical structure that provides food, water, cover, and shade for a diversity of amphibians, reptiles, birds, mammals, and invertebrates, including neotropical migrant birds, special status bats, and the valley elderberry longhorn beetle (USFWS 2003). Riparian communities also function as dispersal and migration corridors for many wildlife species.

An important associate of riparian habitat is SRA cover, which has ecosystem-level values. This near shore aquatic area occurring at the stream-riparian habitat interface consists of vegetation that either overhangs or protrudes into the water; instream woody debris, such as leaves, logs, branches and roots; and often substantial amounts of detritus (USFWS 1992). SRA cover provides high quality food and cover for fish, amphibians, and terrestrial wildlife that use riparian and aquatic edge habitat (USFWS 1992). The amount of SRA cover present along the San Joaquin River has not been inventoried. Because SRA cover is largely associated with riparian vegetation and wetted habitat area, higher minimum instream flows and groundwater levels from the Project would be expected to enhance SRA cover.

6. The Restoration Project is Expected to Benefit Riparian Ecological Processes.

Restoring larger flows to the San Joaquin River System may not restore riparian ecosystems to pre-dam conditions (Shafroth et al. 2002), but would restore valuable components of riparian ecosystems. Enhanced SRA cover would be expected to provide greater input of leaves, woody material, and insects into the stream ecosystem. Increased minimum flows should better transport and distribute these materials downstream. Additionally associated riparian vegetation in side channels and backwaters areas could be sustained and these habitats combined with other riparian habitats on the San Joaquin River, could provide better connectivity, and more effective filtering for better water quality.

7. Expected Riparian Habitat Benefits Would be Monitored.

The SJRRP would develop a strategy to monitor riparian habitat for both benefits and adverse effects from the Project. This strategy would become part of the Project's Adaptive Management Plan. The strategy could include aerial photograph analyses of riparian habitat throughout the project area for existing conditions and at some specified intervals following Project construction and release of full Restoration Flows, ground monitoring of the riparian vegetation community, and invasive species monitoring. This strategy could also include an operations and maintenance

plan for any habitat created within the newly created floodplain. This plan should be coordinated with the Service and the entity responsible for long-term maintenance of the site.
Studies along the Sacramento River have shown not only are localized restoration projects successful in providing habitat for species fairly rapidly, but they also produce positive spill-over effects. For example increases in abundances of bird species occur not only locally, but also across the larger riparian landscape (Gardali et al. 2006). Equally important is restoring the natural riverine processes where possible within the San Joaquin River. This is needed so that riparian areas, and their remnant counterparts, can be rejuvenated, lost, and created as necessary to meet the diverse life-history needs of the native species that have evolved in the system. Additionally, the Service would like to see the restored floodplain remain hydraulically connected to the river, allowed to meander somewhat, and the flow regime managed to meet ecological as well as human needs.

RECOMMENDATIONS

Based on the information contained in the draft PEIS/R, the Conservation Strategy, and the Fish Management Plan, the SJRRP has the potential to vastly improve the diversity, quality, and quantity of habitat along the San Joaquin River system, thus benefiting a variety of resident and migratory wildlife species, especially riparian dependent species such as migratory birds, amphibians, and fish species.

The Service recommends:

- Construction or modification of riverine structures, such as fish ladders at dams, incorporate designs that accommodate and improve passage for all native fishes, including lamprey. Lamprey struggle to negotiate standard sharp-edged fish ladder baffles and thus require specific modifications, such as rounded corners and "lamprey slots," like those used at the Coleman National Fish Hatchery on the new barrier weir (Pers. Comm. Damon Goodman 3/4/2010).

- Restoration actions should be prioritized for bird conservation taking into account the surrounding land use and surrounding landscape conditions, such as the proximity and prevalence of other natural areas, urban areas, agricultural areas, or brown-headed cowbird foraging areas (RHJV 2004). For example, areas near unimproved parks/open spaces (provided substantial invasive species issues do not exist) and appropriately managed grazing areas. Brown-headed cowbirds may commute more than 12 kilometers (7.45 miles) between foraging grounds and the nest sites of their hosts (Mathews and Gougen 1997). Brown-headed cowbirds can have a significant impact on the reproductive success of species including the least bell's vireo, whose small populations are frequently parasitized by the brown-headed cowbird.

- Flow releases should be managed, to the extent possible, to align with the near natural hydrograph (i.e., mimic natural flood events) sufficient to support scouring, deposition, and point bar formation. However, timing of pulse flows should be time managed to avoid detrimental impacts to bank swallow nesting colonies and should not raise levels more that 2-3 feet during the breeding season (April-July) (RHJV 2004).

- Continuance of the collaborative approach to the planning and implementation of this Program with the Service.

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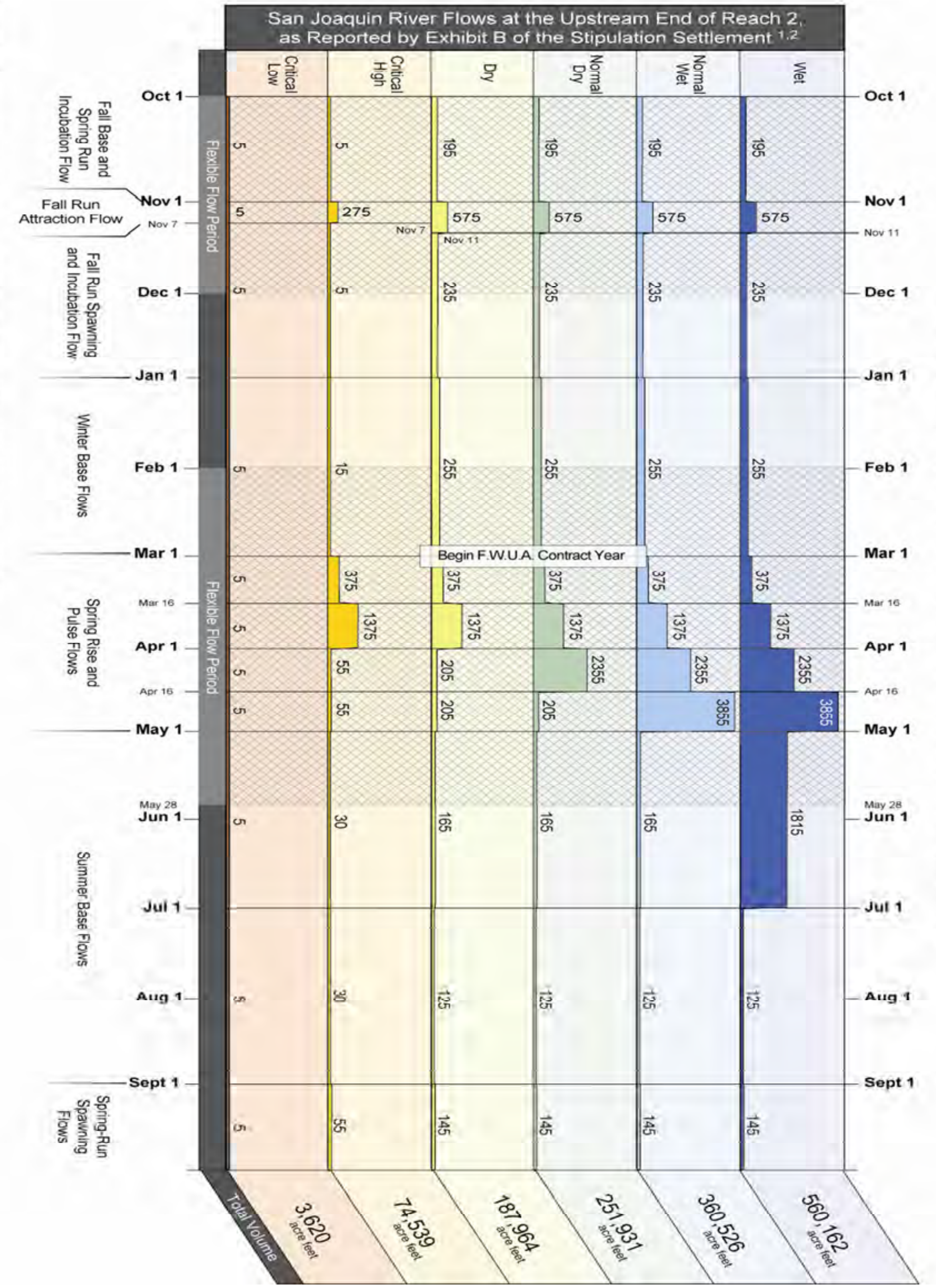
Personal Communication

Damon Goodman, Arcata Fish and Wildlife Service; Arcata, CA 95521, July 2009

Appendix A

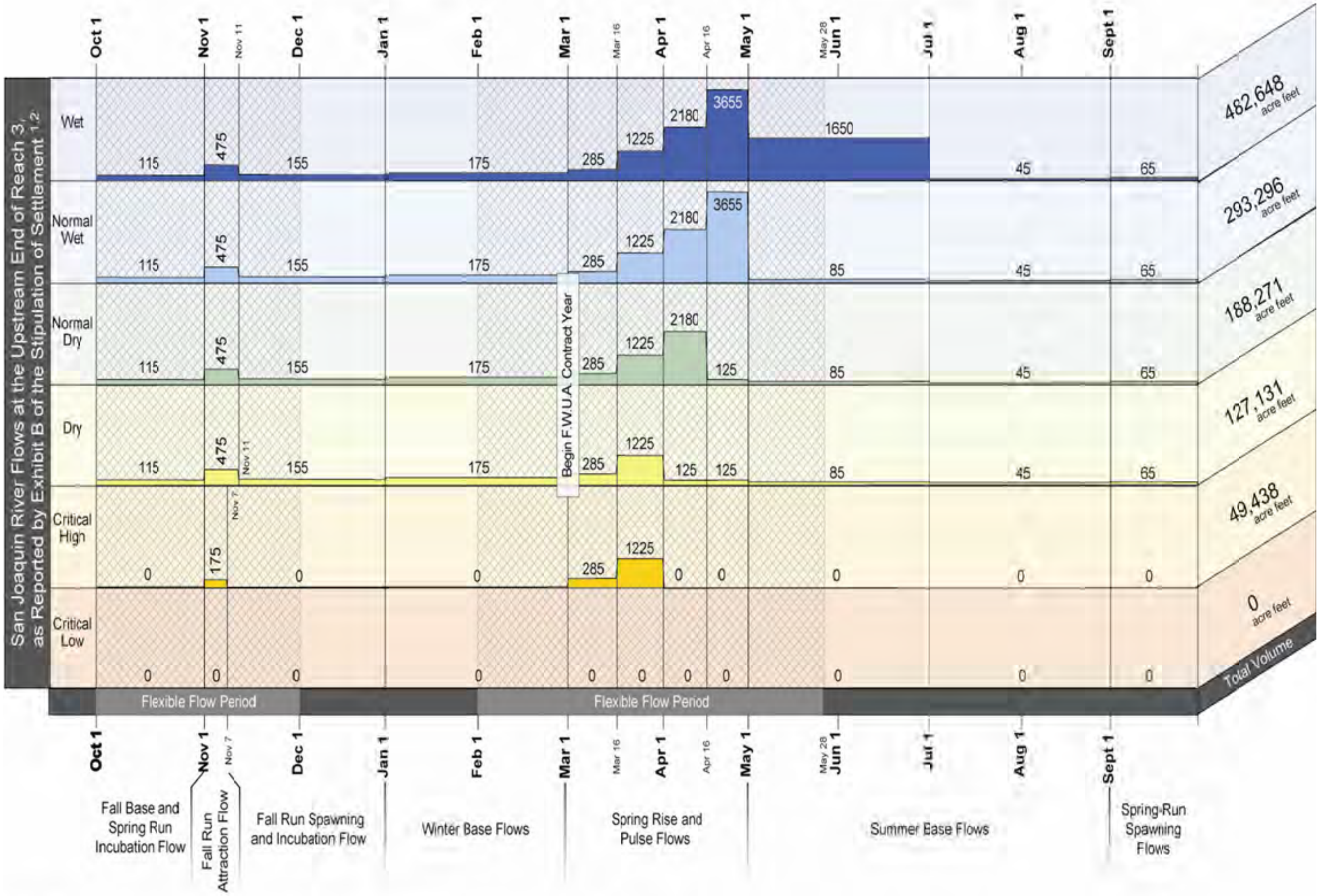


San Joaquin River Flows at the Upstream End of Reach 2, as Reported by Exhibit B of the Stipulation of Settlement[1,2]

1 - NRDC v Rodgers, Stipulation of Settlement, CIV NO. S-88-1658 - LKK/GGH, Exhibit B, September 13, 2006

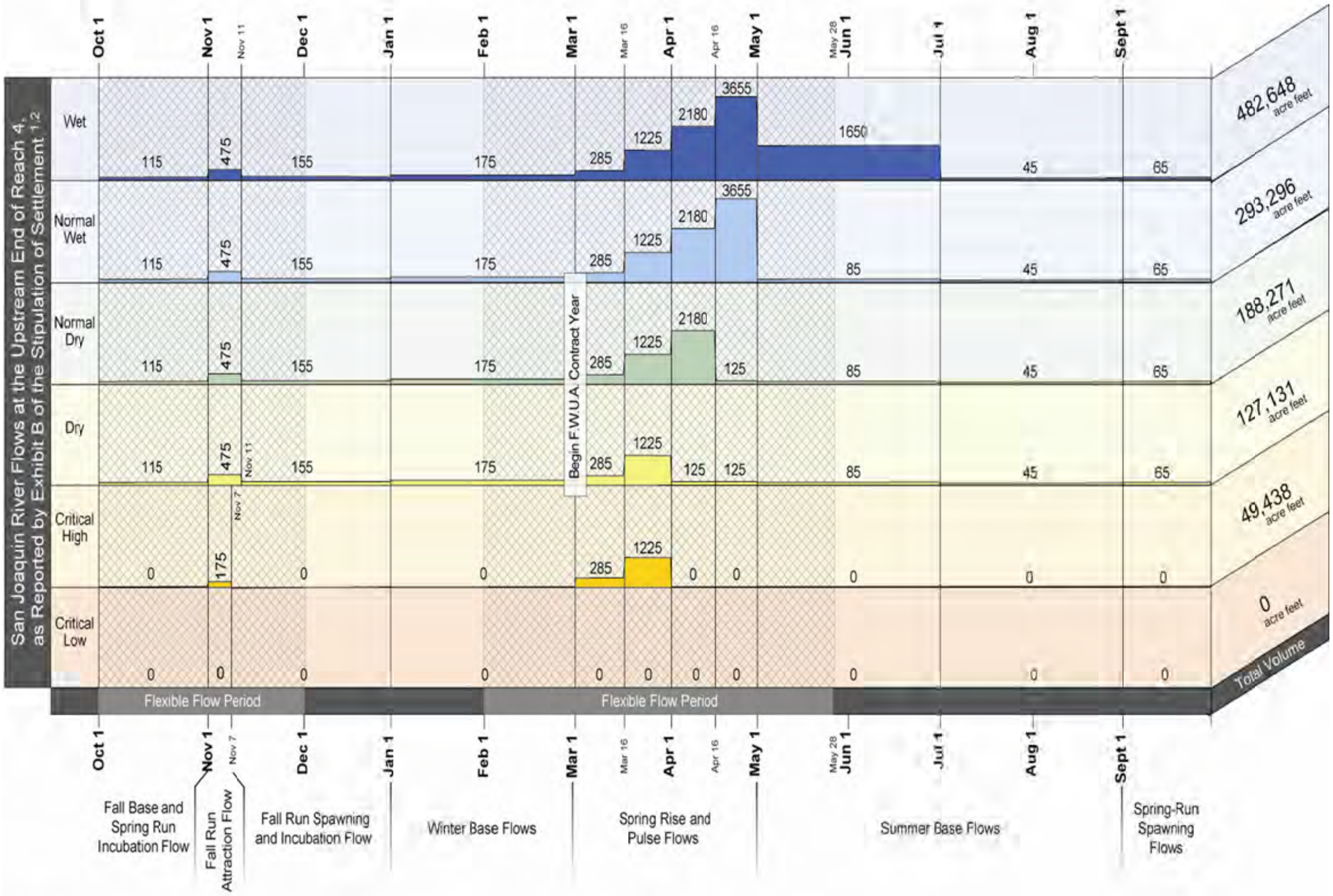
2 - Hydrographs reflect assumptions about seepage losses and tributary inflows which are specified in the settlement

San Joaquin River Flows at the Upstream End of Reach 3, as Reported by Exhibit B of the Stipulation of Settlement[1,2]



1 - NRDC v Rodgers, Stipulation of Settlement, CIV NO. S-88-1658 - LKK/GGH. Exhibit B. September 13, 2006
2 - Hydrographs reflect assumptions about seepage losses and tributary inflows which are specified in the settlement

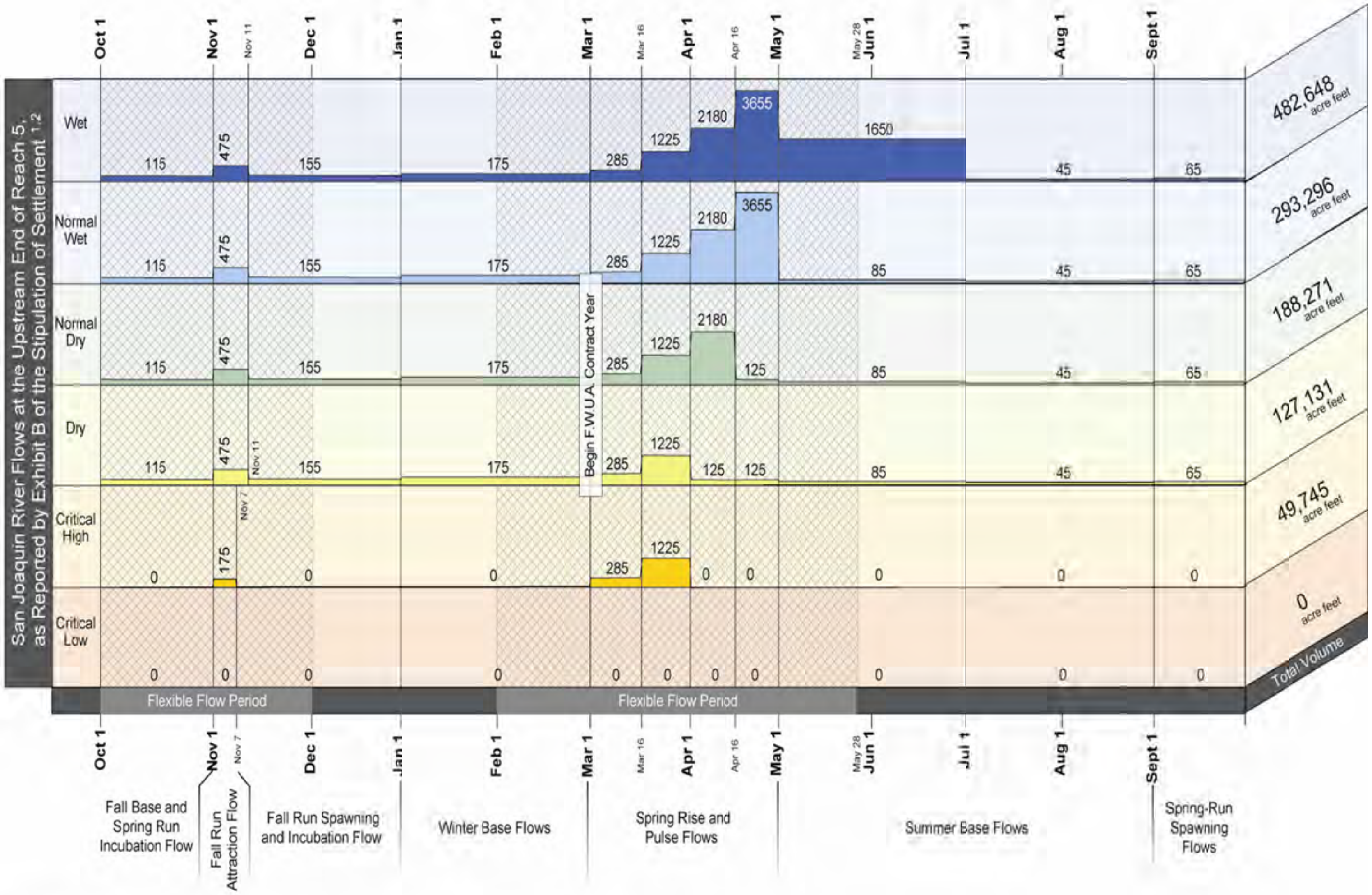
San Joaquin River Flows at the Upstream End of Reach 4, as Reported by Exhibit B of the Stipulation of Settlement[1,2]



1 – NRDC v Rodgers, Stipulation of Settlement, CIV NO. [illegible] Exhibit B. September 13, 2006

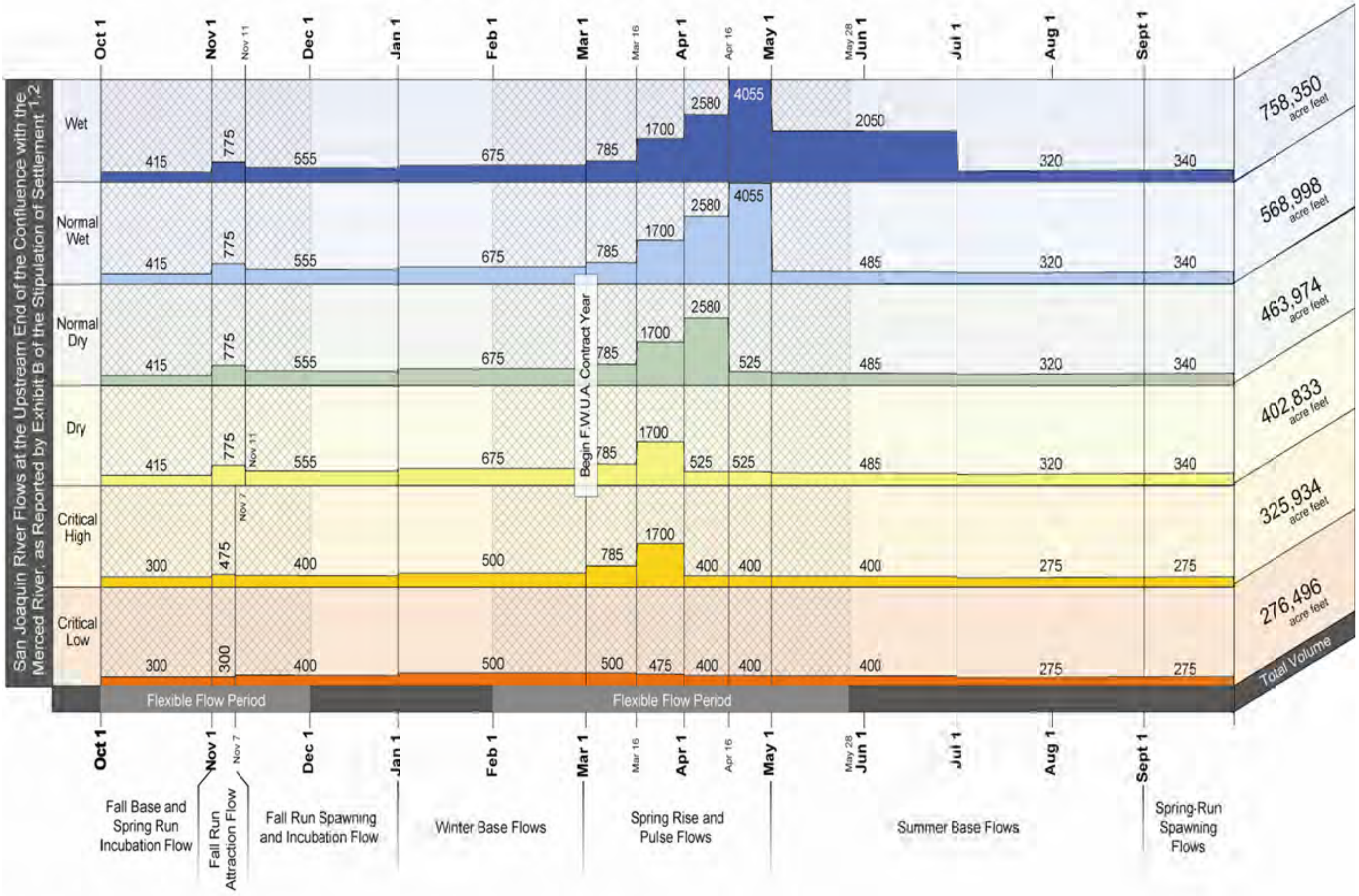
2 – Hydrographs reflect assumptions about seepage losses [illegible] are specified in the settlement

San Joaquin River Flows at the Upstream End of Reach 5, as Reported by Exhibit B of the Stipulation of Settlement[1,2]



1 - NRDC v Rodgers, Stipulation of Settlement, CIV NO. S-88-1658 - LKK/GGH Exhibit B. September 13, 2006
2 - Hydrographs reflect assumptions about seepage losses and tributary inflows which are specified in the settlement

San Joaquin River Flows at the Upstream End of the Confluence with the Merced River, as Reported by Exhibit B of the Stipulation of Settlement[1,2]



1 = NRDC v Rodgers, Stipulation of Settlement, CIV NO. S-88-1658 LKK/GGH, Exhibit B, September 13, 2006
2 = Hydrographs reflect assumptions about seepage losses and tributary inflows which are specified in the settlement

APPENDIX B- From the Project Description in the draft EIS/R
Conservation Measures for Biological Resources that may be affected by SJRRP Actions

Conservation Measure and Identifier	Description	Program or Project-Level Action	Implementing Agency	Reporting Agency
VP	Vernal pool habitats, fleshy (succulent) owl's clover, Hoover's spurge, Bogg's Lake hedge-hyssop, Colusa grass, San Joaquin Valley Orcutt grass, hairy Orcutt grass, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, vernal pool tadpole shrimp, and western spadefoot toad			
VP-1. Avoid effects to species for implementation of the SJRRP	a. A qualified biologist shall identify and map vernal pool and seasonal wetland habitat potentially suitable for listed vernal pool plants, invertebrates, and western spadefoot toad within the project footprint. b. Facility construction and other ground-disturbing activities shall be sited to avoid core areas identified in the Vernal Pool Recovery Plan (USFWS 2005) because conservation of these areas is a high priority for recovering listed vernal pool species	Project & Program	Lead Agency	USFWS DFG
VP-2. Minimize effects to species for implementation of the SJRRP	a. If vernal pools are present, a buffer around the microwatershed or a 250-foot wide buffer, whichever is greater, will be established prior to ground-disturbing activities around the perimeter of vernal pools and seasonal wetlands that provide suitable habitat for vernal pool crustaceans or vernal pool plants and remain until ground-disturbing activities in that area are completed. Suitable habitat and buffer areas will be clearly identified in the field by staking, flagging, or fencing. b. Appropriate fencing will be placed and maintained around all preserved vernal pool habitat buffers during ground-disturbing activities to prevent impacts from vehicles and other construction equipment. c. Additional worker awareness training and on-site biological monitoring shall occur during ground-disturbing activities to ensure buffer areas are being maintained.	Program	Lead Agency	Lead Agency
VP-3. Compensate for temporary or permanent loss of habitat for implementation of the SJRRP	a. If activities occur within the microwatershed or250 foot buffer for vernal pool habitat would be affected by the SJRRP, the Lead Agency will develop and implement a compensatory mitigation plan, consistent with USACE's and EPA's April 10, 2008 *Final Rule for Compensatory Mitigation for Losses of Aquatic Resources* (33 CFR Parts 325 and 332 and 40 CFR Part 230) and other applicable regulations and rules at the time of implementation that will result in no net loss of acreage, function, and value of affected vernal pool habitat. Unavoidable effects will be compensated through a combination of creation, preservation, and restoration of vernal pool habitat or purchase of credits at a mitigation bank approved by the applicable regulatory agency/agencies. b. Project effects and compensation will be determined in consideration of the Vernal Pool Recovery Plan goals for core areas, which call for 95 percent preservation for habitat in the Grasslands Ecological Area and Madera core areas, and 85 percent habitat preservation in the Fresno core area (USFWS 2005). c. Appropriate compensatory ratios for loss of habitat both in and out of core areas would be determined during coordination and consultation with USFWS and/or DFG, as appropriate.	Project & Program	Lead Agency	USFWS DFG

	d. If off-site compensation includes dedication of conservation easements, purchase of mitigation credits, or other off-site conservation measures, the details of these measures will be included in credits, or other off-site conservation measures, the details of these measures will be included in and developed as part of the USFWS and/or DFG coordination and consultation process. The plan will include information on responsible parties for long-term management, holders of conservation easements, long-term management requirements, and other details, as appropriate, for the preservation of long-term viable populations. Any impacts that result in a compensation purchase will be required to do so with an endowment for land management in perpetuity prior to any project groundbreaking activities.			
CH	Critical habitat			
CH-1. Avoid and minimize effects to critical habitat for implementation of the SJRRP	a. Designated critical habitats shall be identified and mapped. b. All SJRRP actions will be designed to avoid direct and indirect adverse modifications to these areas. c. Minimization measures, such as establishing and maintaining buffers around areas of designated critical habitat shall be implemented in the event that avoidance is not feasible.	Project & Program	Lead Agency	USFWS
CH-2. Compensate for unavoidable adverse effects on Federally designated critical habitat	a. If critical habitat may be adversely modified by the implementation of SJRRP actions, the area to be modified will be evaluated by a qualified biologist to determine the potential magnitude of the project effects (e.g., description of primary constituent elements present and quantification of those affected) at a level of detail necessary to satisfy applicable environmental compliance and permitting requirements. b. Implement compensatory conservation measures developed through section 7 consultation with USFWS. If off-site compensation includes dedication of conservation easements, purchase of mitigation credits, or other off-site conservation measures. The details of these measures will be included in and developed as part of the USFWS and/or DFG coordination and consultation process. The plan will include information on responsible parties for long-term management, holders of conservation easements, long-term management requirements, and other details, as appropriate, for the preservation of long-term viable populations. Any impacts that result in a compensation purchase will be required to do so with an endowment for land management in perpetuity prior to any project groundbreaking activities.	Project & Program	Lead Agency	USFWS
CTS	California tiger salamander			
CTS-1. Avoid and minimize effects to species for implementation of the SJRRP	a. Within one year prior to project construction activities, a qualified biologist shall identify and map California tiger salamander habitat within the project footprint. One week prior to ground-disturbing activities, a qualified biologist will survey for and flag the presence of ground squirrel and gopher burrow complexes. Where burrow complexes are present, a 250-foot buffer shall be placed in order to ensure avoidance and minimization of disturbance to the species. b. Facility construction and other ground-disturbing activities shall be sited to avoid areas of known California tiger salamander habitat and avoidance buffers. c. To eliminate an attraction to predators of the California tiger salamander, all food-related trash items such as wrappers, cans,	Program	Lead Agency	USFWS DFG

	bottles, and food scraps must be disposed of in closed containers and removed at least once every day from the entire project site.			
CTS-2: Minimize effects to species for implementation of the SJRRP	a. Before and during construction activities, construction exclusion fencing will be installed just outside of the work limit or around vernal pools where California tiger salamander may occur. This fencing shall be maintained throughout construction and will be removed at the conclusion of ground-disturbing activities. No vehicles will be allowed beyond the exclusion fencing. A USFWS-approved biological monitor shall be present on site, during intervals as recommended by USFWS, to provide inspection of the fencing. b. The biological monitor will be onsite each day during any wetland restoration or construction, and during initial site grading or development of sites where California tiger salamanders have been found. c. Before the start of work each day, the biological monitor will check for animals under any equipment to be used that day, such as vehicles or stockpiles of items such as pipes. If California tiger salamanders are present, they will be allowed to leave on their own, prior to the initiation of construction activities for the day. To prevent inadvertent entrapment of California tiger salamanders during construction, all excavated, steep-walled holes or trenches more than 1 foot deep shall be covered at the close of each working day by plywood or similar materials, or provided with one or more escape ramps constructed of earth fill or wooden planks. Before such holes or trenches are filled, they must be thoroughly inspected for trapped animals. d. Plastic monofilament netting (erosion control matting) or similar material shall not be used at the project site because California tiger salamanders may become entangled or trapped. Acceptable substitutes include coconut coir matting or tackified hydroseeding compounds. e. All ground-disturbing work shall occur during daylight hours. Clearing and grading will be conducted between April 15 and October 15, in coordination with USFWS and DFG, and depending on the level of rainfall and site conditions. f. Revegetation of project areas temporarily disturbed by construction activities will be conducted with locally-occurring native plants.	Program	Lead Agency	USFWS
CTS-3: Compensate for temporary or permanent loss of habitat for implementation of the SJRRP	a. If California tiger salamander or areas within 250 feet of California tiger salamander habitat would be affected by the SJRRP, the Lead Agency will develop and implement a compensatory mitigation plan in coordination with USFWS and DFG, as appropriate. Unavoidable effects will be compensated through a combination of creation, preservation, and restoration of habitat or purchase of credits at a mitigation bank approved by the regulatory agencies. b. If off-site compensation includes dedication of conservation easements, purchase of mitigation credits, or other off-site conservation measures, the details of these measures will be included in and developed as part of the USFWS and/or DFG coordination and consultation process. The plan will include information on responsible parties for long-term management, holders of conservation easements, long-term management requirements, and other details, as appropriate, for the preservation of long-term viable populations. Any impacts that result in a compensation purchase will be required to do so with an endowment for land management in perpetuity prior to any	Program	Lead Agency	USFWS DFG

	project groundbreaking activities.			
DBC	Delta button-celery			
DELTA-1. Avoid and minimize loss of habitat and individuals due to the implementation of the SJRRP	a. Comprehensive surveys to identify, quantify, and map occurrences of Delta button-celery will be conducted prior to potential impacts or inundation of Delta button-celery plants within the bypasses. Surveys will include remapping and recensus of the documented occurrences within Reaches 4B and 5 and the Eastside and Mariposa bypasses (DFG 2003) during at least 2 consecutive or nonconsecutive years when habitat conditions are favorable to detect the species to determine the population trend. Status updates for these occurrences will be provided to DFG. b. A Delta button-celery conservation plan will be developed and implemented that includes a preservation and adaptive management strategy for existing occurrences within the Restoration Area. The conservation plan will be developed in collaboration with DFG and other species experts and be supported by review of the existing literature, including information on species' life history characteristics, historic and current distribution, and microhabitat requirements.	Project & Program	Lead Agency	DFG
DELTA-2. Avoid and minimize loss of habitat and risk of take for implementation of SJRRP construction activities	a. If Delta button-celery plants are found on or adjacent to the project site, a 100-foot wide buffer will be established during construction activities that is clearly identified in the field by staking, flagging, or fencing around depressions, swales, or other features containing Delta button-celery plants. Construction-related activity will not occur within the occupied habitat and buffer areas. b. Additional worker awareness training and on-site biological monitoring shall occur to ensure buffer areas are being maintained.	Program	Lead Agency	Lead Agency

DELTA-3. Compensate for temporary or permanent loss of habitat for implementation of the SJRRP	a. Compensatory mitigation for Delta button-celery will be developed in consultation with DFG. Mitigation will include the development and implementation of habitat creation and enhancement designs to incorporate habitat features for Delta button-celery (e.g., depressions within seasonally-inundated areas) into floodplains with potentially suitable habitat conditions. Compensatory mitigation may also include efforts to establish additional populations in the Restoration Area or to enhance existing populations on or off site. Mitigation sites will avoid areas where future SJRRP activities are likely. The lead agency will obtain site access through a conservation easement or in-lieu fee title and will provide adequate funding to implement the required compensation measures and to monitor compliance with and success of the conservation measures. b. Establishment of new occurrences will be attempted by transplanting seed and plants from affected locations to created habitat or suitable, but unoccupied, existing habitat. c. Monitoring, performance criteria, and protective measures will be applied to compensatory mitigation sites. The replacement requirements, as well as any additional conservation and mitigation measures, will be determined in coordination with DFG.	Project & Program	Lead Agency	DFG
PALM	Palmate-bracted bird's beak			
PALM-1. Avoid and minimize effects to species for implementation of the SJRRP	a. A qualified botanist will identify and map the location of palmate-bracted bird's beak plants within the project footprint, within 1 year prior to the start of activities that may cause disturbance from either release of flows over 1,660 cfs or from ground disturbing actions. b. A 500-foot buffer shall be placed around occurrences of palmate-bracted bird's beak during construction activities, consistent with recommendations in the Recovery Plan for Upland Species of the San Joaquin Valley, California (USFWS 1998). The 500-foot wide buffer will be clearly identified in the field by staking, flagging, or fencing. Project activity will avoid buffer areas, and work awareness training and biological monitoring will be conducted to ensure that the buffer area is not being encroached upon and that effects are being avoided.	Project & Program	Lead Agency	USFWS DFG
PALM-2. Compensate for temporary or permanent loss of occupied habitat	a. A compensatory conservation plan shall be developed in coordination with USFWS and DFG, as appropriate. The conservation plan will require the Lead Agency to maintain viable plant populations in the Restoration Area and will identify compensatory measures for any populations affected. The conservation plan shall include monitoring and reporting requirements for populations to be preserved in or adjacent to construction areas or populations to be protected or enhanced off site. b. If relocation efforts are part of the conservation plan, the plan will include details on the methods to be used: collection, relocation/transplant potential, storage, propagation, preparation of receptor site, installation, long-term protection and management, monitoring and reporting requirements, and remedial action responsibilities should the initial effort fail to meet compensation requirements. c. If off-site compensation includes dedication of conservation easements, purchase of mitigation credits, or other off-site conservation measures, the details of these measures will be included in the conservation plan and must occur with full endowment for management in perpetuity prior to	Project & Program	Lead Agency	USFWS DFG

	groundbreaking. The plan will include information on responsible parties for long-term management, holders of conservation easements, long-term management requirements, and other details, as appropriate, for the preservation of long-term viable populations.			
VELB	Valley elderberry longhorn beetle			
VELB-1. Avoid and minimize effects to species for implementation of the SJRRP	a. Within 1 year prior to the commencement of ground-disturbing activities a qualified biologist shall identify any elderberry shrubs in the project footprint. Qualified biologist(s) will survey potentially affected shrubs for valley elderberry longhorn beetle exit holes in stems greater than I- inch in diameter. b. If elderberry shrubs are found on or adjacent to the construction project site, a 100-foot wide avoidance buffer – measured from the dripline of the plant - will be established around all elderberry shrubs with stems greater than 1-inch diameter at ground level and will be clearly identified in the field by staking, flagging, or fencing. No activities will occur within the buffer areas and worker awareness training and biological monitoring will be conducted to ensure that avoidance measures are being implemented.	Project & Program	Lead Agency	USFWS
VELB -2. Compensate for temporary or permanent loss of habitat	a. The Lead Agency will consult with USFWS to determine appropriate compensation ratios. Compensatory mitigation measures will be consistent with the Conservation Guidelines for Valley Elderberry Longhorn Beetle (USFWS 1999a), or current guidance. b. Compensatory mitigation for adverse effects may include the transplanting of elderberry shrubs during the dormant season (November 1 to February 15), if feasible, to an area protected in perpetuity as well as required additional elderberry and associated native plantings and approved by the USFWS. c. If off-site compensation includes dedication of conservation easements, purchase of mitigation credits, or other off-site conservation measures, the details of these measures will be included in the mitigation plan and must occur with full endowments for management in perpetuity. The plan will include information on responsible parties for long-term management, holders of conservations easements, long-term management requirements, and other details, as appropriate, for the preservation of long-term viable populations.	Project & Program	Lead Agency	USFWS
BNLL	Blunt-nosed leopard lizard			
BNLL-1. Avoid and minimize effects to species for implementation of the SJRRP.	a. Within 1 year prior to the commencement of the proposed project, a qualified biologist shall provide a general habitat assessment survey to identify and map potentially suitable habitat for blunt-nosed leopard lizard within the project footprint and where populations may be affected by the actions. b. If areas of suitable habitat could be affected by the project actions, focused surveys will be conducted in coordination with USFWS and DFG. USFWS and DFG will be consulted to develop additional avoidance and habitat minimization measures, as appropriate. c. If suitable burrow habitat is found for blunt-nosed leopard lizard within the project footprint, prior to the commencement of activities that may cause disturbance, a minimum 491-foot buffer will be established around the burrows and will be clearly identified in the field by staking, flagging, or fencing. Activities will not occur within the buffer areas and worker awareness training and biological monitoring will be conducted to ensure	Project & Program	Lead Agency	USFWS DFG

	that avoidance measures are being implemented.			
PLANTS	Other special-status plants			
PLANTS-1. Avoid and minimize effects to special-status plants for implementation of the SJRRP.	a. Within one year prior to the commencement of ground disturbing activities, habitat assessment surveys for the special-status plants listed in Table 1 of Appendix L, Biological Resources-Vegetation and Wildlife, will be conducted by a qualified botanist, in accordance with the most recent USFWS and DFG guidelines and at the appropriate time of year when the target species would be in flower or otherwise clearly identifiable. b. Locations of special-status plant populations will be clearly identified in the field by staking, flagging, or fencing a 100-foot wide buffer around them prior to the commencement of activities that may cause disturbance. No activity shall occur within the buffer area and worker awareness training and biological monitoring will be conducted to ensure that avoidance measures are being implemented. Some special-status plant species are annual plants, meaning the plant completes its entire lifecycle in one growing season. Other special-status plant species are perennial plants that return year after year until they reach full maturity. Due to the differences in life histories, all general conservation measures will be developed on a case-by-case basis and will include strategies that are species and site-specific in order to avoid impacts to special-status plants.	Program	Lead Agency	USFWS DFG
PLANTS-2. Compensate for temporary or permanent loss of special-status plants	a. USFWS and/or DFG will be consulted to determine appropriate compensation measures for the loss of special-status plants, as appropriate. b. Appropriate mitigation measures may include the creation of offsite populations through seed collection or transplanting, preservation and enhancement of existing populations, restoration or creation of suitable habitat, or the purchase of credits at a regulatory agency-approved mitigation bank. If off-site compensation includes dedication of conservation easements, purchase of mitigation credits, or other off-site conservation measures, the details of these measures will be included in the mitigation plan and must occur with full endowments for management in perpetuity. The plan will include information on responsible parties for long-term management, holders of conservations easements, long-term management requirements, and other details, as appropriate, for the preservation of long-term viable populations.	Program	Lead Agency	USFWS DFG
GGS	Giant garter snake			

GGS-1. Avoid and minimize loss of habitat for giant garter snake for implementation of the SJRRP	a. Pre-construction surveys will be completed by a qualified biologist approved by USFWS and DFG within a 24-hour period prior to any ground disturbance of potential giant garter snake habitat. If construction activities stop on the project site for a period of 2 weeks or more, a new giant garter snake survey will be completed no more than 24 hours prior to the re-start of construction activities. Avoidance of ponds, streams, lakes and other wetland and water courses, and their immediately adjacent upland habitats that may provide suitable breeding and foraging habitat will occur by demarcating and maintaining a 300-foot buffer around these areas. b. For projects within potential giant garter snake habitat, all activity involving disturbance of potential giant garter snake habitat will be restricted to the period between May 1 and October 1, the active season for giant garter snakes. The construction site shall be re-inspected when a lapse in construction activity of two weeks or greater has occurred. c. Clearing will be confined to the minimal area necessary to facilitate construction activities. Giant garter snake habitat within or adjacent to the project will be flagged, staked, or fenced and designated as an Environmentally Sensitive Area. No activity shall occur within this area and USFWS approved worker awareness training and biological monitoring will be conducted to ensure that avoidance measures are being implemented. Construction activities shall be minimized within 200 feet of the banks of giant garter snake habitat. Movement of heavy equipment will be confined to existing roadways to minimize habitat disturbance. d. Vegetation shall be hand cleared in areas where giant garter snakes are suspected to occur. Exclusionary fencing with one-way exit funnels shall be installed at least one month prior to activities to allow the species to passively leave the area and to prevent re-entry into work zones, per USFWS and/or DFG guidance. e. If a giant garter snake is found during construction activities, the USFWS, DFG, and the project's biological monitor will immediately be notified. The biological monitor, or his/her assignee, will stop construction in the vicinity of the find and allow the snake to leave on its own. The monitor will remain in the area for the remainder of the work day to ensure the snake is not harmed. Escape routes for giant garter snake should be determined in advance of construction and snakes will be allowed to leave on their own. If a giant garter snake does not leave on its own within one working day, USFWS and DFG will be consulted. f. All construction-related holes shall be covered to prevent entrapment of individuals. Where applicable, construction areas shall be dewatered two weeks prior to the start of activities to allow giant garter snakes and their prey to move out of the area prior to any disturbance.	Program	Lead Agency	Lead Agency USFWS DFG

GGS-2. Compensate for temporary or permanent loss of habitat.	a. Temporarily affected giant garter snake aquatic habitat will be restored in accordance with criteria listed in the USFWS *Mitigation Criteria for Restoration and/or Replacement of Giant Garter Snake Habitat* (Appendix A to Programmatic Formal Consultation for U.S. Army Corps of Engineers 404 Permitted Projects with Relatively Small Effects on the Giant Garter Snake within Butte, Colusa, Glenn, Fresno, Merced, Sacramento, San Joaquin, Solano, Stanislaus, Sutter, and Yolo Counties, California (USFWS 1997) or the most current criteria from the agencies. b. Permanent loss of giant garter snake habitat will be compensated at a ratio and at a manner consulted on with USFWS and DFG. Compensation may include preservation and enhancement of existing populations, restoration or creation of suitable habitat, or purchase of credits at a regulatory agency approved mitigation bank in a sufficient quantity to compensate for the effect. Credit purchases, land preservation or enhancement to minimize effects to giant garter snakes should occur geographically close to the impact area.	Program	Lead Agency	USFWS DFG
WPT	Western pond turtle			
WPT-1. Avoid and minimize loss of individuals due to implementation of the SJRRP	a. A qualified biologist will conduct surveys in aquatic habitats to be dewatered and/or filled during project construction. Surveys would be conducted immediately after dewatering and before fill of aquatic habitat suitable for pond turtles. If pond turtles are found, the biologist will capture them and move them to nearby USFWS and/or DFG-approved areas of suitable habitat that will not be disturbed by project construction.	Program	Lead Agency	DFG
EAGLE	Bald eagle and golden eagle			
EAGLE-1. Avoid and minimize effects to bald and golden eagles (as defined in the Bald and Golden Eagle Protection Act)	a. Surveys for bald and golden eagle nests will be conducted within 2 miles of any proposed project within areas supporting suitable nesting habitat and important eagle roost sites and foraging areas. These surveys will be conducted in accordance with the USFWS's Protocol for Evaluating Bald Eagle Habitat and Populations in California and DFG's Bald Eagle Breeding Survey Instructions or current guidance (*USFWS Draft Project Design Criteria and Guidance for Bald and Golden Eagles).* b. If an active eagle's nest is found, project disturbance will not occur within ½ mile of the active nest site during the breeding season (typically December 30th until July 1st) or any disturbance if that action is shown to disturb the nesting birds. A no-disturbance buffer will be established around the nest site for construction activities in consultation with USFWS and DFG and will depend on ecological factors, including topography, surrounding vegetation, nest height, and distance to foraging habitat; as well as the type and magnitude of disturbance. c. Project activity will not occur within the ½ mile buffer areas and worker awareness training and biological monitoring will be conducted to ensure that avoidance measures are being implemented.	Program	Lead Agency	USFWS DFG
SWH	Swainson's hawk			
SWH-1. Avoid and minimize impacts to Swainson's Hawk	a. Pre-construction surveys for active Swainson's hawk nests will be conducted in area supporting potentially suitable nesting habitat. b. If active nests are identified through pre-construction surveys, a ½ mile no-disturbance buffer shall be established around all active nest sites if construction cannot be limited to occur outside of the nesting season (March 1 through September 15).	Program	Lead Agency	DFG

	c. Worker awareness training and biological monitoring will be conducted to ensure that avoidance measures are being implemented.			
SWH-2. Compensate for loss of nest trees and foraging habitat	a. If foraging habitat for Swainson's hawk is removed in association with project implementation, foraging habitat compensation will occur in coordination with DFG. Foraging habitat mitigation may consist of the planting and establishment of alfalfa, row crops, pasture, or fallow fields. b. If potential nesting trees are to be removed during construction activities, removal will take place outside of Swainson's hawk nesting season and the lead agency will develop a plan to replace known Swainson's hawk nest trees with a number of equivalent native trees that were previously determined to be impacts through consultation with DFG.	Program	Lead Agency	DFG
RAPTOR	Other nesting raptors			
RAPTOR-1. Avoid and minimize loss of individual raptors due to implementation of the SJRRP	a. Construction activity, including vegetation removal, will only occur outside the typical breeding season for raptors (September 1 to February 28), if raptors are determined to be present. b. Pre-construction surveys will be conducted by a qualified biologist in areas of suitable habitat in order to identify active nests in the project footprint. c. If active nests are located in the project footprint, a no-disturbance buffer will be established until a qualified biologist determines that the nest is no longer active. The size of the buffer shall be established by a qualified biologist in coordination with DFG based on the sensitivity of the resource, the type of disturbance activity, and nesting stage. No activity shall occur within the buffer area and worker awareness training and biological monitoring will be conducted to ensure that avoidance measures are being implemented.	Program	Lead Agency	DFG
RAPTOR-2. Compensate for loss of nest trees	a. Native trees removed during project activities will be replaced with an appropriate number of native trees, in coordination with DFG.	Program	Lead Agency	DFG
MBTA	Other birds protected by the Migratory Bird Treaty Act			
MBTA-1. Avoid and minimize effects to species due to implementation of the SJRRP	a. Native nesting birds will be avoided by not conducting project activity, including vegetation removal, during the typical breeding season (February 1 to September 1), if species covered under the Migratory Bird Treaty Act are determined to be present. b. An Avian Protection Plan shall be established in coordination with USFWS and DFG. Any overhead utility companies within the project area, whose lines, poles, or towers may be moved in association with the project, would also be Consulted as part of the Avian Protection Plan.	Program	Lead Agency	USFWS
BRO	Burrowing Owl			
BRO-1. Avoid loss of species due to implementation of the SJRRP	a. Pre-construction surveys for burrowing owls will be conducted in area supporting potentially suitable habitat and within 30 days prior to the start of construction activities. If ground-disturbing activities are delayed or suspended for more than 30 days after the pre-construction survey, the site should be resurveyed. b. Occupied burrows shall not be disturbed during the breeding season (February 1 through August 31). A 160-foot buffer shall be placed around occupied burrows during the non-breeding season (September 1 through January 31), and a 250-foot buffer shall be placed around occupied burrows during the breeding season. Ground-disturbing activities shall not occur within the designated buffers.	Program	Lead Agency	DFG

BRO-1. Minimize impacts to species due to implementation of the SJRRP	a. If a DFG-approved biologist can verify through non-invasive methods that the owls have not begun egg-laying and incubation, or that juveniles from the occupied burrows are foraging independently and are capable of independent survival, a plan shall be coordinated with DFG to offset the burrow habitat and foraging area on the project site if burrows and foraging areas are taken by the SJRRP actions. b. If destruction of occupied burrows occurs, existing unsuitable burrows should be enhanced (enlarged or cleared of debris) or new burrows created. This should be done in consultation with DFG. c. Passive owl relocation techniques must be implemented. Owls should be excluded from burrows in the immediate impact zone within a 160-foot buffer zone by installing one-way doors in burrow entrances. These doors shall be in place at least 48 hours prior to excavation to insure the owls have departed. d. The project area shall be monitored daily for one week to confirm owl departure from burrows prior to any ground-disturbing activities. e. Where possible, burrows should be excavated using hand tools and refilled to prevent reoccupation. Sections of flexible plastic pipe should be inserted into the tunnels during excavation to maintain an escape route for any animals inside the burrow.	Program	Lead Agency	DFG
BAT	Special-status bats			
BAT-1: Avoid and minimize loss of species due to implementation of the SJRRP.	a. If suitable roosting habitat for special-status bats will be affected by project construction (e.g., removal or buildings, modification of bridges), surveys for roosting bats on the project site will be conducted by a qualified biologist. The type of survey will depend on the condition of the potential roosting habitat and may include visual surveys or use of acoustic detectors. Visual surveys may consist of a daytime pedestrian survey looking for evidence of bat use (e.g., guano) and/or an evening emergence survey to note the presence or absence of bats. The type of survey will depend on the condition of the potential roosting habitat. If no bat roost are found, then no further study is required. b. If evidence of bat use is observed, the number and species of bats using the roost will be determined. Bat detectors may be used to supplement survey efforts. c. If roosts are determined to be present and must be removed, the bats will be excluded from the roosting site before the facility is removed. A mitigation program addressing compensation, exclusion methods, and roost removal procedures will be developed in consultation with DFG prior to implementation. Exclusion methods may include use of one-way doors at roost entrances (bats may leave, but not re-enter), or sealing roost entrances when the site can be confirmed to contain no bats. Exclusion efforts may be restricted during periods of sensitive activity (e.g., during hibernation or while females in maternity colonies are nursing young).	Program	Lead Agency	DFG
BAT-2: Compensate for loss of habitat	a. The loss of each roost will be replaced in consultation with DFG and may include construction and installation of bat boxes suitable to the bat species and colony size excluded from the original roosting site. Roost replacement will be implemented before bats are excluded from the original roost sites. Once the replacement roosts are constructed and it is confirmed that bats are not present in the original roost sites, the structure may be removed.	Program	Lead Agency	DFG

SJAS	San Joaquin antelope squirrel			
SJAS-1: Avoid and minimize loss of individuals due to implementation of the SJRRP	a. Preconstruction surveys will be conducted by a qualified biologist per DFG survey methodology to determine if active potential burrows for San Joaquin antelope squirrel are present in the project footprint. Surveys will be conducted within 30 days prior to ground-disturbing activities. The biologist will conduct burrow searches by systematically walking transects, which shall be adjusted based on vegetation height and topography, and in coordination with DFG. Transects shall be used to identify the presence of burrows. When a burrow is found, the biologist will measure the diameter of the burrow(s); evaluate the shape of the burrow and entrance(s); and note tracks, scat, and tail drags at the site. Scat may be collected for later confirmation of species by known experts. Focused surveys, which may involve live trapping, may be required in coordination with DFG, as appropriate. Additional conservation measures may developed pending the results of surveys and in consultation with DFG. b. Construction activities shall be conducted at a time that is least likely to affect the species (i.e., after the normal breeding season). This timing shall be coordinated with USFWS and DFG.	Program	Lead Agency	DFG
FKR	Fresno kangaroo rat			
FKR-1: Avoid and minimize effects to species due to implementation of the SJRRP	a. Preconstruction surveys will be conducted by a qualified biologist per USFWS and DFG survey methodology to determine if potential burrows for Fresno kangaroo rat are present in the project footprint. Surveys will be conducted within 30 days prior to ground-disturbing activities. The biologist will conduct burrow searches by systematically walking transects, which shall be adjusted based on vegetation height and topography, and in coordination with USFWS and DFG. Transects shall be used to identify the presence of burrows. When a burrow is found, the biologist will measure the diameter of the burrow(s); evaluate the shape of the burrow and entrance(s); and note tracks, scat, and tail drags at the site. Scat may be collected for later confirmation of species by known experts. Focused surveys, which may involve live trapping, may be required in areas of potential habitat in coordination with USFWS and DFG, as appropriate. Additional conservation measures may be developed pending the results of surveys and in consultation with USFWS and DFG. b. Construction activities shall be conducted at a time that is least likely to affect the species (i.e., after the normal breeding season). This timing shall be coordinated with USFWS and DFG.	Program	Lead Agency	USFWS DFG
FKR-2: Avoid disturbance of designated critical habitat	a. Facility construction and modification and other restoration projects shall be sited to avoid primary constituent elements of designated critical habitat for Fresno kangaroo rat.	Program	Lead Agency	USFWS DFG
SJKF	San Joaquin kit fox			
SJKF-1: Avoid and minimize effects to species due to the implementation of the SJRRP	a. A qualified biologist will conduct preconstruction surveys no less than 14 days and no more than 30 days prior to the commencement of activities to identify potential dens more than 5 inches in diameter. The lead agency shall implement USFWS' (1999b) *Standardized Recommendations for Protection of San Joaquin Kit Fox Prior to or During Ground*	Program	Lead Agency	USFWS DFG

	Disturbance. The lead agency will notify USFWS and DFG in writing of the results of the preconstruction survey within 30 days after these activities are completed. b. If dens are located within the proposed work area and cannot be avoided during construction activities, a Service-approved biologist will determine if the dens are occupied. c. If occupied dens are present within the proposed work, their disturbance and destruction shall be avoided. Exclusion zones will be implemented following the latest USFWS procedures (currently USFWS 1999b). d. The lead agency will notify USFWS and DFG immediately if a natal or pupping den is found in the survey area. The lead agency will present the results of preactivity den searches within 5 days after these activities are completed and before the start of construction activities in the area. e. Construction activities shall be conducted at a time that is least likely to affect the species (i.e., after the normal breeding season). This timing shall be coordinated with USFWS and DFG.			
SJKF-2: Compensate for loss of habitat	a. The lead agency, in coordination with USFWS and/or DFG, will determine if kit fox den removal is appropriate. If unoccupied dens need to be removed, the Service-approved biologist shall remove these dens by hand-excavating them in accordance with USFWS procedures (USFWS 1999b). b. Additional conservation measures will be coordinated with USFWS and DFG and may include replacement of dens, installation of off-site artificial dens, or other options to be determined. c. The lead agency will present the results of den excavations to USFWS and DFG within 5 days after these activities are completed.	Program	Lead Agency	USFWS DFG
PL	Pacific Lamprey			
PL-1: Avoid and minimize effects to species due to the implementation of the SJRRP	a. A qualified biologist will conduct preconstruction surveys as outlined in Attachment A of USFWS' *Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (Entosphenus tridentatus), April 2010*. The biologist shall conduct electrofishing to determine the presence of ammoceoetes in the project area. b. Work in documented areas of Pacific Lamprey presence will be timed to avoid in-channel work during typical lamprey spawning, March 1 to July 1. c. If temporary dewatering in documented areas of lamprey presence is required for instream channel work, salvage methods shall be implemented to capture and move Ammocoetes to a safe area, in consultation with USFWS.	Program	Lead Agency	USFWS
DS	Delta Smelt			
DS-1: Avoid and minimize effects to species due to the implementation of the SJRRP	a. All in-water work within Delta smelt habitat shall be confined to a seasonal work window of August 1 - November 30 when delta smelt are least likely to be present. Because this species does not regulate its movements strictly within this time frame, modifications to the work windows may be approved by the USFWS prior to project implementation based on information from the various in-Delta monitoring programs. b. Prevention of shading suitable shallow water habitat by the project will be taken, if activities occur within Delta smelt habitat. The project will also avoid areas deemed suitable for Delta smelt habitat that have established aquatic vegetation or have not been previously disturbed.	Program	Lead Agency	USFWS DFG

RHSNC	Riparian Habitat and Other Sensitive Natural Communities			
RHSNC-1. Avoid and minimize loss of riparian habitat and other sensitive natural communities	a. Biological surveys will be conducted to identify, map, and quantify riparian and other sensitive habitats in potential construction areas. b. Construction activities will be avoided in areas containing sensitive natural communities, as appropriate. c. If effects occur to riparian habitat, emergent wetland, or other sensitive natural communities associated with streams, the State lead agency will comply with Section 1602 of the California Fish and Game Code which may include measures to protect fish and wildlife resources while conducting the project.	Project and Program	Lead Agency	DFG
RHSNC-2: Compensate for loss of riparian habitat and other sensitive natural communities	a. The Riparian Habitat Mitigation and Monitoring Plan for the SJRRP will be developed and implemented in coordination with DFG. Credits for increased acreage or improved ecological function or riparian and wetland habitats resulting from the implementation of SJRRP actions will be applied as compensatory mitigation before additional compensatory measures are required. b. If losses of other sensitive natural communities (e.g., recognized as sensitive by CNDDB, but not protected under other regulations or policies) would not be offset by the benefits of the SJRRP, then additional compensation will be provided through creating, restoring, or preserving in perpetuity in-kind communities at a sufficient ratio for no net loss of habitat function or acreage. The appropriate ratio will be determined in consultation swith USFWS or DFG, depending on agency jurisdiction.	Project and Program	Lead Agency	DFG
WUS	Waters of the United States/waters of the State			
WUS-1. Identify and quantify wetlands and other waters of the United States prior to the implementation of SJRRP actions	a. Prior to SJRRP actions that may affect waters of the United States or waters o the State, Reclamation will map the distribution of wetlands (including vernal pools and other seasonal wetlands) in the Eastside and Mariposa bypasses. b. The Lead Agency will determine, based on the mapped distribution of these wetlands and hydraulic modeling and field observation, the acreage of effects, if any, on waters of the United States. c. If it is determined that vernal pools or other seasonal wetlands will be affected by the SJRRP, the lead agency will conduct a delineation of waters of the United States, and submit the delineation to USACE for verification. The delineation will be conducted according to methods established in the USACE Wetlands Delineation Manual (Environmental Laboratory, 1987) and Arid West Supplement (Environmental Laboratory 2008). d. Construction and modification of road crossings, control structures, fish barriers, fish passages, and other structures will be designed to minimize effects on waters of the United States and waters of the State and will employ best management practices to avoid indirect effects on water quality.	Project and Program	Lead Agency	USACE
WUS-2. Obtain permits and compensate for any loss of wetlands and other waters of the United States/waters of the State	a. The lead agency, in coordination with USACE, will determine the acreage of effects on waters of the United States and waters of the State that will result from implementation of the SJRRP. b. The Lead Agency will adhere to a “no net loss” basis of the acreage of wetlands and other waters of the United States and waters of the State that will be removed and/or degraded. Wetland habitat will be restored, enhanced, and/or replaced at an acreage and location and by methods agreeable to USACE and CVRWQCB, as appropriate, depending on agency	Project and Program	Lead Agency	USACE

	jurisdiction. c. The Lead Agency will obtain Section 404 and Section 401 permits and comply with all permit terms. The acreage, location, and methods for compensation will be determined during the Section 401 and Section 404 permitting processes. d. The compensation will be consistent with recommendations in the Fish and Wildlife Coordination Act Report.			
INV	Invasive Plants			
INV-1. Implement an invasive vegetation monitoring and management plan for the implementation of the SJRRP	a. Reclamation and the project lead agencies will implement the Invasive Vegetation Monitoring and Management Plan for the SJRRP, which includes measures to monitor, control, and where possible eradicate, invasive plant infestations during flow releases and construction activities. b. The implementation of the Invasive Vegetation Monitoring and Management Plan will include monitoring procedures, thresholds for management responses, success criteria, and adaptive management measures for controlling invasive plant species. c. The control of invasive weeds and other recommended actions in the Invasive Vegetation Monitoring and Management Plan will be consistent with recommendations in the Fish and Wildlife Coordination Act Report.	Project and Program	Lead Agency	Lead Agency
CP	Conservation Plans			
CP-1. Remain consistent with approved conservation plans	a. Facility siting and construction activities will be conducted in a manner consistent with the goals and strategies of adopted Habitat Conservation Plans, Natural Community Conservation Plans, or other approved local, regional, or State habitat conservation plans to the extent feasible. Coordination shall occur with USFWS and/or DFG, as appropriate.	Program	Lead Agency	USFWS DFG
CP-2. Compensate effects consistent with approved conservation plans	a. The lead agency shall compensate effects consistent with applicable conservation plans and implement all applicable measures required by the plan.	Program	Lead Agency	USFWS DFG
GS	Southern Distinct Population Segment of North American green sturgeon			
GS-1. Avoid and minimize loss of habitat and individuals due to the implementation of the SJRRP	a. The SJRRP will be operated in such a way that actions related to the Program in the vicinity of green sturgeon habitat shall be done in accordance with existing operating criteria of the CVP and SWP, and prevailing and relevant laws, regulations, BOs, and court orders in place at the time the action is performed.	Project and Program	Lead Agency	NMFS
CVS	Central Valley steelhead			
CVS-1. Avoid loss of habitat and risk of take of species due to the implementation of the SJRRP	a. Impacts to habitat conditions (i.e., changes in flows potentially resulting in decreased flows in the Tributaries, increases in temperature, increases in pollutant concentration, change in recirculation/recapture rates and methods, decrease in floodplain connectivity, removal of riparian vegetation, decreased in quality rearing habitat, and similar impacts) must be analyzed in consultation with NMFS. b. Maintain and operate Hills Ferry Barrier to exclude Central Valley steelhead from Restoration Area during construction activities and until suitable habitat conditions are restored. c. Maintenance of conservation measures will be conducted to the	Project and Program	Lead Agency	NMFS

	extent necessary to ensure that the overall long-term habitat effects of the project are positive. d. Prior to implementation of site-specific actions, the action agency shall conduct an education program for all agency and contracted employees relative to the federally listed species that may be encountered within the Action Area and required practices for their avoidance and protection. A NMFS-appointed representative shall be identified to employees and contractors to ensure that questions regarding avoidance and protection measures are addressed in a timely manner. e. Disturbance of riparian vegetation will be avoided to the greatest extent practicable. f. A spill prevention plan will be prepared describing measures to be taken to minimize the risk of fluids or other materials used during construction (oils, transmission and hydraulic fluids, cement, fuel, and similar materials) from entering the San Joaquin River or contaminating riparian areas adjacent to the river itself. In addition to a spill prevention plan, a cleanup protocol will be developed before construction begins and shall be implemented in case of a spill. g. Stockpiling of materials, including portable equipment, vehicles and supplies, including chemicals, shall be restricted to the designated construction staging areas, exclusive of any riparian and wetland areas. h. A qualified biological monitor will be present during all construction activities including clearing and grubbing and pruning and trimming of vegetation at each job site during construction initiation, midway through construction, and at the close of construction to monitor implementation of conservation measures and water quality. i. The San Joaquin River channel shall be designed to decrease or eliminate predator holding habitat, in coordination with NMFS.			
CVS-2. Minimize loss of habitat and risk of take of species from implementation of SJRRP.	a. In-channel construction activities which could affect designated critical habitat for Central Valley steelhead will be limited to the low-flow period between June 1 and October 1 to minimize potential for adversely affecting federally listed anadromous salmonids during their emigration period. b. In-channel construction activities which could affect designated critical habitat for Central Valley steelhead will be limited to daylight hours during weekdays, leaving a nighttime and weekend period of passage for federally listed fish species. c. Construction Best Management Practices (BMPs) for off-channel staging and storage of equipment and vehicles will be implemented to minimize the risk of contamination of the waters of the San Joaquin River by spilled materials. BMPs will also include minimization of erosion and stormwater runoff, as appropriate. d. Riparian vegetation removed or damaged will be replaced at a ratio, coordinated with the Service, within the immediate area of the disturbance to maintain habitat quality. e. If individuals of listed species are observed present within a project area, then NMFS must be notified. NMFS personnel shall have access to construction sites during construction and following completion in order to evaluate species presence and condition and/or habitat conditions. f. If bank stabilization activities should be necessary, then such stabilization shall be constructed to minimize predator habitat, minimize erosion potential, and contain material suitable for	Program	Lead Agency	NMFS

	supporting riparian vegetation.			
WRCS	Sacramento Valley winter-run Chinook salmon			
WRCS-1. Avoid and minimize loss of habitat and individuals due to the implementation of the SJRRP	a. The Program will be operated in such a way that actions related to the SJRRP in the vicinity of winter-run Chinook salmon habitat shall be done in accordance with existing operating criteria of the CVP and SWP, and prevailing and relevant laws, regulations, BOs, and court orders in place at the time the action is performed.	Project and Program	Lead Agency	NMFS DFG
SRCS	Central Valley spring-run Chinook salmon			
SRCS-1. Avoid and minimize loss of habitat and individuals due to the implementation of the SJRRP	a. The SJRRP will be operated in such a way that actions in the vicinity of spring-run Chinook salmon habitat shall be done in accordance with existing operating criteria of the CVP and SWP, and prevailing and relevant laws, regulations, BOs, and court orders in place at the time the action is performed. b. SJRRP actions shall be performed in accordance with the Experimental Population 4(d) rule as it is developed and where applicable.	Project and Program	Lead Agency	NMFS DFG
EFH	Essential Fish Habitat (Pacific salmonids & starry flounder)			
EFH-1. Avoid loss of habitat and risk of take of species due to the implementation of the SJRRP	a. Impacts to habitat conditions (i.e., changes in flows potentially resulting in decreased flows in the Tributaries, increases in temperature, increases in pollutant concentration, change in recirculation/recapture rates and methods, decrease in floodplain connectivity, removal of riparian vegetation, decreased in quality rearing habitat, and similar impacts) must be analyzed in consultation with NMFS. b. Maintain and operate Hills Ferry Barrier to exclude Pacific salmonids from Restoration Area during construction activities and until suitable habitat conditions are restored. c. Maintenance of conservation measures will be conducted to the extent necessary to ensure that the overall long-term habitat effects of the project are positive. d. Prior to implementation of site-specific actions, the action agency shall conduct an education program for all agency and contracted employees relative to the federally listed species that may be encountered within the Action Area and required practices for their avoidance and protection. A NMFS-appointed representative shall be identified to employees and contractors to ensure that questions regarding avoidance and protection measures are addressed in a timely manner. e. Disturbance of riparian vegetation will be avoided to the greatest extent practicable. f. A spill prevention plan will be prepared describing measures to be taken to minimize the risk of fluids or other materials used during construction (oils, transmission and hydraulic fluids, cement, fuel, and similar materials) from entering the San Joaquin River or contaminating riparian areas adjacent to the river itself. In addition to a spill prevention plan, a cleanup protocol will be developed before construction begins and shall be implemented in case of a spill. g. Stockpiling of materials, including portable equipment, vehicles and supplies, including chemicals, shall be restricted to the designated construction staging areas, exclusive of any riparian and wetland areas. h. A qualified biological monitor will be present during all construction activities including clearing and grubbing and	Project and Program	Lead Agency	NMFS

	pruning and trimming of vegetation at each job site during construction initiation, midway through construction, and at the close of construction to monitor implementation of conservation measures and water quality. i. The bottom topography of the San Joaquin River channel will be designed to decrease or eliminate predator holding habitat.			
EFH-2. Minimize loss of habitat and risk of take from implementation of SJRRP construction activities	a. In-channel construction activities which could affect habitat for will be limited to the low-flow period between June 1 and October 1 to minimize potential for adversely affecting federally listed anadromous salmonids during their emigration period. b. In-channel construction activities which could affect habitat for starry flounder and Pacific salmonids will be limited to daylight hours during weekdays, leaving a nighttime and weekend period of passage for federally listed fish species. c. Construction Best Management Practices (BMPs) for off-channel staging and storage of equipment and vehicles will be implemented to minimize the risk of contamination of the waters of the San Joaquin River by spilled materials. BMPs will also include minimization of erosion and stormwater runoff, as appropriate. d. Riparian vegetation removed or damaged will be replaced at a ratio, coordinated with the Service, within the immediate area of the disturbance to maintain habitat quality. e. If individuals of listed species are observed present within a project area, then NMFS must be notified. NMFS personnel shall have access to construction sites during construction and following completion in order to evaluate species presence and condition and/or habitat conditions. f. If bank stabilization activities should be necessary, then such stabilization shall be constructed to minimize predator habitat, minimize erosion potential, and contain material suitable for supporting riparian vegetation.	Program	Lead Agency	NMFS
	References: CNPS. See California Native Plant Society. California Department of Fish and Game. 2003. Eastside Bypass Monitoring Report for Delta Button-Celery (Eryngium racemosum) 2001–2003. Prepared by San Joaquin District, Environmental Services Section. Fresno, California. California Native Plant Society. 1998. Mitigation guidelines regarding impacts to rare, threatened, and endangered plants. California Native Plant Society Scientific Advisory Committee. Prepared February 1991, revised April 1998. Available: http://www.cnps.org/cnps/archive/mitigation.pdf> Accessed: August 24, 2008. DFG. See California Department of Fish and Game. U.S. Fish and Wildlife Service. 2010 (April). Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (Entosphenus tridentatus). U.S. Fish and Wildlife Service. 1999a. Conservation Guidelines for the Valley Elderberry Longhorn Beetle. Sacramento Fish and Wildlife Office, Sacramento, California. U.S. Fish and Wildlife Service. 2009 (March 25). Blunt-nosed Leopard Lizard Survey Protocols for the San Joaquin River Restoration Program: Including WY 2010 Interim Flow, Interim Flows, and Restoration Flows. Memo to U.S. Bureau of Reclamation from U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Field Office. USFWS. See U.S. Fish and Wildlife Service.			