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.

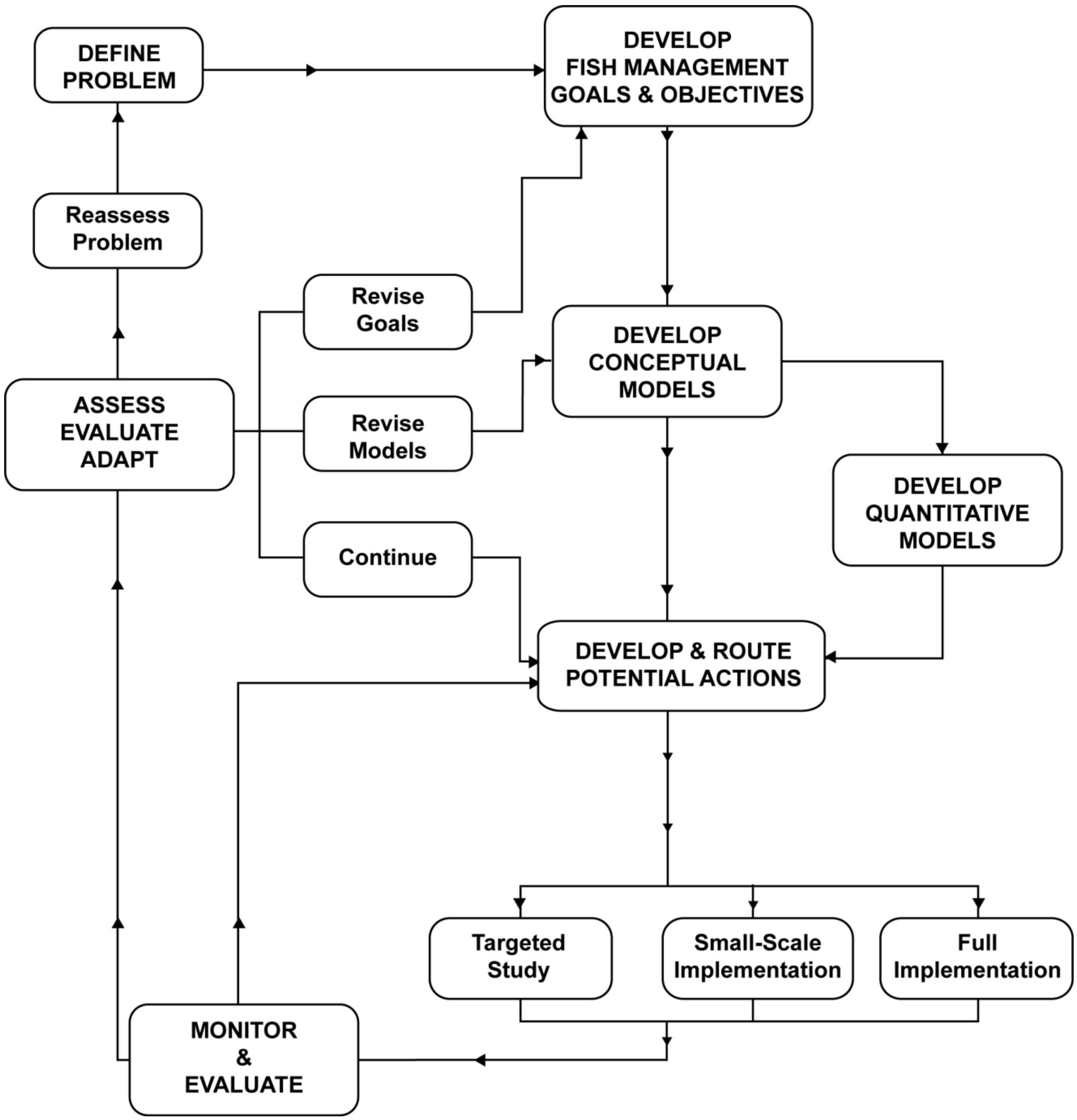

Figure 1-1.
San Joaquin River Restoration Fisheries Management Plan
Adaptive Management Approach

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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.

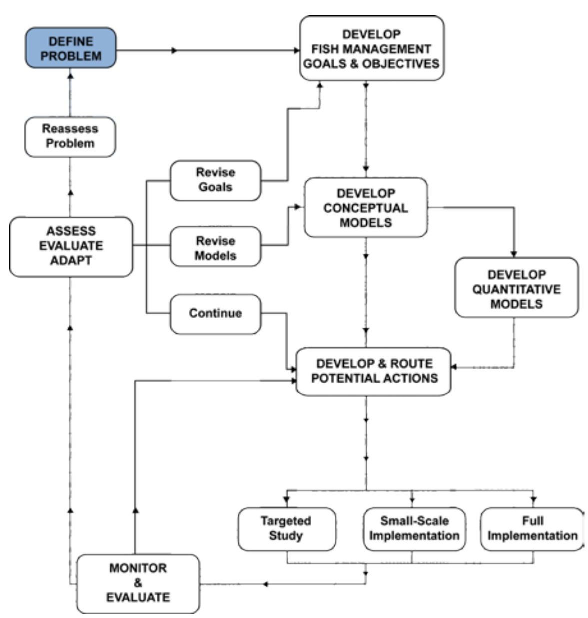


**Figure 2-1.
Fisheries Management Plan Adaptive Management Approach – Defining the Problem**

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.

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.

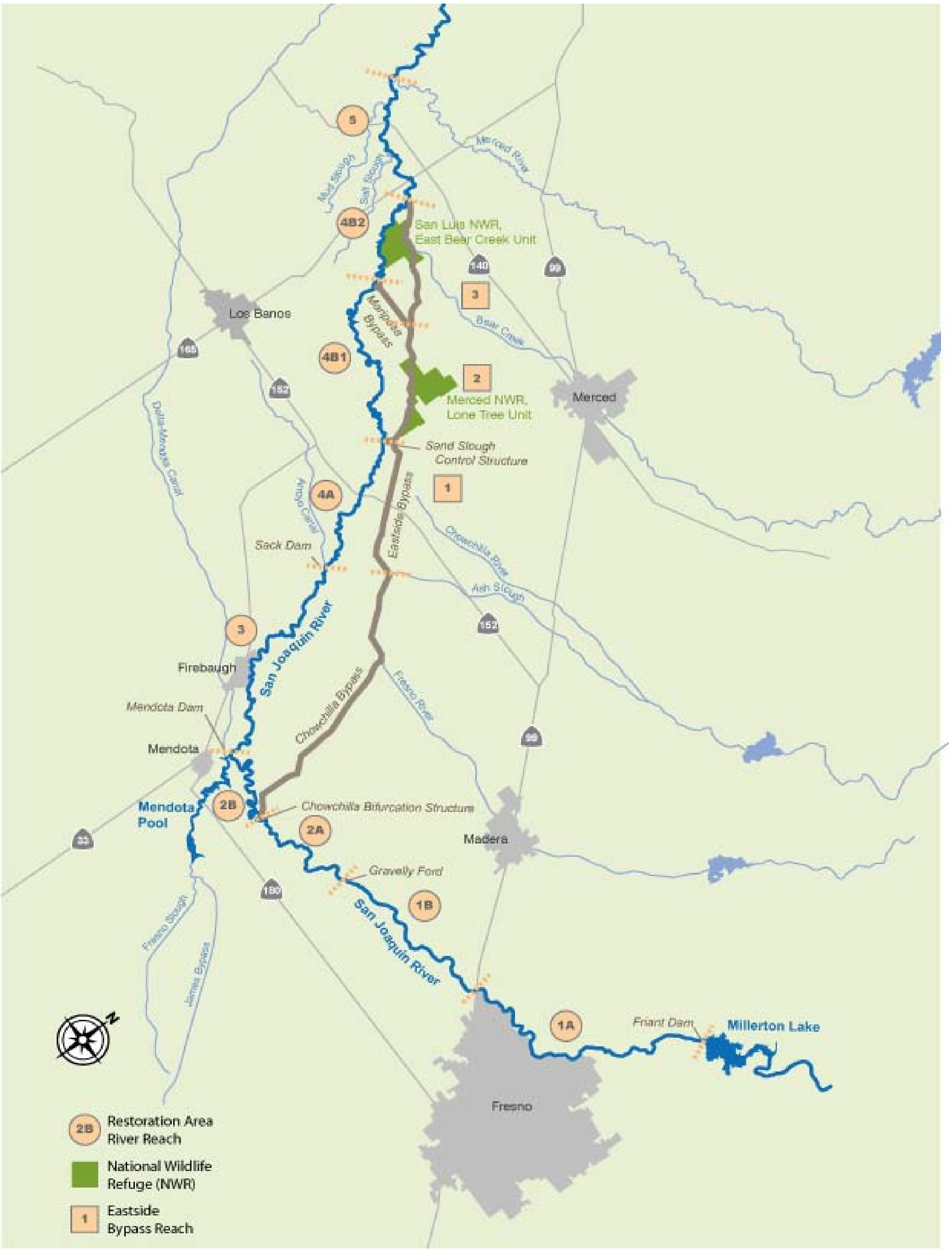


Figure 2-2.
San Joaquin River Restoration Area and the Defined River Reaches

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. Photo: USFWS, San Joaquin River Restoration Program

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.

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).

Salmon Lifecycle. Figure: USFWS, Anadromous Fish Restoration Program

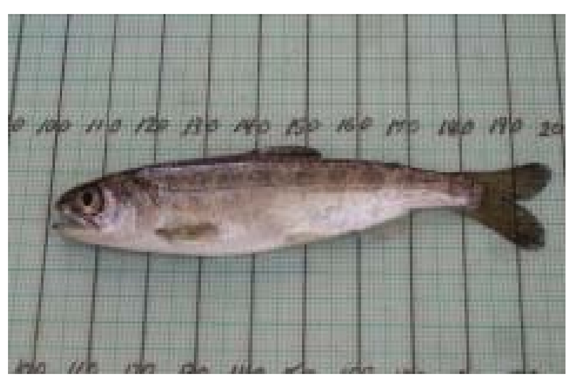
The life-history strategies and requirements of spring-run and late fall-run Chinook salmon are summarized below and described in more detail in Exhibit A and in Chapter 5 of the PEIS/R. Fall-run Chinook salmon are currently the most abundant race of salmon in California (Mills et al. 1997). Fall-run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



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

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 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. Photo: USFWS, Delta Juvenile Fish Monitoring Program

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.

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. Photo: Juan Cervantes ©

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).

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.

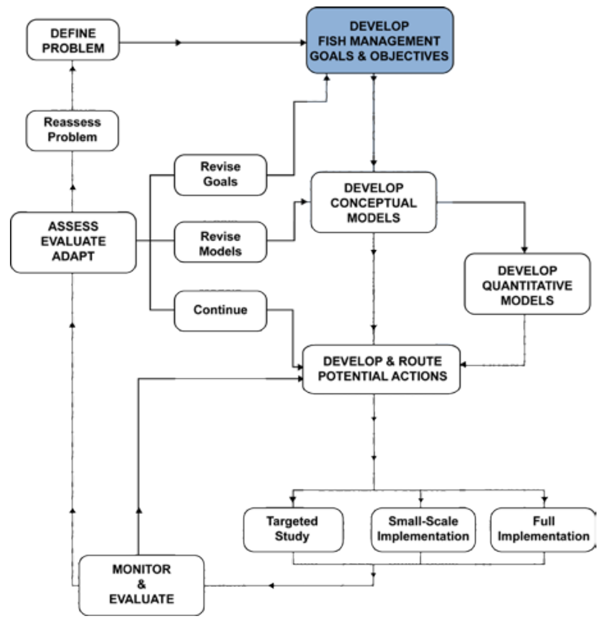


Figure 3-1.
Fisheries Management Plan Adaptive Management Approach – Develop Goals and Objectives

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 ($3.15x10^7$ m^2) of floodplain rearing habitat for spring-run Chinook salmon subyearling rearing/migrating juveniles and 2,595 acres (1.05 $x10^7$ 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], $3.1x10^7$ 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.

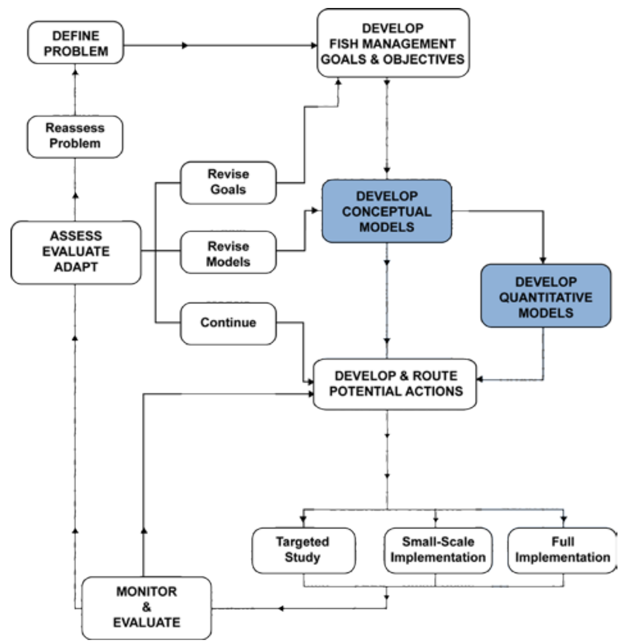

Figure 4-1. Fisheries Management Plan Adaptive Management Approach – Model Development

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.

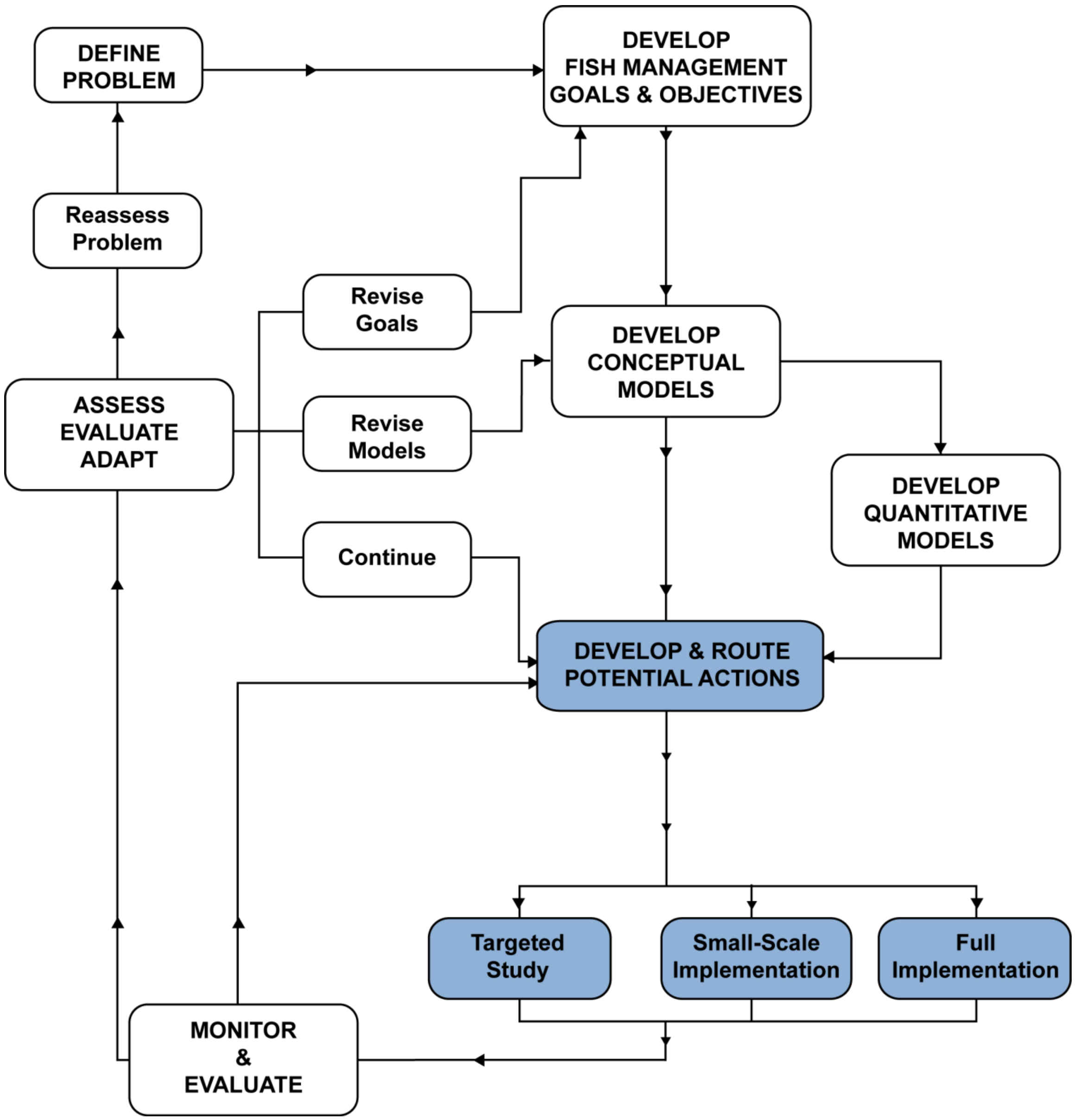

Figure 5-1.
Fisheries Management Plan Adaptive Management Approach – Develop and Route Potential Actions

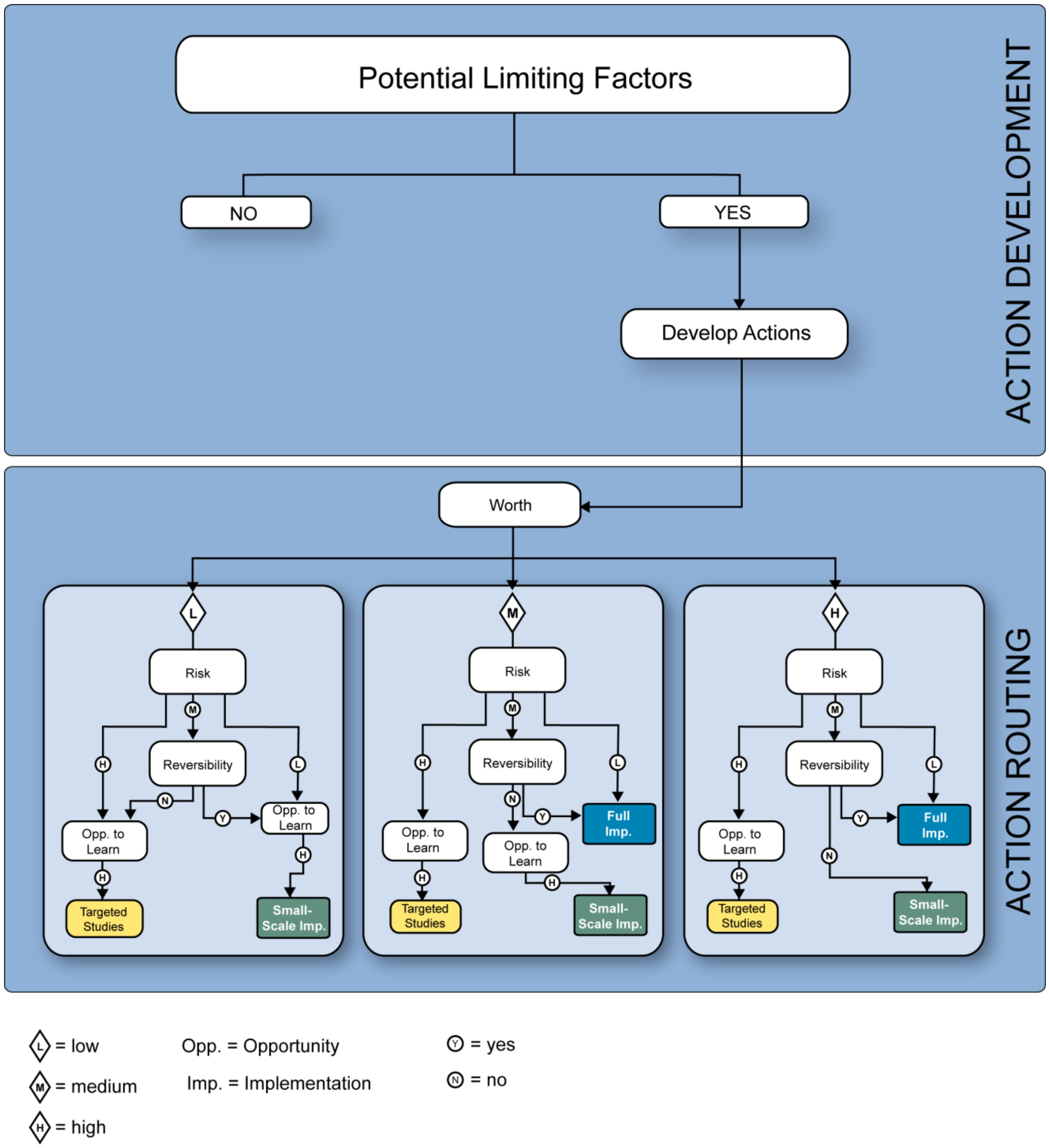

Figure 5-2.
Limiting Factor Prioritization and the Routing of Potential Actions

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

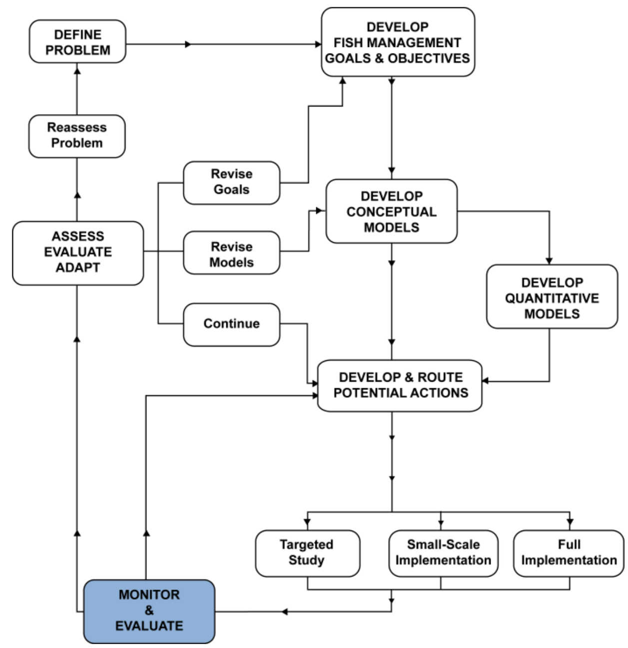

Figure 7-1. Fisheries Management Plan Adaptive Management Approach – Monitor and Evaluate

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.

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.

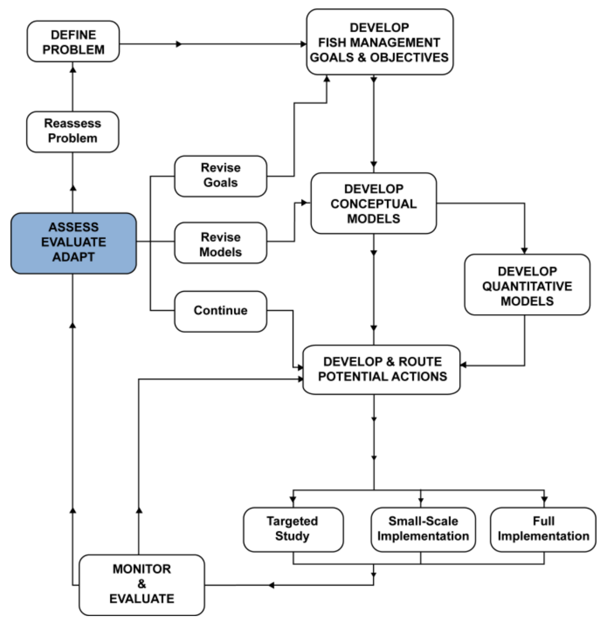

Figure 8-1.
Fisheries Management Plan Adaptive Management Approach – Assess, Evaluate and Adapt

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

Bailey, E.D. 1954. Time pattern of 1953-54 migration of salmon and steelhead into the upper Sacramento River. Unpublished report. California Department of Fish and Game.

Bailey, H.C., E. Hallen, T. Hampson, M. Emanuel, and B.S. Washburn. 2000. Characterization of reproductive status and spawning and rearing conditions for splittail *Pogonichthys macrolepidotus*, a cyprinid of Special Concern, endemic to the Sacramento-San Joaquin estuary. Unpublished manuscript. University of California, Davis.

Bams, R.A. 1970. Evaluation of a revised hatchery method tested on pink and chum salmon fry, Journal of the Fisheries Research Board of Canada: 27: 1429–1452.

Barbour, M.T., J.M. Diamond, and C.O. Yoder. 1996. Biological assessment strategies: Applications and Limitations. Pages 245-270 *in* D.R. Grothe, K.L. Dickson, and D.K. Reed-Junkins (editors). Whole effluent toxicity testing: An evaluation of methods and prediction of receiving system impacts, SETAC Press, Pensacola, Florida.

Barnhart, R.A. 1991. Steelhead *Oncorhynchus mykiss*. Pages 324-336 *in* J. Stolz and J. Schnell, editors. The wildlife series: trout. Stackpole Books, Harrisburg, Pennsylvania.

Baxter, R.D. 1999. Status of splittail in California. California Fish and Game 85: 28–30.

———. 2000. Splittail and longfin smelt. IEP Newsletter 13: 19–21.

Beamish, R.J. 1980. Adult biology of the River Lamprey (*Lampetra ayresi*) and the Pacific Lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Science 37: 1906–1923.

Behnke, R.J. 1992. Native trout of western North America, American Fisheries Society, Bethesda, Massachusetts.

Bergstedt, R.A., and J.G. Seelye. 1995. Evidence for lack of homing by sea lampreys. Transactions of the American Fisheries Society 124:235–239.

Bilby, R.E., Fransen, B.R., Bisson, P.A., and J.K. Walter. 1998. Response of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) to the addition of salmon carcasses to two streams in southwestern Washington, USA. Canadian Journal of Fisheries and Aquatic Sciences 55: 1909-1918.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83–138 in W. R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication No. 19.

Bormann, B.T., P.G. Cunningham, M.H. Brookes, V.W. Manning, and M.W. Collopy. 1993. Adaptive ecosystem management in the Pacific Northwest. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-341. 22 pages.

Brandes, P.L. and J.S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Pages 39-138 in Brown, R.L., editor. Fish Bulletin 179: Contributions to the biology of Central Valley salmonids. Volume 2. California Department of Fish and Game, Sacramento, California.

Brewer, Shannon. Habitat Restoration Coordinator. U.S. Fish and Wildlife Service. Conversation on May 1, 2009 with Jeff McLain.

Brown, L.R., and P.B. Moyle. 1993. Distribution, ecology, and status of the fishes of the San Joaquin River drainage, California. California Fish and Game 79: 96-114.

Bryant, M. 2009. Global Climate Change and Potential Effects on Pacific Salmonids in Freshwater Ecosystems of Southeast Alaska. Climatic Change, 95.1/2: 169-193.

Cada, G.F., J.M. Loar, and M.J. Sale. 1987. Evidence of food limitation of rainbow and brown trout in Southern Appalachian soft-water streams. Transaction of the American Fisheries Society 116:692-702.

CALFED Bay-Delta Program (CALFED). 2001. 2001 Strategic Plan for Ecosystem Restoration.

CALFED. *See* CALFED Bay-Delta Program.

California Department of Fish and Game (DFG). 1957. Report on water right applications 23, 234, 1465, 5638, 5817, 5818, 5819, 5820, 5821, 5822, 9369, United States of America – Bureau of Reclamation; water right applications 6771, 6772, 7134, 7135, City of Fresno; water right application 6733 – Fresno Irrigation District on the San Joaquin River, Fresno/Madera, and Merced counties, California, DFG, Region 4, Fresno, California.

———. 1990. Annual Report, Fiscal Year 1988–1989, San Joaquin River Chinook Salmon Enhancement Project. Sport Fish Restoration Act, Project F–51–R–1, Sub Project Number IX, Study Number 5, Jobs 1 through 7. Region 4, Fresno, California.

———. 1998a. California Stream Habitat Restoration Manual. 3rd Edition. State of California. The Resources Agency. California Department of Fish and Game. Inland Fisheries Division.

———. 1998b. Report to the Fish and Game commission: A status review of the spring-run Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento River Drainage. Candidate Species Status Report 98-01. June 1998.

———. 2007a. San Joaquin River fishery and aquatic resources inventory, September 2003 – September 2005. Final report. Cooperative Agreement 03FC203052.

———. 2007b. Response to Comments San Joaquin River Group Authority's Written Comments to Proposal by Central Valley Regional Water Quality Control Board to List the San Joaquin, Tuolumne, Merced and Stanislaus Rivers as Impaired Bodies of Water for Temperature Pursuant to Section 303(d). Central Region, Fresno, California.

———. 2008. Butte and Big Chico Creeks Spring-Run Chinook Salmon, Oncoryhnchus Tshawytscha Life History Investigation 2006-2007, Inland Fisheries Report 2008-1, table 8, 18pp.

California Department of Water Resources (DWR). 2006. Progress on incorporating climate change into planning and management of California's water resources: Technical Memorandum Report. Sacramento, California.

———. 2008. Managing an uncertain future: Climate change adaptation strategies for California's water. State of California. October.

Carl Mesick Consultants and KDH Environmental Services. 2009. 2004 and 2005 Phase II Studies: Knights Ferry gravel replenishment project. Prepared for USFWS Anadromous Fish Restoration Program. Stockton, California. 43 p.

Central Valley Regional Water Quality Control Board (CVWB). 1998. The Water Quality Control Plan (basin plan) for the California Regional Water Quality Control Board Central Valley Region, Fourth Edition California Regional Water Quality Control Board Central Valley Region, Sacramento, California.

Chapman, D.W. 1958. Studies on the life history of Alsea River steelhead. Journal of Wildlife Management: 3–134.

Clark, G.H. 1943. Salmon at Friant Dam - 1942. California Fish and Game 29(3):89-91.

Crozier, L.G., P.W. Lawson, T.P. Quinn, A.P. Hendry, J. Battin, N.J. Mantua, W. Eldridge, and R.G. Shaw. 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. Evolutionary Applications 1:252–270.

Cummins, K., C. Furey, A. Giorgi, J. Nestler, and J. Shurts. 2008. Listen to the river: an independent review of the CVPIA Fisheries Program. December 2008.

CVWB. *See* Central Valley Water Board and Central Valley Water Quality Control Board.

DFG. *See* California Department of Fish and Game.

DFG Report Card Data. 2008. Gleason, E., M. Gingras, and J. DuBois. 2007 Sturgeon fishing report card: preliminary data report. Stockton, California: California Department of Fish and Game, Bay Delta Region.

———. 2009. DuBois, J., M. Gingras, and R. Mayfield. 2008 Sturgeon fishing report card: preliminary data report. Stockton, California: California Department of Fish and Game, Bay Delta Region. June 17.

———. 2010. DuBois, J., T. Matt, and B. Beckett. 2009 Sturgeon fishing report card: preliminary data report. Stockton, California: California Department of Fish and Game. Bay Delta Region (East). March 29. Available at: ftp://ftp.delta.dfg.ca.gov/Adult_Sturgeon_and_Striped_Bass/2009%20Sturgeon%20Card%20Complete%20Draft%20Version%201.pdf

DWR. *See* California Department of Water Resources.

EA Engineering, Science, and Technology. 1992. Don Pedro Project fisheries studies report (FERC Article 39, Project No. 2299). Report to Turlock Irrigation District and Merced Irrigation District.

EPA. *See* U.S. Environmental Protection Agency.

Filbert, R.B., and C.P. Hawkins. 1995. Variation in condition of rainbow trout in relation to food, temperature, and individual length in the Green River, Utah. Transactions of the American Fisheries Society 124:824-835.

Fisher, F.W. 1994. Past and present status of Central Valley Chinook salmon, Conservation Biology 8: 870–873.

Flemming, I.A., and M.R. Gross. 1994. Breeding Competition in a Pacific Salmon (Oncorhynchus kisutch): Measures of natural and sexual selection. Evolution: 48(3): 637-657.

Foott, S, R. Harmon, and R. Stone. 2003. Ceratomyxosis resistance in juvenile Chinook Salmon and steelhead trout from the Klamath River, 2002 Investigational Report. U.S. Fish & Wildlife Service, California – Nevada Fish Health Center, Anderson, California. 25 p.

Foott, S. 1995. Preliminary results of Spring 1995 Klamath R. Chinook smolt study (95-FP-01), Iron Gate Hatchery June release group. U.S. Fish and Wildlife Service California-Nevada Fish Health Center, Anderson, California. 6 p.

Foott, Scott. Project Leader. U.S. Fish and Wildlife Service. Anderson, CA. April 13, 2009 – e-mail message to Zachary Jackson of U.S. Fish and Wildlife Service regarding fish disease.

Fry, D.H. Jr. 1961. King salmon spawning stocks of the California Central Valley, 1940-1959. California Fish and Game 47: 55-71.

Garman, C.E., and T.R. McReynolds. 2006. Butte and Big Chico Creeks spring-run Chinook salmon, *Oncorhynchus tshawytscha* life history investigation, 2006-2007. CDFG Inland Fisheries Report No 2008-1.

Goodman, D.H., S.B. Reid, M.F. Docker, G.R. Haas, and A.P. Kinziger. 2008. Mitochondrial DNA evidence for high levels of gene flow among populations of a widely distributed anadromous lamprey *Entosphenus tridentatus* (Petromyzontidae). Journal of Fish Biology 72:400-417.

Gregory, R.S. and C.D. Levings. 1996. The effects of turbidity and vegetation on the risk of juvenile salmonids, *Oncorhynchus* sp, to predation by adult cutthroat trout, *O. clarkia*. Environmental Biology of Fishes 46: 279-288.

Guillen, G. 2003. Klamath River fish die-off, September 2002: Report on estimate of mortality. Report number AFWO-01-03. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office. Arcata, California. 35 p.

Hallock, R.J., W.F. Van Woert, and L. Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) in the Sacramento River system. Fish Bulletin 114. California Department of Fish and Game.

Harrington, J.M. 1999. California stream bioassessment procedures. California Department of Fish and Game, Water Pollution Control Laboratory. Rancho Cordova, CA.

Healey, M.C. 1991. The life history of Chinook salmon. Pages 311–393 in C. Groot and L Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, Canada.

———. 2001. 2001 Patterns of reproductive investment by stream- and ocean-type Chinook salmon (*Oncorhynchus tshawytscha*). Journal of Fish Biology 58:1545-1556.

Helfield, J.M, and R.J. Naiman. 2001. Effects of salmon-derived nitrogen on riparian forest growth and implications for stream productivity. Ecology. 82:2403-2409.

Heming, T.A. 1982. Effects of temperature on utilization of yolk by Chinook salmon (*Oncorhynchus tshawytscha*) eggs and alevins. Canadian Journal of Fisheries and Aquatic Sciences 39: 184–190.

Henson, S.S., D.S. Ahearn, R.A. Dahlgren, E.V. Nieuwenhuyse, K.W. Tate and W.E. Fleenor. 2007. Water quality response to a pulse-flow event on the Mokelumne River, California. River Research and Applications 23:185-200.

Higgins, C.L. and R.E. Strauss. 2008 Modeling Stream Fish Assemblages with Niche Apportionment Models: Patterns, Processes, and Scale Dependence Transactions of the American Fisheries Society 137:696–706.

Hocking, M.D., and T.E. Reimchen. 2002. Salmon-derived nitrogen in terrestrial invertebrates from coniferous forests of the Pacific Northwest. BMC Ecology.

Instream Flow Council. 2004. Instream flows for riverine resource stewardship (revised ed.): Chapter 6, Instream flow assessment tools, p. 129-189.

Intergovernmental Panel on Climate Change (IPCC). 1995. Intergovernmental Panel on Climate Change Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change.

IPCC. *See* Intergovernmental Panel on Climate Change.

Jager, H., and K.A. Rose. 2003. *North American Journal of Fisheries Management* 23:1–21, 2003. Designing Optimal Flow Patterns for Fall Chinoook Salmon in a Central Valley, California, River.

Jeffres, C.A., J.J. Opperman, and P. B. Moyle.2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes 83: 449-458.

Jones and Stokes. 1999. Use of floodplain habitat on the Sacramento and American rivers by juvenile Chinook salmon and other fish species. 29 pages.

———. 2002. Revised Quantitative Objectives for the San Joaquin River Restoration Plan.

Kan, T.T. 1975. Systematics, variation, distribution, and biology of lampreys of the genus *Lampetra* in Oregon. Dissertation for the Doctor of Philosophy. Oregon State University, Corvallis, Oregon. 194 pp.

Kohlhorst, D.W. 1976. Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae. California Fish and Game 62:32-40.

Kohlhorst, D.W., L.W. Botsford, J.S. Brennan, and G.M. Cailliet, 1991. Aspects of the structure and dynamics of an exploited central California population of white sturgeon (Acipenser transmontanus), in "Acipenser," P. Williot, ed., Bordeaux, France, pp. 277 – 293.

Kondolf, G.M. 2005. Expert Report of Professor Mathias Kondolf, Ph.D. E.D. Cal. No. Civ. 88-1658 LKK. 122 pp.

Lambeck, R.J. 1997. Focal species: A multi-species umbrella for nature conservation. Conservation Biology 11: 849-856.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, editors. 1980. Atlas of North American freshwater fishes. North Carolina State Museum of Natural History, Raleigh, NC.

Lee, K.N. 1993. Compass and gyroscope: Integrating science and politics for the environment. Island Press, Washington D.C.

Lindley S.T., R.S. Schick, E. Mora, P.B. Adams, J.J. Anderson, S. Greene, C. Hanson, B.P. May, D.R. McEwan, R.B. MacFarlane, C. Swanson, and J.G. Williams. 2007. Framework for assessing viability of threatened and endangered salmon and steelhead in the Sacramento- San Joaquin Basin. San Francisco Estuary and Watershed Science Volume 5, Issue 1 (February 2007), Article 4. Available at: http://repositories.cdlib.org/jmie/sfews/vol5/iss1/art4

Mazur, M.M. and D.A. Beauchamp. 2003. A comparison of visual prey detection among species of piscivorous salmonids: effects of light and low turbidities. Environmental Biology of Fishes 67: 397-405.

McAllister, M.K. and G.P. Kirkwood. 1998. Bayesian stock assessment: a review and example application using the logistic model. – ICES Journal of Marine Science, 55: 1031–1060

McBain, S. and W. Trush. 2002. San Joaquin River restoration study background report. Prepared for Friant Water Users Authority, Lindsay, California and Natural Resources Defense Council, San Francisco, California. Arcata, California. December.

McCabe, G.D. and W.J. O'Brien. 1983. The effects of suspended silt on feeding and reproduction of *Daphnia pulex*. American Midland Naturalist 110: 324-337.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. NOAA Technical Memorandum NMFS-NWFSC-42. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington. 156 p.

McEwan, D., and T.A. Jackson. 1996. Steelhead restoration and management plan for California. Management report. California Department of Fish and Game, Inland Fisheries Division, Sacramento, California.

McEwan, D.R. 2001. Central Valley steelhead. Pages 1-43 in R. L. Brown, editor. Contributions to the biology of Central Valley salmonids. Fish Bulletin 179: Volume 1. California Department of Fish and Game, Sacramento.

Meade, R.J. 2007. Recommendations on restoring spring-run Chinook salmon to the upper San Joaquin River. Prepared for San Joaquin River Restoration Program Restoration Administrator Roderick J. Meade Consulting, Inc. Prepared by San Joaquin River Restoration Program Technical Advisory Committee. October.

———. 2009. Recommendations on monitoring and evaluation of Interim Flows of the Upper San Joaquin River. Prepared for the San Joaquin River Restoration Administrator Roderick J. Meade Consulting, Inc. Prepared by the San Joaquin River Restoration Technical Advisory Committee. February.

Meeuwig, M.H., J.M. Bayer, and J.G. *See*lye. 2005. Effects of temperature on survival and development of early life stage Pacific and western brook lampreys. Transactions of the American Fisheries Society 134:19–27.

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

Merz, J.E., and P.B. Moyle. 2006. Marine-derived nutrients in human-dominated ecosystems of Central California. Ecological Applications 16: 999-1009.

Michael, J.H. 1980. Repeat spawning of Pacific Lamprey. California Fish and Game Notes 66:186–187.

Miller, J.A. and C.A. Simensted. 1994. Growth of juvenile Coho salmon in natural and created estuarine habitats: A comparative study using otolith microstructure analysis. Fisheries Research Institute, University of Washington.

Mills, T.J., D. McEwan, and M.R. Jennings. 1997. California salmon and steelhead: beyond the crossroads. Pages 91-111 in D. J. Strouder, P.A. Bison, and R.J. Naiman, eds. Pacific salmon and their ecosystems. New York: Chapman and Hall.

Moise, G.W. and B. Hendrickson. 2002. Riparian vegetation of the San Joaquin River. Technical Information Record SJD-02-1. California Department of Water Resources, San Joaquin District. Fresno, California.

Moore, J.W., and J.M. Mallatt. 1980. Feeding of larval lamprey. Canadian Journal of Fisheries and Aquatic Sciences 37:1658–1664.

Morrill, J.C., Bales, R.C., and M.H. Conklin. 2005. Estimating stream temperature from air temperature: implications for future water quality. Journal of Environmental Engineering 131:139–145.

Moyle, P.B., J.E. Williams, and E.D. Wikramanayake. 1989. Fish species of special concern of California. Final report. Prepared by Department of Wildlife and Fisheries Biology, University of California, Davis for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

Moyle, P.B., M.P. Marchetti, J. Baldrige, and T.L. Taylor. 1998. Fish health and diversity: justifying flows for a California stream. Fisheries (Bethesda) 23(7):6-15.

Moyle, P.B. 2002. Inland Fishes of California. University of California Press, Berkeley. 502 pp.

———. 2005. Final Expert Report of Professor Peter B. Moyle, PhD, E.D., for Natural Resources Defense Council, et al., v. Kirk Rodgers, et al. Cal. No. Civ. 88-1658 LKK.77 pp. August 15.

Moyle, P.B., R.D. Baxter, T. Sommer, T.C. Foin, and S.A. Matern. 2004. Biology and population dynamics of Sacramento Splittail (Pogonichthys macrolepidotus) in the San Francisco Estuary: a review. San Francisco Estuary and Watershed Science [online serial] 2(2):1-47. http://repositories.cdlib.org/jmie/sfews/

Moyle, P.B. and J.A. Israel. 2005. Untested assumptions: effectiveness of screening diversions for conservation of fish populations. Fisheries 30 (5):20-28.

National Ecological Assessment Team. 2006. Strategic Habitat Conservation Planning: Final report of the National Ecological Assessment Team.

Nicholas, J.W., and D.G. Hankin. 1989. Chinook salmon populations in Oregon coastal river basins: descriptions of life histories and assessment of recent trends in run strengths, Report EM 8402-Oregon Department of Fish and Wildlife, Research and Development Section, Corvallis, Oregon.

Nichols, K. and J.S. Foott. 2005. Health Monitoring of Juvenile Klamath River Chinook Salmon, FY 2004 Investigational Report. USFWS California-Nevada Fish Health Center, Red Bluff, California.

NMFS. *See* National Marine Fisheries Service.

O'Neal, K. 2002. Effects of Global Warming on Trout and Salmon in U.S. Streams Abt Associates, Inc. for Natural Resources Defense Council and Defenders of Wildlife 46pp May.

Peven, C.M., R.R. Whitney, and K.R. Williams. 1994. Age and length of steelhead smolts from the mid-Columbia River basin, Washington. North American Journal of Fisheries Management 14: 77–86.

Pilgrim, J.M., Fang, X., and H.G. Stefan, 1998. Stream temperature correlations with air temperature in Minnesota: Implications for climate warming. Journal of the American Water Resources Association 34(5), 1109–1121.

Plotnikoff, R.W. and J. Polayes. 1999. The Relationship Between Stream Macroinvertebrates and Salmon in the Quilceda/Allen Drainage. Washington State Department of Ecology. Olympia, Washington.

Rader, R.B. 1997. A functional classification of the drift: traits that influence invertebrate availability to salmonids. Canada Journal of Fisheries and Aquatic Sciences 54:1211-1234.

Rehn, A.C. and P.R. Ode. 2005. Development of a benthic index of biotic integrity for wadeable streams in Northern Coastal California and its application to regional 305(b) assessment. Draft report.

Reimers, P.E. 1973. The length of residence of juvenile fall Chinook salmon in Sixes River, Oregon. Oregon Fish Commission, Research Report 4, 43 p.

Reynolds, F.L, Reavis, R. L., and J. Schuler. 1990. Central Valley salmon and steelhead and restoration enhancement plan. Final. Calif. Dept. of Fish and Game. Sacramento California. 115 p.

Rich, A.A. and Associates. 2007. Impacts of Water Temperature on Fall-Run Chinook Salmon, *Oncorrhyncus tshawytscha*, and Steelhead, *O. mykiss*, in the San Joaquin River System. San Anselmo, California.

Rich, A.A., and W.E. Loudermilk. 1991. Preliminary evaluation of Chinook salmon smolt quality in the San Joaquin drainage. California Department of Fish and Game and Federal Aid Sport Fish Restoration Report.

Roelofs, T.D. 1985. Steelhead by the seasons. The News-Review, Roseburg, Oregon. 31 October. A4, A8.

Rutter, C. 1908. The fishes of the Sacramento-San Joaquin basin, with a study of their distribution and variation, Bulletin of the U. S. Bureau of Fisheries 27: 103–152.

Saiki, M.K. 1984. Environmental conditions and fish faunas in low elevation rivers on the irrigated San Joaquin Valley floor, California. California Fish and Game 70: 145-157.

San Joaquin River Restoration Program (SJRRP) Water Management Work Group (WMWG). 2008a. Temperature Model Sensitivity Analyses Sets 1 and 2. Draft Technical Memorandum.

———. 2008b. Temperature Model Sensitivity Analyses Set 3. Draft Technical Memorandum.

Scheuerell, M., R. Zabel, and B. Sandford. 2009. Relating Juvenile Migration Timing and Survival to Adulthood in Two Species of Threatened Pacific Salmon (*Oncorhynchus Spp*.). Journal of Applied Ecology 46.5: 983-990.

Scientific Panel for Sustainable Forest Practices in Clayoquot Sound. 1995. Sustainable Ecosystem Management in Clayoquot Sound: Planning and practices. Victoria, BC. 296 pages.

Shapovalov, L., and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game Fish Bulletin 98.

Shea, K. and the NCEAS Working Group on Population Management. 1998. Management of populations in conservation, harvesting, and control. Trends in Ecology and Evolution 13: 371-375.

SJRRP. *See* San Joaquin River Restoration Program.

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

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

Sommer, T.R., W.C. Harrell, and M.L. Nobriga. 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain. North American Journal of Fisheries Management 25: 1493-1504.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. Funded jointly by the U.S. EPA, U.S. Fish and Wildlife Service and National Marine Fisheries Service. TR-4501-96-6057. Man Tech Environmental Research Services Corp., Corvallis, Oregon.

Stillwater Sciences. 2003. Restoration Strategies for the San Joaquin River. Prepared by Stillwater Sciences, Berkeley, California for Natural Resources Defense Council, San Francisco, California and Friant Water Users Authority, Lindsay, California.

Terraqua, Inc. 2004. Draft Battle Creek salmon and steelhead restoration project adaptive management plan. Prepared for the U.S. Bureau of Reclamation, Pacific Gas and Electric Company, National Marine Fisheries Service, U.S. Fish and Wildlife Service, and California Department of Fish and Game. Wauconda, Washington. April.

U.S. Bureau of Reclamation. 2003. Grassland Bypass Project Annual Report. Prepared by Michael C. S. Eacock. January 1-December 31, 2003. p107

U. S. Environmental Protection Agency. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water Seattle, Washington.

U.S. Fish and Wildlife Service (USFWS). 2004. Endangered and threatened wildlife and plants: 90-day finding on a petition to list three species of lampreys as threatened or endangered. 50 CFR Part 17. USFWS, Pacific Region, Portland, Oregon.

USFWS. *See* U.S. Fish and Wildlife Service.

Van de Wetering, S.J. 1998. Aspects of life history characteristics and physiological processes in smolting pacific lamprey (*Lampetra tridentata*) in a central Oregon coast stream. Master of Science Thesis. Oregon State University. Corvallis, Oregon 59 pp.

Vernier, J.M. 1969. Chronological table of embryonic development of rainbow trout, Canada Fisheries and Marine Service Translation Series 3913.

Voight, H.N., and D.B. Gale. 1998. Distribution of fish species in tributaries of the lower Klamath River: an interim report, FY 1996. Technical report, No. 3. Yurok Tribal Fisheries Program, Habitat Assessment and Biological Monitoring Division.

Wahl, K.L., W.O. Thomas, and R.M. Hirsch. 1995. Stream-Gaging Program of the U.S. Geological Survey – U.S. Geological Survey Circular 1123, Reston, Virginia. Walker, R.L. and J.S. Foott. 1993. Disease survey of Klamath River salmonid smolt populations, 1992. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center. Anderson, California. 46 pp.

Walker, R.L. and J.S. Foott. 1993. Disease survey of Klamath River salmonid smolt populations, 1992. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center. Anderson, CA. 46 pp.

Walters, C.J. and C.S. Hollings. 1990. Large-scale management experiments and learning by doing. Ecology 71: 2060-2068.

Walters, C.J. 1986. *Adaptive management of renewable resources*. MacMillan, New York, New York, USA.

Walters, C.J. and R. Hilborn. 1978. Ecological optimization and adaptive management. Annual Reviews of Ecology and Systematics 9: 157-188.

Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin estuary and adjacent waters, California: a guide to the early life histories. Technical Report 9. Prepared for the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary by California Department of Water Resources, California Department of Fish and Game, U. S. Bureau of Reclamation and U. S. Fish and Wildlife Service.

———. 1995. Observations of early life stages of splittail (*Pogonichthys macrolepidotus*) in the Sacramento-San Joaquin estuary, 1988 to 1994. IEP Technical Report 43.

Ward, B.R., and P.A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relation to smolt size. Canadian Journal of Fisheries and Aquatic Science 45: 1110–1122.

Ward, P.D., and T.R. McReynolds. 2001. Butte and Big Chico creeks spring-run Chinook salmon, *Oncorhynchus tshawytscha*, life history investigation 1998-2000, Inland Fisheries Administrative Report No. 2001-2, California Department of Fish and

Game, Sacramento Valley and Central Sierra Region, Rancho Cordova, California.

Warner, G. 1991. Remember the San Joaquin: California's salmon and steelhead. Pages 61-69 in A. Lufkin, editor. The struggle to restore an imperiled resource. University of California Press, Berkeley, California.

Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Williams, J.G. 2006. Central Valley salmon: a perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary Watershed Science. 4:1-416.

Wu, F.C. 2000. Modeling embryo survival affected by sediment deposition into salmonid spawning gravels: Application to flushing flow prescriptions. Water Resources Research. 36(6):1595-1603.

Yates, D., H. Galbraith, D. Purkey, A. Huber-Lee, J. Sieber, J. West, S. Herrod-Julius, and B. Joyce. 2008. Climate Warming, Water Storage, and Chinook Salmon in California's Sacramento Valley. Climatic Change 91.3/4: 335-350.

Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle. 1996. Historical and present distribution of chinook salmon in the Central Valley drainage of California, Sierra Nevada Ecosystem Project: final report to congress, Volume III: Assessments, commissioned reports, and background information. University of California, Center for Water and Wildland Resources, Davis, California, pp. 309-362.

Young, P.S., and J.J. Cech, Jr. 1995. Salinity and dissolved oxygen tolerance of young-of-the-year and juvenile Sacramento splittail. Consensus building in resource management. American Fisheries Society, California-Nevada Chapter.

Young, P.S., and J.J. Cech, Jr.. 1996. Environmental tolerances and requirements of splittail. Transactions of the American Fisheries Society 125: 664–678.

9.1 Personal Communications

Ligon, F., and Orr, B. Still Water Sciences. Bruce Orr, Principle/Senior Scientist. Frank Ligon, Senior Aquatic Ecologist/Geomorphologist. Personal communication to AJ Keith, Aquatic Ecologist, Stillwater Sciences.

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Exhibits

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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